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BUSINESS & “INDUSTRY 4.0”

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ASSESSMENT OF READINESS FOR „INDUSTRY 4.0“

Prof. Dr. Batchkova I. A., Prof. D.Sc. Popov G.T., Eng. Ivanova Ts. A., Eng. Belev Y.A.
Dept. of Industrial Automation, University of Chemical Technology and Metallurgy
Bul. Kl. Ohridski 8, Sofia, Bulgaria

idilia@uctm.edu

Abstract: *The Industry 4.0 initiative poses great challenges to the world, countries and companies connected with the provided digital transformation and the new intelligent technologies in all areas of the industry. This requires the development and follow-up of a national strategy for the adoption and implementation of Industry 4.0. It is important in this case to assess the Industry 4.0 readiness of each country for transformation and change. The main aim of the paper is to present, analyse and compare some of the most promised existing approaches for calculation of Industry 4.0 readiness at national level. Some results are presented and compared.*

Keywords*:* INDUSTRY-4.0, READINESS, MANUFACTURING, ASSESSMENT

1. Introduction

The European Commission's strategy for European Reindustrialization aims of increasing the industrial sector's share of gross value added in the European Union to 20% in 2020, based on European strengths in the fields of engineering, automotive, aeronautics, etc. [1]. The Industry 4.0 platform is an initiative of the German Federal Government to support German industry in the transition to digital production with intelligent, digital networks and systems that enable largely self-control and self-management of manufacturing processes [2, 3]. Especially strong is the focus of Industry 4.0 on the functions of future intelligent adaptive and predictive technical systems that need to be self-optimizing, self-configurable and self-diagnosable, enabling cognitive information processing and intelligent networking in continuous interaction with environment. That is why the strategic initiative Industry 4.0 implies integration of Cyber-Physical Systems (CPS), the Internet of Things (IoT) and cloud computing leading to what is called "smart factory".

The speed and scope of technological changes coupled with the emergence of new technologies and trends makes the task of developing and implementing new industrial strategies too complex. The Industry 4.0 initiative is a great challenge for both national economies and individual companies. To deal with it, countries should develop national strategies tailored to the specifics and capacities of their economy, based on an in-depth analysis of the factors, indicators and conditions that have the most impact on business and production systems. With regard to the national strategy, there must be a consensus of industry, academia and civil society.

An important role in building a life strategy for Industry 4.0 are the results of an assessment of the readiness of national economies to adopt and adapt the initiative. Readiness according [4] is defined as “the ability to capitalize on future production opportunities, mitigate risks and challenges, and be resilient and agile in responding to unknown future shocks.” There are different approaches to such an assessment that use different quantitative and qualitative key indicators, both for the assessment the readiness of countries and individual companies. Among the approaches to assessing the readiness of countries and national economies, some of the most significant assessments are derived from the approach developed by the World Economic Forum [4], the approach of the Danish Institute Industry 4.0 [5] and the Roland Berger readiness index [6]. In the area of company stand-alone assessment of readiness, the IMPULS model [7] is the most popular, assessing the maturity of manufacturing enterprises in 6 dimensions: strategy and organization, smart factory, smart operations, smart products, data-driven services and employees. The analysis, proposed in this paper is limited to the approaches for readiness assessment of countries. Reasoning and conclusions about global, local and group trends and initiatives are also possible. The results from assessment may be used to identify specific opportunities and challenges for individual countries for the future of production.

The main aim of the paper is to analyse the existing approaches and methods for assessing the readiness of the countries and their economies to adopt and implement the Industry 4.0 initiative. Some comparisons and analysis of the obtained results regarding the position and readiness of Bulgaria are also discussed. After the introduction, in the second part of the paper the challenges of Industry 4.0 and the main difficulties with its perception are briefly discussed. Sequentially, in parts 3, 4 and 5, three of the most representative and complete readiness assessment approaches have been shortly presented and analysed. In the last part, as conclusions, some comparisons and recommendations on the implementation of the results in preparing of national strategies for Industry 4.0 are presented.

2. Challenges and difficulties in implementing Industry 4.0 initiatives

"Industry 4.0" or IIoT are related to the new industrial revolution and focus on the integrated use of state-of-the-art information (IT) and operational technologies (OT) such as IoT, cyber-physical systems, big data and advanced data analytics and decision making methods, artificial intelligence and robotics, cloud and fog calculations, virtual and augmented reality and others, as shown in Fig.1. With a view to a more rapid adoption of the new concept by industry, it is desirable to ensure a smooth transition to these new technologies through the use of transition technologies and standards and reasonable investment to achieve the objectives, including OT and IT integration (Fig.2). There are a number of industry prerequisites: embedded devices and controllers, wireless sensor networks, RFID technologies, and more. While the hardware industry is relatively well prepared for a transition to IIoT, there are serious challenges to software applications and architectures.

Fig.1: *Basic technologies for Industry 4.0*

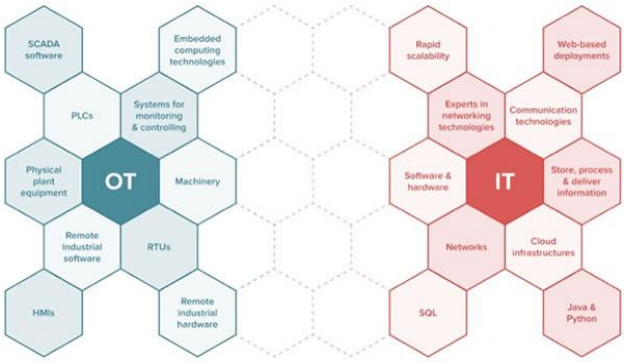

Fig.2: *Integration of OT and IT*

3. *The approach of World Economic Forum*

The readiness assessment of the World Economic Forum [4] includes two main components: the Structure of Production and Drivers of Production, or the key enablers that capitalize on the Fourth Industrial Revolution to transform production systems. The Structure of Production as shown in Fig.3 is assessed in terms of its complexity and scale, while the component "Drivers of Production", shown on Fig.4 includes categories such as: technology and innovation, human resources (capital), global trade and investment, institutional framework, sustainable resources and the demand environment. The study, conducted in 2018, includes 100 countries and their economies, which are valued on 59 key indicators, which are measured by internationally recognized organizations. The assessment also includes indicators from the World Economic Forum's Executive Opinion Survey (EOS) measuring different qualitative aspects of some indicators, or are used as a substitute in the case when statistical data was not available. All indicators as well as the total scores are in the intervall from 0 to 10, with a maximum value (10), representing the best situation. Indicators values are normalized in the range from 0 to 10 based on the min-max approach. The normalized scores are combined to produce the aggregated and total scores.

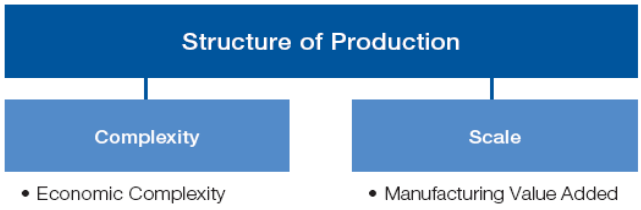

Fig.3: *Component "Structure of Production"*

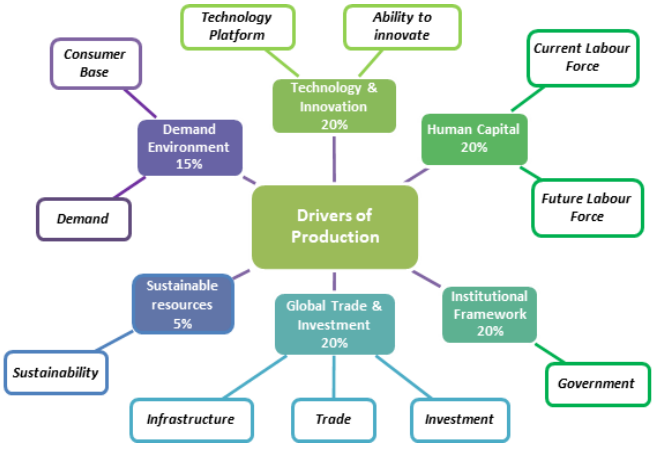

Fig.4: *Component "Drivers of Production"*

The approach does not offer a global ranking, but classifies the countries into one of the four archetypes, the boundaries of which are determined by the average estimates of Drivers of Production (5.7) and Structure of Prodution (5.7) for the Top 75 countries, ordered by the Structure of Prodution rating (Fig.5). These 4 archetypes are named: High potential, Leading, Nascent and Legacy. They are determined by the complex assessment of the existing basis (limited or strong) and positioning for the future (at risk and well). The countries in the Leading archetype are with a strong production base today and a high level of readiness for the future. The countries in the Legacy archetype are with a strong production base today but they are at risk for the future due to weaker performance across the Drivers of Production component. The countries from the High-Potential archetype are with a limited production base today but have good score in respect to Drivers of Production component. This is an indication for existing capacity for increasing of production in near future. Countries in the Nascent archetype are with a limited production base today and a low level of readiness for the future.

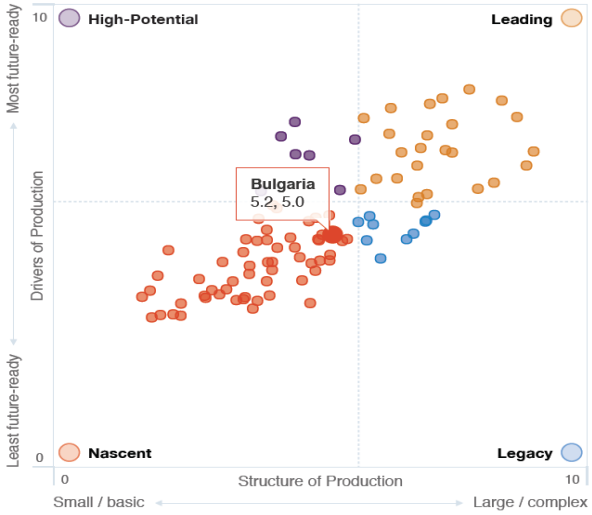

Fig.5: *Readiness assessments according the approach of WEF [4]*

On Fig.5 some of the results are shown. From 100 countries and economies included in the assessment, 25 of them are "Leading" countries, 10 "Legacy" countries and 7 "High-Potential" countries/economies. The remaining 58 countries are "Nascent" countries. The majority of the EU Member States belong to the first three archetypes. 5 EU countries fall into the archetype "Nascent". Unfortunately, one of these countries is Bulgaria, which has a score of 5.23 for Structure of Production and 5.02 for Drivers of Production and occupies 40 and 48 rang respectively. For comparison with the other approaches only, in the first six are the United States (1 st rank), Singapore (2 rank), Switzerland (3 rank), the United Kingdom (4 rank), the Netherlands (5 rank) and Germany (6 rank).

4. *Danish global Industry 4.0 readiness approach*

The DII 4.0 approach for calculation of Industry 4.0 Readiness Index [5] is a part of Danish Institute of Industry 4.0's annual global analysis supporting governments, companies, academics and institutions interesting in implementation of Industry 4.0.

The Industry 4.0 readiness of the countries is assessed based of 7 main pillars, which are weighted as shown in Fig.6. Each pillar comprises of different measurements, which are a total of 24. The measurements have its own weights in the overall score according to their relevance and importance. The Global Industry 4.0 Readiness report includes 120 countries. In order to obtain more adequate assessments in this approach, a score correction based on simple exponential regression is used. It corrects with higher value the higher scores and with lower value – the lower ones, according to equation (1).

$$\text{Adjusted score} = e^{0.24 \cdot \text{original score}} - e^{0} \quad (1)$$

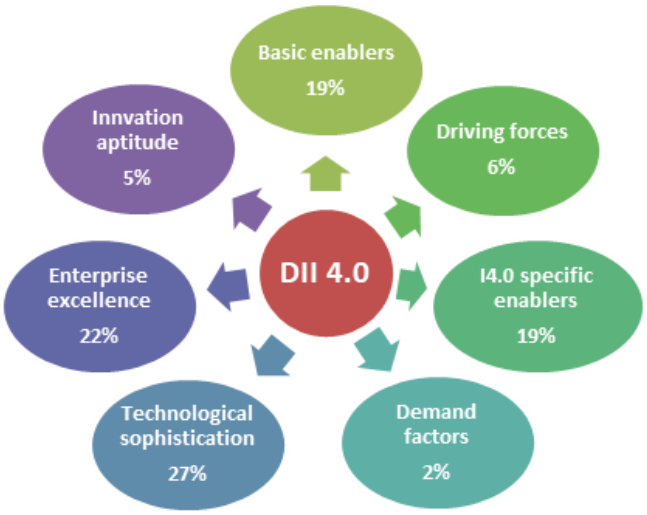

***Fig.6**: Basic pillars of DII 4.0 approach*

On the basis of the assessments received, a total of 9 groups of countries worldwide are identified, as shown in Fig.7. To all these groups certain strategies for Industry 4.0 are recommended. For groups 1 and 2 the strategy is named "Foster manufacturing & strengthen position" for 3 and 4 - "Further strengthen position", for 5 and 6 - "Catch up to protect", for group 7 is "Foster manufacturing & Complete turnaround", and for 8 and 9 - "Complete Turnaround".

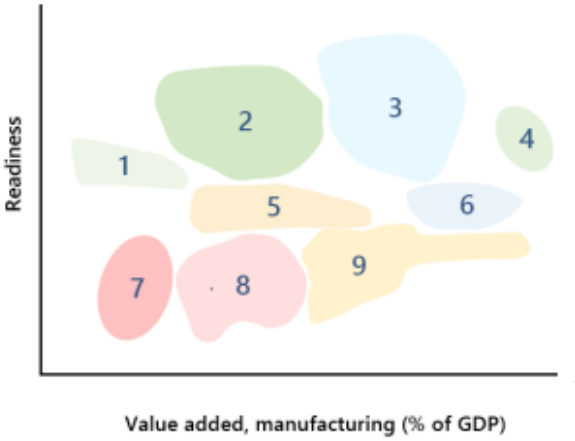

***Fig.7:** Readiness assessments according DII 4.0 approach [5]*

The results of Bulgaria put it in 9 group and occupies 63 place with a rating of 2.5 in ranking of countries by Readiness index. With the same rating are Croatia, Ukraine, Iran and Jamaica. Leading positions are for Singapore (6.6), Switzerland (6.6), Finland (6.0) and Germany (5.9). For the countries of group 9 the manufacturing is an important driver of their economies, they are not well-positioned for Industry 4.0 but quite the contrary and probably they will have problems with their status quo. Bulgaria's scores on individual pillars, compared to the average world scores are shown in the radar diagram of Fig.8.

The clustering results of the European Union countries are also presented. Similarly to the first approach presented in part 3, four groups of countries are identified: Growers, which are well-positioned for Industry 4.0, and thus their manufacturing sectors are likely to grow in the future; Leaders with high level of Industry 4.0 readiness and an important position of manufacturing; Laggards: manufacturer is moderately important but they lack of readiness and therefor the outlook is rather negative and Unprepared: manufacturing is very important however but they are not prepared for Industry 4.0, and they will probably have problems. Bulgaria falls again into the group of countries Unprepared for Industry 4.0, although it was omitted from the graphical illustration of the results.

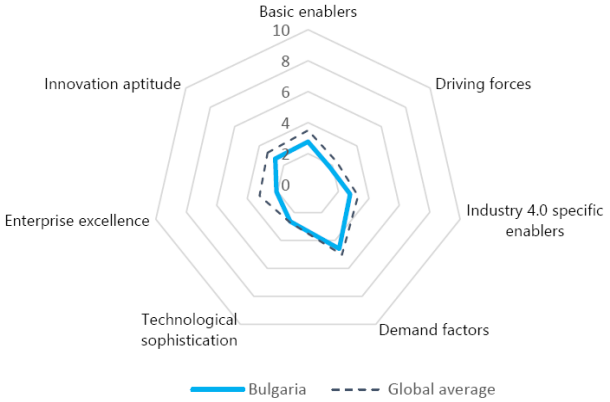

***Fig.8:** Comparison of Bulgarian scores with the global average [5]*

5. *Roland Berger readiness index*

The RB Industry 4.0 Readiness Index [6] is calculated using two categories of indicators. The first category, named "industrial excellence" includes production process sophistication, degree of automation, workforce readiness and innovation intensity. The second category covers high value added, industry openness, innovation network and Internet sophistication, and is labeled "value network". The indicators of both categories are evaluated on a five-point scale with score "5"signifying that the country is excellently prepared for Industry 4.0. Assessments of both categories are the averages of the indicator scores included. The RB Industry 4.0 readiness index is a combination of category assessments. In the graphical representation of the assessments, the index is plotted on the vertical axis, the horizontal axis is represented by the production share.

The approach is applied to the European economies as shown in Fig.9. On the basis of the assessments in both categories, a matrix is formed that roughly divides European economies into four main groups: Frontrunners, Traditionalists, Hesitators and Potentialists. Frontrunners are characterized by a solid industrial base and modern, promising business conditions and technologies (Sweden, Austria and Germany). Traditionists have a solid industrial base, but have few Industries 4.0 initiatives. This group mainly includes Eastern European countries. The third group of Hesitators includes countries with an unreliable industry base, many of them with fiscal problems. Their joining the initiative now is difficult, even impossible. Most countries in this group are from South and Southeast Europe, among which, unfortunately, Bulgaria. Potentialists are the fourth group that is characterized by a weakening industrial base but with signs of modern, innovative thinking, however, having the potential to find the right approach to Industry 4.0.

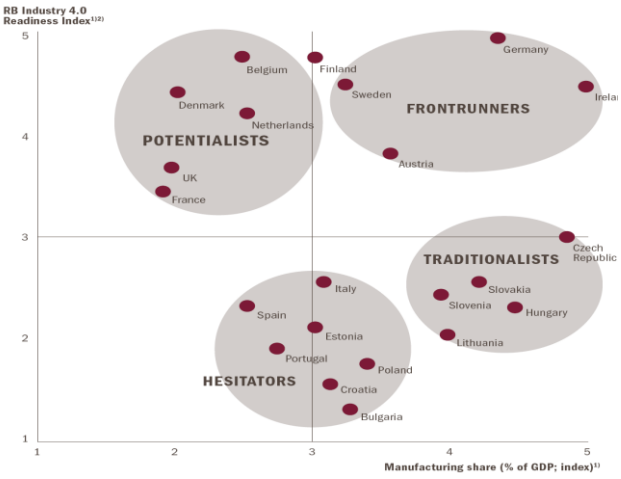

***Fig.9:** RB Industry 4.0 Readiness Index [6]*

6. Conclusions

The presented and analyzed approaches for Industry 4.0 readiness assessment have many similarities and differences. The similarities are that they use relatively simple clustering methods based on the stand-by index and production share. The differences are in the selected indicators and indicators and the selected evaluation methods, as well as the evaluation scales used. The results obtained and the analysis of the hidden, not obvious knowledge is of substantial benefit for the stakeholders, related to the development of strategies and policies for raising the index of readiness. Their in-depth comparison and analysis is forthcoming with a view to revealing the strengths and weaknesses of each of the approaches considered.

There are some shortcomings common to the approaches considered, such as:

- There are no quantitative estimates of key concepts, so indirect estimates are used.
- Strong variability and uncertainty of the information received and used

The evaluation, made using different approaches, imposes the following main global conclusions: When building national strategies for Industry 4.0, account should be taken not only of national solutions, but of global and regional conclusions. National solutions must be consistent with assessments and conclusions on readiness, as well as with the country's specific positioning. The fourth industrial revolution will cause changes in global value chains, global transformation of manufacturing systems leading to a two-speed world. There are few countries that can create a cluster of new industries. Countries can cope with transformation using different paths, each country having a way and a chance to improve its readiness for Industry 4.0. Each of the defined groups of countries with approximatelly equal readiness faces common challenges that can be shared by finding common solutions.

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MODEL-BASED APPROACH OF A DECISION PROCESSING UNIT IN A SMART WOOD-PROCESSING COMPANY

M.Sc. Stalinski D.[1,2], Prof. Dr.-Ing. Scholz D.[1]
Department of Mechanical Engineering, Münster University of applied Science, Germany [1]
hobb Holzveredlung GmbH & Co. KG, Germany [2]

dstalinski@fh-muenster.de

Abstract: *The paper deals with the development of a new type of production planning and control in a wood-processing company. The production is already highly automated and data from the production processes are gathered and stored in a database. The project picks up these technical basements in order to automatically provide intelligent decisions and make the factory even smarter.*

Keywords: SMART FACTORY, OPTIMIZATION, DATA-DRIVEN PRODUCTION PLANNING AND CONTROL, ARTIFICIAL INTELLIGENCE, DECISION SYSTEM

1 Introduction

For a manufacturing company, the logistical performance is a fundamental competition factor just like high quality and low prices of the products. It is measured in short order throughput times and great adherence to schedules [1, 2]. In order to achieve high logistic performances, the production planning and control generally takes care of the best possible usage of the given resources of the enterprise. Thus, it has to take control of a high capacity utilization level, a low level of work in progress, short setup times and a low production delay [3]. Therefore, these logistical objectives are manipulated by defining production programs in the form of processing sequences and capacity allocations [4].

Improving one of the mentioned logistical objectives often leads to deteriorating at least one of the other objectives. This is well known as the dilemma of production planning and control [5]. Practically these tasks result in complex, multicriteria optimization problems. On the one hand these are complicated mathematical problems [6]. On the other hand there may be untapped logistical potentials which could be practically used by solving these problems. Nevertheless, these tasks are often still performed manually [7].

Innovative technologies in the context of industry 4.0 like CPS (Cyber-Physical Systems) and the IoT (Internet of Things) are found in smart factories. Besides the technical automation of processes and material flows, these technologies can lead in combination with ERP software (Enterprise-Resource-Planning) and MES (Manufacturing Executive System) to a high quality data base [8]. This even increases the logistical potentials by using modern computers and technologies to process the (big) data and automatically use it for planning and controlling a factory [8]. Nevertheless this is a highly nontrivial task and still requires a lot of engineering.

The subject matter of this paper is a project with a company called hobb Holzveredlung GmbH & Co. KG which is a german system manufacturer of fixed sizes for the wood-processing industry. It is part of a group of companies of a well-known german furniture brand and delivers semi-finished products for the furniture and the flooring industry as well as interior construction. The company already uses modern technologies regarding automation of processes, transportation, material handling and tracking. The last links in the chain of automation are the decisions taken in the production planning and control.

A cooperative research project was started in 2016 together with the Münster University of applied Science and the University of Wuppertal in order to develop a so-called decision processing unit [9]. This paper deals with the overall problems and issues which are identified within that development and will present integrated solution approaches.

In section 2 the prerequisites and the problems are presented. An approach for a solution to the problem is presented in section 3. The results and the current status of the entire system are presented in section 4.

2 Prerequisites

While nearly all relevant technical aspects of the production regarding material flow, material handling, booking of confirmations and technical processes are automized, the supervising tasks of planning and controlling the production is still done by hand. As described in the previous section, a high quality data basis which includes the production data necessary for the decision taking already exists. Therefore, a decision processing unit which is able to process this data into useful decisions is in development.

2.1 Description of the discussed process

Production processes can basically be distinguished between the following three criteria [10].

- The technique differentiates between a continuous and a discontinuous process manufacture of products as well as a process of a single product.
- Different quantities of production are unit production, batch production and large series production.
- Last there is the relationship with the customer. Production to stock concerns a push-flow production while production to order concerns a pull-flow production.

Based on the introduced criteria, the discussed production process of the case study can be described as a discontinuous pull-flow batch production to order.

Fig. 1 *Automized sawing machine*

All products in the discussed processes are rectangular shaped wooden boards. These boards are produced exclusively to order, so that every board has a reference to a customer and a production

order and no product is produced without a customer order. Master data like order number, material number, geometric dimensions, quality, surface design etc. as well as process related data is part of every order, even if one specific product will never be ordered again. The range of products consists of three different types of semi-finished products respectively processes.

- There is the craft-based production of coating materials for furniture boards. This can on the one side be the manufacturing of veneer boards with specific dimensions. On the other side there is the trimming of artificial coatings like decor foils, paper, vinyl, etc.
- There is the cutting and trimming of wooden boards on automated saw machines (see Fig. 1). Boards made of chip, mdf, hdf, solid wood, etc. are cut to size on these machines.
- There is the pressing and gluing of the coating materials onto the cut to size boards (see Fig. 2).

***Fig. 2** Automized material handling of a pressing machine*

The manufacturing process comprises a manual and an automized part. While the production of the coating materials consists of many craft-based and manual processes, the production of the wooden boards (cutting and coating) is nearly fully automized and controlled by RFID. Thus, the development of the decision processing unit focuses on this modern area of the production. The considered manufacturing system consists of two sawing machines, four pressing machines and one area for the crafted manufacturing of coating materials. As described, the coating area is not part of the decision processing. Furthermore there is a managed raw material warehouse which contains the „motherboards“ for cutting to size on the saws. If boards have to be coated on a pressing machine after sawing, they are transported to the machines and stored on roller conveyors.

The sawing machines are fed with boards from the warehouse by a forklift and there are no relevant setup times between different materials and production orders. On the pressing machines there are setup times between 15 minutes and 8 hours. The setup times depend on the different coating materials which need to be processed with different glues, different processing temperatures and different equipment. Some of the coating materials leave residues on the press plates, so that after processing these materials several times the machine must be cleaned. This results in possible setup times for heating up and cooling down, changing the glue for a pressing machine which implies cleaning up the gluing system and mounting different tools for handling different coating materials.

The boards are transported as stacks via automated roller conveyors on slave boards, while each of these stacks only consist of one material and one production order. The slave boards are equipped with a RFID tag (radio-frequency identification) which is linked to the production order of the board stack. This is in combination with RFID antennas the basis of locating and tracking the board stacks in the production. Behind and between specific and relevant production cells there are RFID gates, where the RFID tags of the slave boards are registered by passing them. This triggers logic processes in the ERP system like booking of confirmations and goods movements. The result is a production controlling process which is highly automated and exact to the second. This leads to a high quality data basis, which is the technological basis of the new decision system [9, 11].

2.2 Description of the problem

The requirements of the decision processing unit for controlling the factory are on the one side the computation of allocations of production orders to pressing machines and on the other side the computation of production sequences for each sawing and pressing machine. The further requirements of the system are to take care of the following four criteria:

- minimizing production delay,
- minimizing setup times,
- minimizing work in progress and
- maximizing machine utilization.

It was recognized quickly that planning the production system within a planning horizon longer than one day would be impracticable and that a high amount of flexibility is needed. Due to the knowledge and expertise of the process, scheduling over one day with a rolling horizon in periods of 30 minutes is desired. This follows from the fact that there are frequent events that lead to a new data basis of decision-making. These events are mainly changes of the availability of materials, so that either new raw material has arrived or the coating area finished a production order. Both cases are not predictable and lead to new situations which the system has to re-evaluate.

There are some special characteristics of the production process which require particular attention.

- On the one hand sawing is a separating manufacturing process, where boards with different dimensions are cut out of one board. From a material managing and production controlling point of view this means that a production order for sawing one specific material results in many other production orders with specific materials. In practise, many customer orders which are cut from the same raw material are bundled together to one production order so that they can be cut out of the same raw staple of boards. This allows the use of a software based waste optimization system in order to increase the efficiency and the economy of the sawing process. But from a production planning view this results in a significantly higher level of complexity as it is shown in the following.
- Each of the production orders which are bundled together to one raw material can contain material for a pressing machine or not. As a result one bundled production order can be a mixture of saw-only orders and production orders with material for different pressing machines. Furthermore the pressing production orders can be allocated to different pressing machines. Thus, different production sequences for one sawing machine have huge impacts on the whole production system.
- Not only the production sequences of the sawing machines can be varied, also the decisions taken at the pressing machines have a huge impact on the whole system. There are different opportunities of feeding the pressing machines. The machines can get material over roller conveyors directly from the sawing machines. Material can be buffered and sorted after

sawing before being transported. The pressing machines can additionally be fed without sawing with external material from the warehouse.

- The configuration of a pressing machine (temperature, glue, cleaning and tools) depends on the processed materials. Additionally, for many of the materials there are more than one possible configuration. The machines have different cycle times, so that the processing time of a production order depends not only on the material and on the count of boards, but also on the machines.

2.3 Analysis of the problem

Following detailed issues result from the discussed problems. Scheduling implies in this case the simultaneous computation of sequences of production orders for 6 production cells and the computation of allocations of production orders to a pool of 4 production cells. This is a type of np-hard combinatorial problem with multiple criteria [5]. This type of problems is well known for its complexity so that even small problem instances are practically not solvable [12]. In order to find practically useful solutions of such a mathematical problem, the use of metaheuristics is a proven way [13, 14, 15].

A metaheuristic is a kind of an iterative algorithm which finds solutions to a problem, but it cannot guarantee that it finds the best ones and it doesn't need to know the problem structure [14]. Instead the use of an evaluation function is necessary for the application of a metaheuristic. This leads in this case to three more problems which are described in the following.

1. First there is the question of how a metaheuristic can be applied in general. Therefore, explicit variables of the production system have to be formulated which can be manipulated in order to be optimized. Furthermore there is the question of how possible solutions can be evaluated. A metaheuristic needs to compare different solutions, so that they are evaluated in an adequate way.
2. The second identified problem is the fact that not every single objective and restriction of the production processes can go into this evaluation and not everything will influence the evaluation. The (only) mathematical optimization of a combinatorial problem does not necessarily need to be the best decision in a practical way. As a result, the application of a metaheuristic has to allow to take rule based decisions within a mathematical optimization process. Therefore the metaheuristic shall be combined with different constructive heuristics. A constructive heuristic is generally a rule-based algorithm which is often adapted to a specific problem [16]. It creates a solution for a given problem by following rules instead of mathematically optimizing it.
3. Third there is the problem that not every kind of data that is needed is present in an usable form. Thus, additional data are needed. These are in particular processing times and set up times for the pressing processes. They are of fundamental importance for an automized scheduling process. The effort of additional data maintenance should naturally be low, so that setup times and processing times for each material and for each machine should not be entered manually, because this would be an immense effort.

3 Solution

The general solution of the scheduling problem is divided into the approaches of the discussed sub problems.

1. An approach for the acquisition of the additional data is presented. Therefore, a data model for the production system is developed.
2. A decision model is presented, which allows the application of a metaheuristic to the scheduling problem. Furthermore, this decision model allows the application of constructive heuristics.
3. An agent-based scheduling model is created, where the decision model is combined with an agent-based simulation of the machines.

3.1 Application of a production model

For the scheduling process itself, the missing processing and setup times have to be generated and an additional high amount of data maintenance should be avoided. Thus, confirmation data from the ERP system shall be used for a statistical computation of real processing times. This makes the creation of a data model necessary which allows the analysis of these data in an appropriate way. Therefore, materials, production orders and machines are designed as a data model. Furthermore this model shall be used as a simple way for entering model-based setup times. It is shown in the Fig. 3.

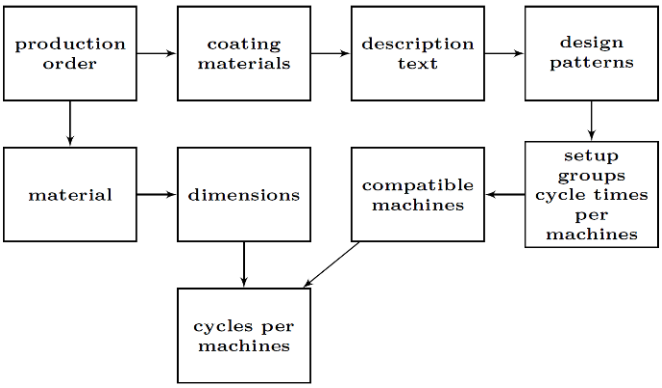

Fig. 3 *Generating data with a production data model*

The data model for the materials consists of the material number, the material description text and the geometric dimensions. These information are directly read from the ERP system. Additionally these information are complemented with the properties material type and material design. Depending on the description text, the materials are categorized by matching design patterns.

The data model for the production orders consists besides the order number and the delivery date additionally of the material designs of the coating materials. Therefore, depending on the different design patterns of the coating materials, production orders are automatically classified in possible setup groups for each possible pressing machine.

The pressing machines are modelled with the properties of their geometric dimensions. There are different rules for the process temperatures, the glue systems, the needed equipment and the residue behaviour, which can be entered for each compatible design patterns. Setup times are entered as cleaning times, times necessary for changing the glue system and time constants for heating up and cooling down.

This production data model is applied in two ways. First it is applied on a large set of historical data. Confirmation data for each pressing machine is interpreted with this model, so that for each confirmation dataset the machine cycles are computed and then cycling times can be estimated and average values are stored in a data base. Second it is applied on the scheduling task. The stored average values for cycling times are used in combination with the model for estimating cycles of new orders in order to compute production times for the production orders on all compatible machines.

3.2 Application of a decision model

For the application of a metaheuristic, specific input variables have to be defined. Therefore, a decision model is created, where discrete, real decisions are formulated. This allows a distinction between real decisions which should be enumerated and optimized and rules which should be implemented as constructive heuristics.

The decisions are modelled separately for the sawing machines and for the pressing machines. They result from a process analysis and are defined as follows. A sawing machine can on the one side be used to produce customer orders, which only have to be formatted without being coated. On the other side it can decide to produce materials, which have to be coated after formatting.

A pressing machine can also decide from a set of decisions. For each setup group the pressing machine can decide to change its setup and produce only orders which are compatible. Additionally it can decide to acquire production orders from the other pressing machines if they are compatible with its current setup.

The advantage of this approach is the concentration on real and relevant decisions so that uncritical or not predictable decisions are not optimized and can be modelled as sets of constructive heuristics [17].

3.3 Application of an agent-based scheduling model

The combination of the decision model with constructive scheduling heuristics is done by creating an agent-based scheduling model. This scheduling algorithm is based on a discrete-event simulation where production cells are implemented as software agents with heuristic-based behaviours. The agents can take the modelled decisions within a simulation run. Different decisions lead to different constructive heuristic behaviours. In this way, scheduling is done by constructive heuristics for each machine agent in a simulation run. The discrete decisions which the agents take shall be optimized by a metaheuristic. Therefore, the model computes a target value to evaluate different selections of the decisions.

During a simulation run, the planning horizon is divided into discrete time intervals. Within these intervals the machine agents can take decisions from their decision sets. The scheduling itself is implemented as constructive heuristics in the agent definitions. The basic sequences for each agent are created by sorting the production orders for each setup group depending on their delivery deadline. Further constraints are implemented as follows. If possible, production orders are sorted additionally depending on the customer and the raw material, in order to reduce travels distances of the forklifts.

3.4 Application of a metaheuristic

The first work on a stochastic optimization method goes back in 1952 [18]. There are many different types of combinatorial problems, so that these types of problems are a well-known matter of researches. Some of them are mostly theoretical problems, but most of them result from practical problems, as it is in this paper. They have in common that they are np-hard, which means, that they can only be solved with exponential time effort. As a result, even small instances of these problems are practically not solvable [19]. This leads to the development of metaheuristics. The most prominent and relevant ones (relating to this paper) are introduced in the following.

The traveling salesman problem is a synonym for finding the shortest way between a given set of points [20]. Typical applications are logistics where a car has to visit different places in a short time and drilling operations where a machine has to drill several holes into a workpiece [20]. Packing problems are in general problems where a given set of items have to be put into a container. A typical application is minimizing the waste of a sawing machine [21]. Scheduling problems are basically problems where processes have to be allocated to limited resources [6]. Prominent applications are besides production planning the scheduling of tasks in a central processing unit (CPU) and the gate assignments at airports [22]. Furthermore there are parameter optimizations in general where individual parameters of a given system shall be optimized [23].

They have in common, that even apparently small instances result in practically not solvable complexities. Thus, there are different approaches of getting sufficiently good solutions in a reasonable amount of time. These metaheuristics are mostly independent of the given problem structures. Proven metaheuristics which are based on swarms and populations are ant colony algorithms, genetic algorithms, simulated annealing algorithms and particle swarm algorithms [14, 24]. They are iterative procedures with a wide range of possible applications. At the beginning of the algorithms they randomly produce populations of possible solutions. These are then compared to each other and based on the quality the algorithms are influenced in certain ways. As a result, these algorithms only need to evaluate many possible solutions without actively knowing of how they are created. By positively feeding the algorithms back with the information of the solution qualities, the algorithms can converge to practically good solutions.

For the application of a metaheuristic to the scheduling problem, a modification of the ant colony optimization is a proven approach as it is presented in [17]. It is applied to the decision model in order to find the best possible decisions for each machine agent.

4 Results

The entire system is technically implemented as a service application with a database on a server. It has a software interface to the ERP system, which enables the transfer of data between the systems.

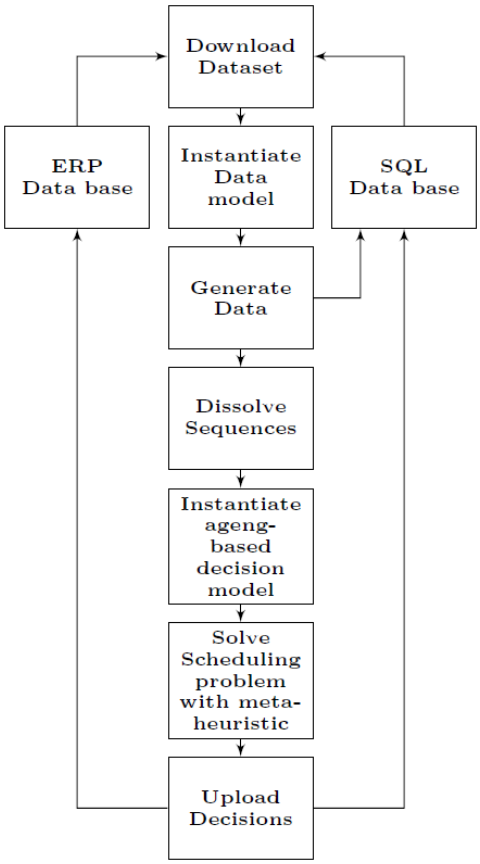

Fig. 4 *Program operation of the decision system*

The program operation is presented in the Fig. 4. It starts with downloading a dataset from the ERP system and instantiating the data model. After generating additional data and storing in the

database, the iterative scheduling process begins. The results in the form of production sequences for each machine are uploaded into the ERP system and into the database. They are visualized in a web application as well as in the ERP system itself.

The system is integrated into the running production process and the computed decisions are already practically used. Field tests and long-term evaluations are performed. Feedback from the production management is discussed in order to evaluate and improve the decision system.

Thus, the target goals of the project are largely achieved and the quality of the decision system is currently analysed. The advantage of the system is the implementation of constructive heuristics in combination with a mathematical optimization using a metaheuristic.

5 Conclusion and future work

This paper presented model-based solution approaches for solving a practical scheduling problem in a highly automated wood-processing company. The main focus was a combination of constructive heuristics with the application of a metaheuristic in order to combine a rule based controlling system with a mathematical optimization method. Furthermore, additional data in the form of processing times had to be generated.

The modelling approaches have been implemented into the new decision system, which is already applied into the running production process. As a future work, an in-depth analysis of different metaheuristics is planned, in order to examine the best possible configuration of the decision system.

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COMPUTER-AIDED MECHATRONIC DEVICES: AESTHETIC DESIGN WITH AN EMPHASIS ON GENERALIZED GOLDEN RATIO

Mg.Sc.Ing. Zaimis U.[1,2,a], Mg.Sc.Ing. Magazeina I.[1,2,b], Assist.Prof.Dr.Biol. Jurmalietis R. [1,2,c], Prof. Dr.Sc.Math. Guseynov Sh.E. [1,2,3,d], Prof.Dr.Sc.Comp. Jansone A.[1,2,e]
Institute of Science and Innovative Technologies, Liepaja University, Latvia[1]
Faculty of Science and Engineering, Liepaja University, Latvia[2]
"Entelgine" Research & Advisory Company, Ltd., Latvia[3]

E-mails: uldis.zaimis@liepu.lv[a], ilva.magazeina@liepu.lv[b], roberts.jurmalietis@liepu.lv[c], sh.e.guseinov@inbox.lv[d], anita.jansone@liepu.lv[e]

Abstract: ***research is devoted to contemporary computer-aided mechatronic devices (like indoor mini-gardens, non-living devices) construction / design issues. Particular emphasis has been put on mechatronic devices` aesthetic design arguing its practical value. Design related discussion as been focused on Golden Ratio archetype in particular (more – Generalized Golden Ratio)***

KEYWORDS: MECHATRONIC DEVICES, COMPUTER AIDED DEVICES, GOLDEN RATIO

Introduction

Contemporary mechatronic devices apart of their basic purpose possess, as a rule, also ergonomic and aesthetic characteristics. Despite the last two concepts – unlike purpose of the device – would not be taken for granted however they can considerably increase price of the device. Moreover, nowadays both ergonomic and aesthetic (i.e. usability and pleasure) considerations have been taken into account more and more when designing mechatronic devices.

Recent paper provides design related advices to mechatronic engineers in order to facilitate development of more user friendly and harmoniously designed final product. Since computer support recently represents an inevitable part of advanced mechatronic devices relevant considerations have been included in designing advices.

1. Mini-gardens as selected Mechatronic Devices

Mechatronic devices particularly attractive for urban-dwelling users could be represented by portable scale ones first of all. Within a spectrum of such devices recent study emphasizes indoor mini-gardens. Mini-gardens have been chosen since they usually possess properties of multifunctional practical value – these devices (aquariums, mini-greenhouses, green walls, balcony herb gardens, etc.) can be useful for healing (e.g. indoor greening: aesthetic/biophilic effect, aromatherapy, air purification), education & research (e.g. demonstration or experimental microcosms), hobbies (especially unconventional ones like micro-aquaponics and paludariums or balcony container gardens for pollinators), urban wildlife attraction (e.g. balcony gardens with nest-boxes), pollution free small-scale food-producing (e.g. spice gardens/hothouses), etc. purposes.

As computer-aided devices (henceforward – CAD) these mini-gardens represent themselves easy-to-sustain ecosystems – this easiness means considerable competitive advantage for potential users who often are not experts in ecosystem management field. Besides, idea of computerized ecosystem could be attractive as an unconventional approach to long-lasted traditional way for indoor plant and animal care. This attractiveness and, accordingly, educational, therapeutical and hobbies-related qualities of CAD could be even more enhanced if aesthetical properties would be particularly emphasized apart from purely functional ones. Within a set of methodological principles / archetypes used for aesthetic design recent research stresses conception of Golden Ratio.

Still, continued Golden Ratio related empirical research on our CAD mini-gardens is necessary (see review below); relevant discussion on non-living systems related mechatronic devices has been added.

2. Golden Ratio – historical testimonies

The Golden Ratio, or "the perfect proportion" has been known from antiquity – there are relevant written testimonies traced back to Euclid of Alexandria (around 300 BC), Pythagoras (6th century BC) and even to earlier authors [1], [2] who used it.

Fig. 1 *A. Semenov. Baba Yaga's Hut*

After antiquity sudden rise of interest on Golden Ratio was observed around the 15th century when it was widely used in art (as an example – see. Figure 1) and architecture.

3. Generalized Golden Ratio

The harmony of the structures of natural systems, that is, their internal organization, is subject to certain mathematical laws. Objective world stable stationary states corresponding to particular figures, called generalized gold sections. These figures are all the structure of the invariant, which are embodied by the dialectic structure of the world and the different variations that can be observed at every step of nature. It is important to note that with the generalized Golden Ratio, not only is the well-known ratio of 0.618 understood, but a whole line of relationships, where like in music, a single major or minor note can be played, and another can stand out from the whole ensemble.

The generalized Golden Ratio can be calculated according to the following scheme. Denote the probability of the event with p, in which case, the complement up to 1 will be $(1-p)$, describing the event default probability. To express the amount of information, we take the logarithms of the above values, and denote the relationship of this logarithms with k:

$$k = \frac{\log(1-p)}{\log p},$$

where from,

$$\log(1-p) = k \log p,$$

which in turn, we obtain [3]:

$$p^k + p - 1 = 0.$$

The set of resulting solutions of the equation is shown in the Table 1.

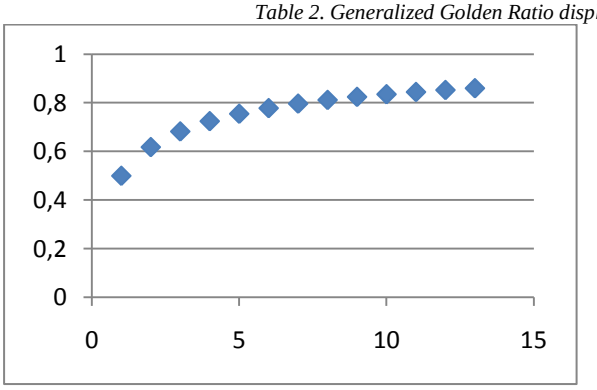
Table 1. *Generalized golden ratio examples*

k	p	1-p
1	0,5000	0,5000
2	0,6180	0,3820
3	0,6823	0,3177
4	0,7245	0,2755
5	0,7549	0,2451
6	0,7781	0,2219
7	0,7965	0,2035
8	0,8117	0,1883
9	0,8243	0,1757
10	0,8351	0,1649
11	0,8444	0,1556
12	0,8525	0,1475

Historically, the ratio applied to $k = 2$ has been often used in architecture and art and found in living organisms and other natural formations [3], [5]. There is a widespread opinion that exactly this proportion mathematically expresses the harmony of natural formations.

The following table 2 shows the different ratios with values rising at an exponential rate.

Table 2. Generalized Golden Ratio display



Other generalized Golden Ratio detection methods can be found in the literature [4], [5].

Higher-level (rank) proportions, whose conformity with nature's harmony gradually decreases [3], shall be used if the number of cells, their role in the situation, or other considerations does not allow the use of commonly known ratio of 1: 1.618 [6].

4. Mechatronic devices analyzed: Golden Ratio applied

Development of mechatronic devices can include the following applications of the generalized golden ratio:

- size of a parts of object relative to the total or boundary area
- object aspect ratio
- small object, logo, switches or buttons centre position coordinates

4.1. Mini-greenhouse prototype for environmental science and biology studies

A mini garden (greenhouse) has been developed for environmental science and biology studies; it can be used also e.g. for home entertainment and spice growing purposes. This device (see Fig. 2) consists of a housing, removable plant box, microcontroller, heater, lighting, irrigation system, ventilation system, data transmission circuit. A Bluetooth communication channel is used for controlling the following parameters of device: temperature, humidity of air, humidity of soil, lighting.

Fig. 2 *Computer-aided mini greenhouse*

Due to the controlling system mini-Greenhouse can work well also in unfavourable external environment – like dark and cool; it can also use natural light and warmth: for this purpose, the top of the body and the partially front panel are made of glass. The controls are located on the side of the cabinet (see Fig. 3).

Fig. 3 *Controlling equipment*

For golden ratio calculations: the main dimensions of a greenhouse are determined by the following scheme:

- the height is determined as the reference point, and it is determined by the full maturity of plants
- the other dimensions (width, length) are determined using generalized golden cuts

In this case, it is hard to apply the well-known classic golden cut of 1:1.62 since the device casing is too wide, resulting thus in interference in the room and maintenance difficulties – that is, which is why the third aspect ratio is selected (see Table 1).

4.2. Aquaponics prototype for environmental science and biology studies

Aquaponics represents itself artificial symbiotic ecosystem which synergically combines aquaculture and hydroponics sub-systems. Despite of various designs, there is just one core idea behind – that of recycling : waste materials produced by fish, crustaceans, molluscs and other aquaculture animals (and representing danger to these animals if accumulated) have been transported by water flow to hydroponics where green plants remove pollution, use animal waste for nutrition and then cleaned water has been returned / pumped back to animals in aquaculture.

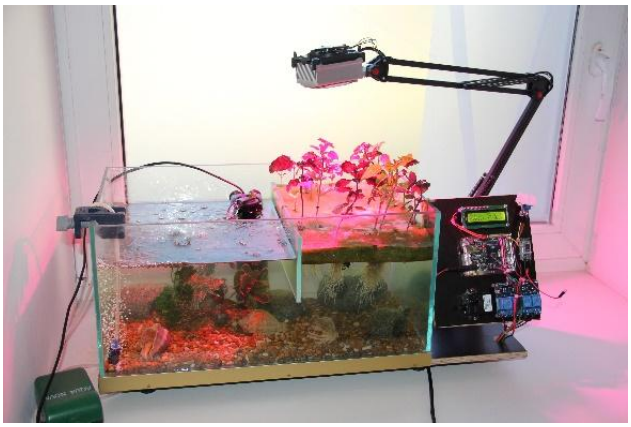


Fig. 4 *Aquaponic system*

Aquaponics are of different scale – from big farms / greenhouses to small portable indoor microponics designed for hobby (utilization spectrum – see 4.1. *Mini-gardens as selected Mechatronic Devices*). Such a small microponics has been designed in the framework of recent research (see Fig. 4) and its functions are computer-aided: light, temperature, water circulation, oxygen availability have been tested and regulated. Golden proportions have been incorporated in aquaponics design – namely, in length, width and height ratio. Further research is necessary to evaluate aquaponics` psychological and even biological impacts

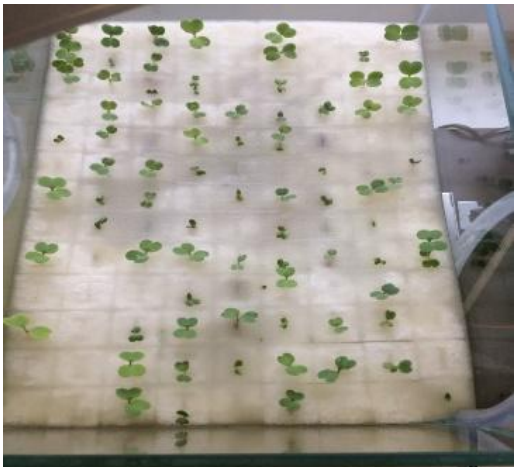


Fig. 5 *Plant sprouts in aquaponic*

6. Generalized Golden Ratio application in electronic devices

If we want to develop an innovative, competitive new product, we need to make a survey on already patented relevant devices. It is necessary to analyze whether new product offered will arise customers` interest, will it be of competitive price.

Several aspects need to be considered when designing a new device:

- device functionality
- technologicality
- safety of use
- ergonomics
- design

In order to reflect device`s planned functionality/functional properties an appropriate technological solution must be applied – constructor needs to know what parts and elements will be used to create the device, which will have a significant impact on both the size of the device and the design solution and, of course, the cost. When designing a project, special attention should be paid to product safety.

The essential component of the device is its ergonomics. When designing a device, its shape must take into account aspects that are convenient for use and health.

All of the above aspects should be taken into account when designing the product. A suitable and interesting design will have a positive effect on both the functionality of the machine and its ergonomics and aesthetic quality.

If the constructor of the equipment is also a designer, it would be desirable to know the basics of design methodology, the importance of colors and textures and their application in product development. The design should be based on a proportional distribution and arrangement of parts and components. One of the options is to choose one of the golden section proportions. Different shapes, color contrasts, and different textures can be used for the presentation of functional areas.

6.1. Pen – SpongeBob

Pen – SpongeBob is used for storing and displaying information. The device consists of a housing, memory device, microcontroller, liquid crystal display, Bluetooth connectivity information input, power supply. Of course, it also has a writing function. Information can be entered with a cordless connection from a smartphone or smart clock used to store information. The proportions of the shape of the device and the layout of the details are utilized in generalized golden cuts; in the case of display, 8 golden ratio (see Table 1).

Fig. 6-7 *From concept to device – student`s "external memory" as a pen*

6.2. Radio receiver

Student-made radio receiver is made with the aspect ratio. The design solution uses a golden ratio of 1:1.62 (see Table 1) with a hull edge size of 17.5 - 10.8 - 6.7 cm. The swivel buttons are located on the right side, their use does not cover the view of the front panel with the speaker, the distance between the centers relative to the height corresponds to the same ratio. The case is made of two-color materials, stainless steel and plastic (3D print) are used.

Fig. 8 *Students-made radio receiver*

6.3. Self-made robot

A simple self-propelled robot (see Fig. 9) is developed for robotic classes for college and high school students. It consists of a base, a transmission, a power supply, a Micro:bit microcontroller, and an ultrasound sensor for obstructing obstacles. The base plate is made close to the 2nd generalized gold ratio, in this case the ratio is calculated by dividing the width with the distance from bow to the optical center of the back (rear support fixing screw).

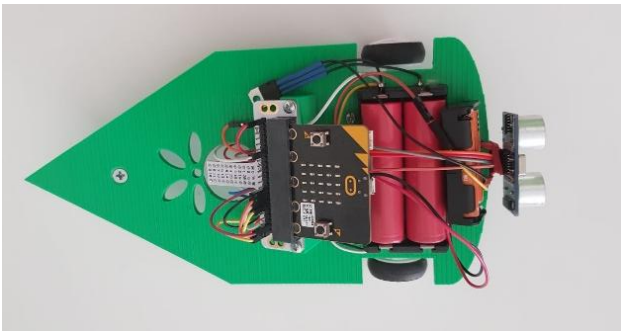


Fig. 9 *Students-made robot*

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DIGITAL MODELS APPLICATION IN INTELLECTUAL PACKAGING MANUFACTURING

Prof. dr. Palchevskyi B.
Technological Faculty – Lutsk National Technical University, Ukraine.
E-mail: pac@tf.dtu.lutsk.ua

***Annotation**: Production systems with elements of intellectual technologies can be found in various fields of production. To ensure the effectiveness of such systems, digital technologies are often used, which allow to create special databases for describing their state in functioning and to analyze data for identifying sources that lead to loss of efficiency. This article focuses on the construction of digital models for analyzing the production system of packaging, taken as an example. It is shown how data analysis is performed to identify critical elements in the production system.*

KEYWORDS: INTELLIGENT MANUFACTURING SYSTEM, PACKING AUTOMATIC MACHINE, INTELLECTUAL PRODUCTION, DIGITAL MODELS, DIGITAL TECHNOLOGIES, SYSTEM ANALYSIS

1. Introduction

It is difficult to imagine a user of a production system that would not want to make it more effective. The exploitation of production system is always accompanied by a number of emerging problems for improving of its efficiency, the most common of which are:

- increasing in production volumes on existing equipment,
- costs reducing in exploitation of existing equipment, etc.

The modern way of problem solving to increase the efficiency is to create intellectual production based on the usage of advanced information technology. It is already built a single approach to building an intellectual production system, which provides opportunities for increasing the production efficiency. In its creation it is monitored the transition from efficiency increasing at each stage of production separately to the optimization of production process in general. Providing the intellectual production efficiency is based on automated procedures for collecting and storing information necessary to track the revenues of raw materials, finished products, equipment and personnel – everything, that is used in production activities [1, 2, 4].

Summarizing the arguments of many researchers of modern automated production [3,6, 7], it can be argued that the production system becomes intelligent if, in problems solving of production, it adapts to work in external conditions that are changed over time, relying on the appropriate knowledge base. So, automatic control system (ACS) must be suitable for working with knowledge bases [5, 6], that is to become intelligent ACS. Since in the formation of a management program possible production situations should be taken into account, intelligent ACS s should compensate for changes in external conditions by making certain changes in the control algorithm to achieve optimal performance parameters of the production system.

Obviously, such a ACS should first of all assess the external conditions in order to make the necessary changes in the algorithm of functioning and also be provided model that describes the production situation at given moments of time, that is, the digital model of the production system.

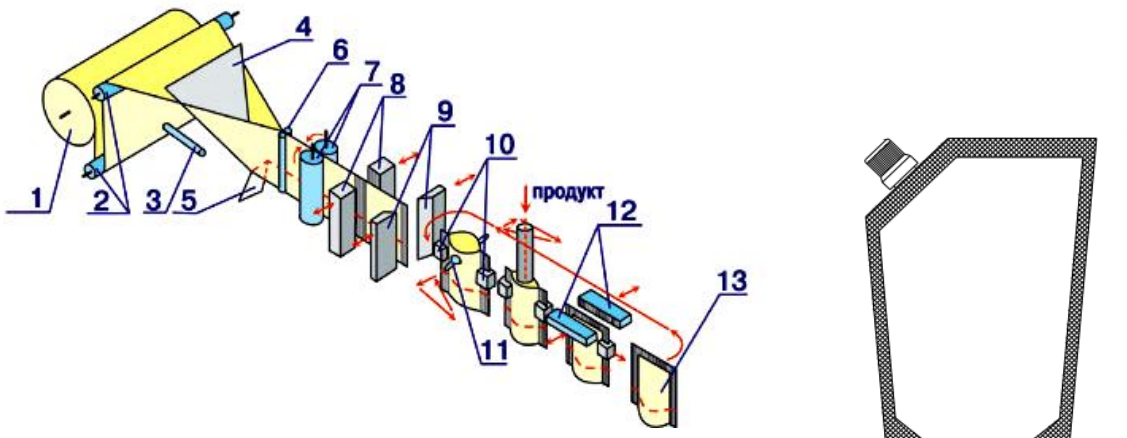
2. Principles of usage of digital models

The digital model of the production system is its "digital double", in the creation of which the most complete available knowledge about the production system is used. It allows you to get the right decisions quickly and to solve analysis problem of the production system behavior in different production conditions or the search for hidden patterns to identify critical elements in the production system.

The usage of digital models that describe a single production cycle involving exclusively machines and mechanisms to solve similar production problems is the implementation subject of digital technologies in production. Creation of digital models of production processes by transferring events from the real physical world to the world of models, as well as their usage for the development and adoption of control decisions, forms the so-called "digital production". This article focuses on the construction of digital models for analyzing the production system of packaging, taken as an example, but in practice this concept can be implemented for all mechanical processes, since all technological characteristics are the same.

3. Digital models for analyzing the production system of packaging

This definition implies that for the whole chain of stages of the packaging process (Fig. 1) should be information confirmation that the production system functions "as needed".



a ***b***

Fig.1.** Technological scheme of paste packing in packages "doypack" **(a)** and a package doypack with a cork **(b)
1-roll of film, 2- film unwrapping, 3-puncher, 4-pipe formation, 5-photosensor, 6,7- swaths, 8-longitudinal welding, 9-cutting, 10-package opening, 12- sealing of the package (in packages with the cork, between the cutting mechanism 9 and the mechanism of package opening 10, there are a mechanism of corner cutting of the package 9-a, a mechanism of cork supplying 9-b and a mechanism of the cork welding 9-c – are not shown).

It was considered and recorded in the database of its simple for the period of its operation in real production conditions from 22.5.2016 to 22.5.2017 to study the sources of the efficiency loss of the multi-positional automatic machine for packing of pastes in packages like "doypack". The multi-positional automatic machine carries out the following technological transitions: film unwrapping from a roll, pipe formation from it, longitudinal welding of sidewalls for the formation of a package, its cutting, corner cutting of the package and welding into it a cork, filling the package and sealing it with welding (see Fig. 1) .

The model of the production system is based on the collection of data on the length of stay of packing automatic machine in an operational state and in idle states for various reasons. To simplify the construction of the model in such cases, a line or a complex machine is divided into autonomous units. The structure of the packing automatic machine is shown in Fig. 2. The usage of the sensors allows you to collect and transmit information quickly, without interruption, and most importantly, even from the most inaccessible places of machines with parts that work at high temperatures and high loads. At the same time, data collection is more accurate and faster, because instead of the engineer the information is read and transmitted by special sensors.

To solve the production problem of efficiency increasing of the multi-positional automatic machine, we can use the tools of applied system analysis and modern environments of data analysis for its operation, which allow us to turn the solution of the general problem into a "technological process", where the sequence and content of the design operations are clearly defined.

The scheme of work with large data is common to all digital production tasks and includes such stages:

- formulation of target indicators,
- data preparation (its coding, structuring, filtering, etc.);
- construction of models,
- checking of models quality,
- adaptation of the received results obtained to production needs

The second stage is the data preparation. Here it is necessary to identify the most important reasons to manage. To do this, each parameter must be evaluated and identified. Some parameters had to be taken as irrelevant on the basis of obvious arguments. Idle time, caused by various reasons of operation stopping, and also by failures in separate nodes and mechanisms of the machine, is given in Table 1.

The first stage of a digital model construction is the definition of factors that influence on the state of production system and the construction of a hierarchical tree of influence on its efficiency. Tree of factors are factors organized in the form of a cause-effect diagram - a tool that allows you to identify the most significant reasons that affect the last result. In this way, you can get to the primary reasons, the elimination of which will most significantly affect the problem solution of increasing the efficiency of the equipment use.

To ensure coverage of all aspects, you can use the Ishikawa diagram or other methods to systematize the sources of idle time in the production system. According to the generally accepted method, the idle time is divided by us into three classes:

1. own idle time, arising in the machine as a result of its implementation of the work process;
2. organizational and technical idle time caused by the influence of the environment of the machine functioning conditions;
3. idle time due to re-adjusting the machine.

Stage 3 – preparation of a digital model of operation of a multi-positional automatic machine. Excel files are used to enter and display information stored in a specialized database, the extract from which is given below (table 2).

Stage 4 - The using of model for increasing the efficiency of production. The problem arises if the value of efficiency does not suit us. To solve the problem (to improve the production system) – means to eliminate the reasons that lead to decrease in its efficiency. Obviously, there are so many reasons, and eliminating each of them is a very troublesome and costly task.

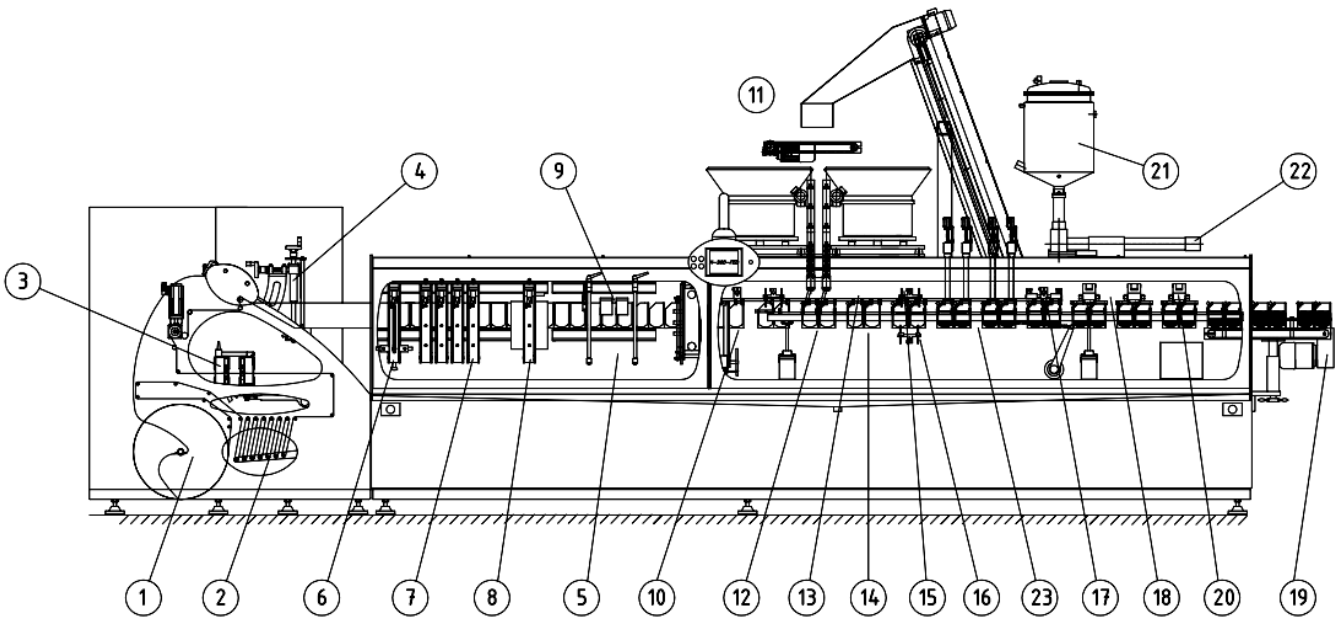


Fig.2 *Technological machine for packing pastes in packages "doypack":*
1-roll of film, 2-mechanism of unwrapping, 3-puncher, 4-forming triangle, 5- guides, 6- soldering iron of bottom with a drive, 7-mechanism of vertical welding, 8-mechanism of cooling, 9- corner stamps, 10- cutting mechanism (scissors), 11- a mechanism of cork supplying, 12- soldering iron of corks, 13-top stretcher with tweezers, 14-lower stretcher with tweezers, 15-top suckers, 16-bottom suckers, 17-mechanism of package stretching, 18-horizontal soldering iron , 19- conveyor, 20-cooling mechanism, 21-bunker with a product, 22-dispenser drive, 23-dispensers (4 pieces) with drive

Table 1.

Classification of sources causing idle time of packing machine

Classes of idle time	*Subclass*	*Idle time group*	*Subg.1*	*Subg. 2*	*CODE*
1. Own idle time-machine failures		1101. Pomp of product supplying			***11010***
		1102. Mechanism of film drawing			***11020***
		1103.Vibrbunker			***11030***
		1104. Mechanism of cork catching			***11040***
		1105. Mechanism of cork supplying and inserting			***11050***
		1106. Mechanism of cork soldering			***11060***
		1107. Mechanism of vertical soldering iron			***11070***
		1108. Dispenser with nozzle			***11080***
		1109. Cooling mechanism with a thermal sensor			***11090***
		1110. Vacuum pump			***11100***
		1111. TEN and thermal sensor			***11110***
		1112. Photosensor of marks			***11120***
		1113. Vibrbunker of corks			***11130***
		1114. Printer			***11140***
		1115. Mechanism of scissors			***11150***
		1116. Mechanism of package opening with suckers			***11160***
		1117. Corner stamp			***11170***
2. Organizational and technical idle time	***21. Power breaks***	211. Lack of electricity			***21100***
		212. Lack of compressed air			***21200***
	22. Breaks in the supplying of materials	221. Lack of film	2211. Delay	Roll changing	***22110***
			22120. Low quality film	Disassembly of film	***22121***
				Corrugated film	***22122***
				Extra switching-on	***22123***
		222. No product	2221. Product delay		***22210***
			22220. Low quality product	Cold product	***22221***
				Hot product	***22222***
		223. No corks	2231. Delay of corks		***22310***
			2232. Low quality corks	Sharpening on the cork	***22321***
				Distorted	***22322***
	23. Staff expectation	231. No staff			***23100***
		232. Staff mistakes			***23200***
	24. Incident	241. **Unpredictable problems**			***24100***
3. Idle time while reconfiguring	31. While changing the film producer				***31000***
	32. While changing the dose of the product				***32000***
	33. While changing the product				***33000***
	34. While changing the package type				***34000***

The logic of system analysis involves the identifying the most significant reasons that lead to a problem, and the concentration of effort on them.

To analyze the reasons of the efficiency loss of the production system, we use aggregation of the data contained in the database. It will allow describing the generalized (aggregate) parameters of the system by formation of the standard summary tables in the Microsoft Excel system.

Such aggregate parameters more precisely describe the target properties of the production system.

Since the model of the production system, based on the data collection about the duration of stay of a multi-positional automatic machine in different states, then, creating aggregate objects, you can determine its efficiency, as a part of the useful time. To set the aggregation rules in the Microsoft Excel system, it only needs to specify which criteria should be in aggregate objects.

Table 2.

Extract from the database of the operation of a multi-positional automatic machine in real production conditions from 22.5.2016 to 22.5.2017

№	Class of idle time	Group of idle time	The reason of idle time	Code of idle time	Duration, min	Starting	Comment
1	1 - Own failures	1102 - Mechanism of drawing	Tightening of film in a triangle	11020	3,00	22.05.202016	During the change
2	1 - Own failures	1102 - Mechanism of drawing	Replacing the spring of the tweezers	11021	3,00	22.05.2016	Packets were sagged
3	1 - Own failures	1107 - Mechanism of soldering iron	Unplanned cleaning of soldering iron	11070	9,00	25.05.202016	Unplanned washing of machine, the car was flooded
	…	…	…	…	…	…	…
123	1 - Own failures	1102 - Mechanism of drawing	Replacing the spring of the tweezers	11021	9,00	26.05.202016	Packets were sagged. And washing of machine ,
124	2 - Org-tech idle time	2221 - Lack of product	Lack of product	22210	35,00	27.05.202016	No steam. Oversealing of the central condensate wire.
	…	…	…	…	…	…	…
417	1 - Own failures	1107 - Mechanism of soldering iron	Unplanned cleaning of soldering iron	11070	9,00	23.05.202017	

Fig.3 shows the classes of idle time. According to the results shown in Fig. 3 it can be concluded that the main source of idle time during the machine exploitation is its unreliability, caused by frequent failures of machine mechanisms. To analyze the major sources of unreliability, we will make a ranking of the causes of failures (Fig. 4).

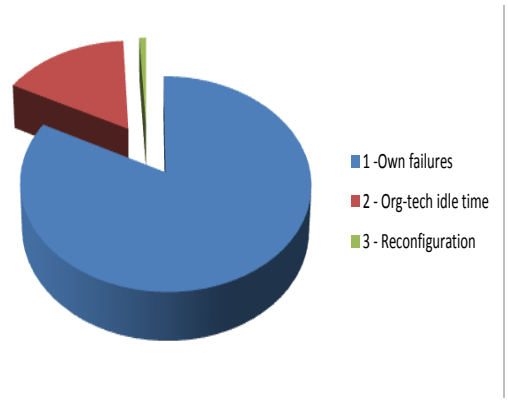


Fig.3.*Determination of the importance of idle time, affecting on the efficiency loss of the packing machine (total 5627 min per year)*

Idle time	Duration, min
1 - Own failures	4219
1102 - Mechanism of drawing	1093
1107 - Mechanism of soldering iron	761
1106 - Mechanism of cork soldering	482
1109 - Cooling mechanism with a thermal sensor	322
1112 – Photosensor	233
1116 - Mechanism of package opening	224
1105 - Mechanism of cork supplying and inserting	196
1115 - Mechanism of scissors	170
1108 - Dispenser with nozzle	133
1111 - Thermoelectric heater and thermal sensor	152
1117 -Mechanism of corner stamp	94
1110 - Vacuum pump	90
1113 - Vibrobunker with controller	50
1114 - Printer	37
1104 - Mechanism of cork catching	10

Table 3.

Aggregation of idle time in a machine

Idle time	Duration, min
2 - Org-tech idle time	919
211 – Lack of electricity	173
2221 - Lack of product	295
2222 - Low quality product - cold	207
23 - Staff expectation	63
24 - Incident	181
3 - Reconfiguration	49
31 - When film changing	49
In total	**5627**

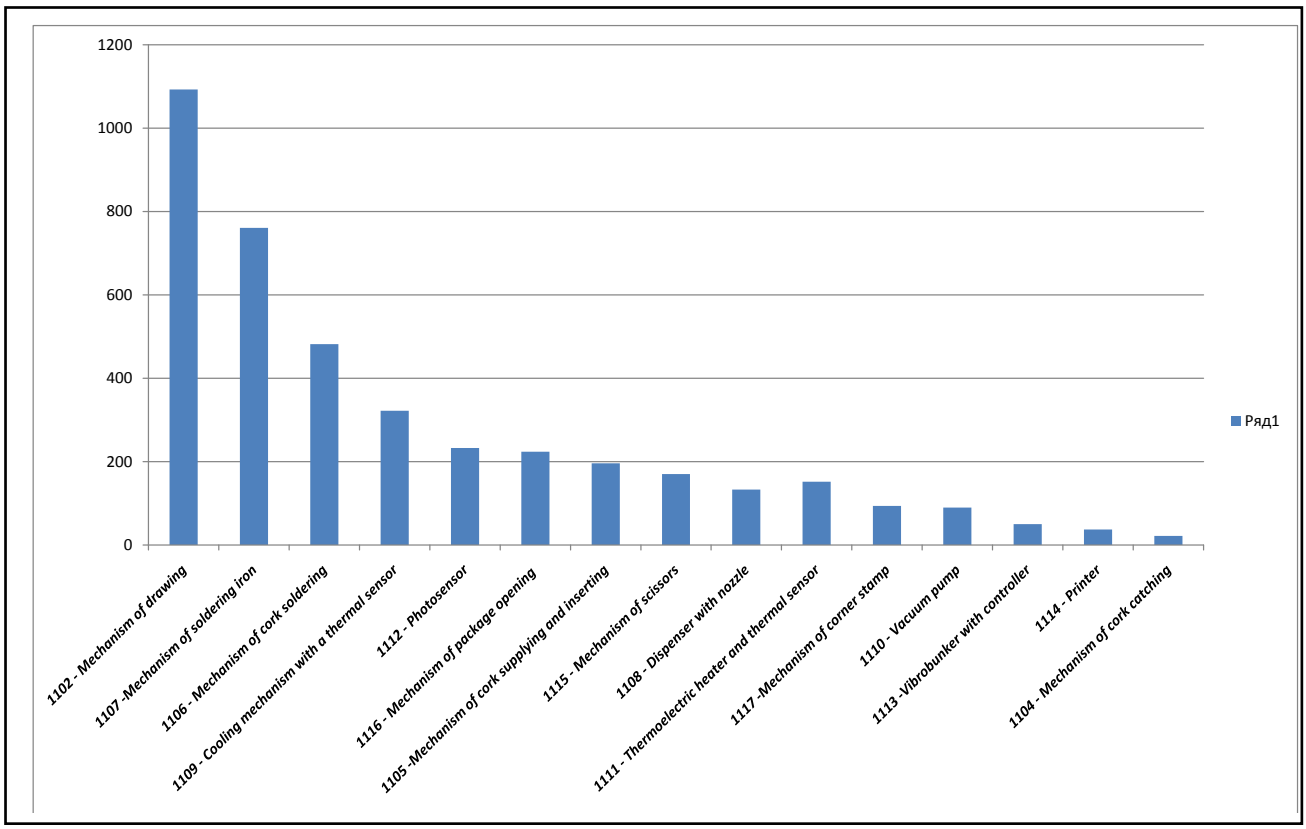


Fig.4. *Types of idle time in machine mechanisms*

The sequence of aggregation and decompositions ends when the critical terms of the system description are discovered - the parameters that influence on the unsatisfied value of the target property of the system. It is necessary to focus on improving and stabilization of these parameters at carrying out of the following stages of system analysis.

The reviewed digital models describe the conditions of exploitation based on the results of events that have already occurred. However, the effectiveness of such use of digital models, despite the possibility of analysis of production and the identification of necessary reasons for correction, has a drawback. Since equipment at many production enterprises operates day and night, then its unexpected stop can lead to a lot of losses. To prevent this problem, we developed a mathematical model for defining of controlled parameters and features that describe the functioning of a technological automatic machine, which allow us to determine the current state of the machine and to predict the necessary preventive actions of service [8].

Lately, researchers from the University of Portsmouth in the UK have used an artificial intelligence to predict when machines need preventive service. The diagnostic system using a branched system of sensors examines how machines work, and uses this information for accurate predictions when it will be necessary to perform technical service.

4. CONCLUSION

1. The main attention in this article is devoted to the construction of digital models for analyzing the exploitation conditions of the packaging process, which was shown as an example, but this concept can be implemented for all mechanical processes (processing, assembling), since all its technological characteristics are the same . Moreover, since the processes of packaging are mechanical processes, during which several elements are periodically processed and merged (that is, the product is often checked and controlled after each stage), this

2. Obviously, the direction of improving of digital technology in automatic production should be predictable for the future states of the production system. If you place sensors in sensitive details and mechanisms of a machine that are detected in the efficiency analysis of machine exploitation, for example by ranking, as shown in Fig. 4, then the special software will be able to monitor and analyze signals and warn technicians about the malfunctioning or the need to change the mechanism, or its detail that are in critical state. Such approach is already developing in real production conditions, which is confirmed by the fact that modern packaging machines already have 120-150 sensors that control the machine functioning.

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HARMONIC COMPONENTS OF ELECTRIC DRIVES WITH FREQUENCY CONTROL FOR CENTRIFUGAL MECHANISMS

Assoc. Prof. Rachev S. PhD, Assist. Prof. Lyubomir Dimitrov PhD, Eng. MSc. Ivaylo Dimitrov Ivanov
Technical University of Gabrovo, Republic of Bulgaria

sratchev@mail.com

Abstract: *The paper deals with the problems in the operation of non-linear loads, causing distortions in the sinewaves of voltages and currents. There is currently increasing use of variable frequency drives (frequency inverters) that drive electric motors and are such loads. The experimental results cover multiple measurements of voltages and currents harmonic components and the calculated values of the total harmonic distortion coefficients of voltage and current for each of the phases, supplying different loads. An analysis of the results obtained has been done and specific conclusions have been pointed out on the basis of the measurements carried out.*

KEYWORDS: *MOTOR DRIVES, ELECTRIC MACHINES, INDUCTION MOTORS, FREQUENCY CONTROL, HARMONIC ANALYSIS, TOTAL HARMONIC DISTORTION*

1. Introduction

In the industry, the number of consumers with non-linear volt-amperage characteristics - electronic converters, static reactive power sources, electric arc furnaces, gas discharge light sources, battery chargers, electronic ballasts and LED light sources, and more, increases continuously. In the group of electronic converters are included - rectifiers, inverters, frequency converters, controllers of induction motors and voltage regulators. All these users consume non-sinusoidal current, resulting in distortion in the sinewaves of voltages and currents [1].

Current harmonics cause voltage drops in the resistances of the electrical circuits that overlap the sinewave of the supply voltage and deform its sinusoidal shape. This leads to a deterioration in the quality of the electrical energy supplied to consumers, which may cause problems in their operation [2, 3].

The supply of non-sinusoidal voltage to the electric motors leads to the movement of harmonic current in their windings [4, 5].

In order to efficiently use electrical energy, it is desirable to change the AC voltage to a constant frequency, to have a sinusoidal shape and a constant size. One of the main factors influencing the change of these characteristics are squirrel-cage induction motors, driving different mechanisms. In this sense, these electricity consumers are an important part of the energy system to undergo research to improve the electricity performance.

2. Technical considerations

There is currently increasing use of variable frequency drives (frequency inverters) that drive electric motors. The voltages and currents of the frequency inverters that power an electric motor are rich in harmonic frequency components [6].

Frequency drives of electric motors lead to increased harmonic distortions in power grids [4, 5, 6]. These distortions are individual. They depend on the mode of operation.

In a three-phase, four-wire power system, neutral (zero) wires can be severely affected by non-linear loads connected to single-phase 230 V circuits. Under normal conditions and a symmetrical linear load, the base 50 Hz portion of the phase currents is reset in the zero conductor. In a four-wire power system with single-phase non-linear loads, odd harmonics, with frequencies that are three times multiples of the fundamental frequency: third, ninth, fifteenth, etc. harmonics - they are not reset but summed up in the zero conductor. For systems with many single-phase non-linear loads, the current in the zero conductor may actually exceed the phase current. The result is excessive overheating. There are no current limit switches in the zero conductor. Greater zero wire current can also cause higher than normal output voltage drop.

Zero busbars and their offsets are dimensioned to carry out the full value of the rated phase current. They may be overloaded as a result of the conducting through the zero wires an additional sum of current harmonics with frequencies that are three times multiples of the fundamental frequency [7].

Meanwhile, IEC 61000-3-4 [1] sets the limit values for harmonic current components in low-voltage power electric distribution systems.

The term ‘frequency regulation’ has a dual meaning and use. In a broader sense, the term ‘frequency regulation’ has the meaning of ‘regulation by means of angular speed change’ without paying attention to the specific technical implementation. In a narrow sense, ‘frequency regulation’ refers to the above-mentioned basic way of varying the rotation by changing the frequency of the current.

With frequency inverter drive, it is possible to adjust the speed, torque, direction, start and stop of standard induction motors. The main advantages of this regulation are: significant opportunities for energy saving; extended life of mechanical equipment; reducing the starting current; higher starting torque; the ability to adjust the motor speed below and above the synchronous value. The frequency converter changes not only the frequency but also the voltage applied to the motor. This provides the required torque of the motor shaft without overheating and provides additional energy savings.

The capital costs of the water pumping stations are high, but the most expensive component is the electricity to drive the pumps. It is therefore important that pump units have to are highly efficient in providing proper maintenance.

Most of the existing pumping systems (of the order of 70%) are over-sized by designers by at least 20%. This reveals excellent retrofit capabilities with frequency inverters to equalize pump flow to the actual needs of the system as accurately as possible. In such cases it is very important to pick over the electrical characteristics of the motor and the inverter. Older inverters create significant harmonic distortions, resulting in additional heating of the motor windings.

3. Measurements results

The purpose of the measurements is to evaluate the operation of centrifugal mechanisms electric motors – a pump unit and a fan.

For the centrifugal pump loading, a method is used for placement (rotation) the revolving valve at different positions. In this way, different load of the electric motor is simulated in operating mode. And since a large number of such aggregates are found in practice, it is expedient to study and analyze them in working mode to assess their impact on the quality of electrical energy.

Measurements have been done with changes in the load on the electric motor with an fully open revolving valve, 2/3 open

revolving valve, 1/3 open revolving valve and 1/4 open revovlving valve, changing the electrical values and indicators.

A centrifugal pump powered by a squirrel-cage induction motor type AO 052-4 with nominal technical data is used for this purpose: P_{RATED}=5.5 kW, U_{RATED} = 380 V, I_{RATED} = 14.2 A, n_{RATED} = 1440 min^{-1}, cosφ = 0.86. Three-phase frequency converter of the *ELDI* series with *U/f* and *Vector Control* is used to control the pump [8].

The centrifugal fan tested has an induction motor type AO 022/2, P_{RATED}=0.55 kW, U_{RATED}=380 V, I_{RATED}=1.4 A, n_{RATED}=2750 min^{-1}, cosφ=0.83. For rotation control, the same type of frequency converter used in the pump unit is used, but in this case it is of less power (P = 0.75 kW) and single-phase power supply $U_{ном.}$ = 230 VAC.

The results have been obtained using a *METREL MI 2292* electrical energy quality analyzer [9]. In addition, centrifugal fan results obtained from a *VOLTCRAFT ENERGY LOGGER 4000* electrical meter have been also provided [10]. The measurements have been done in laboratories at the Technical University of Gabrovo.

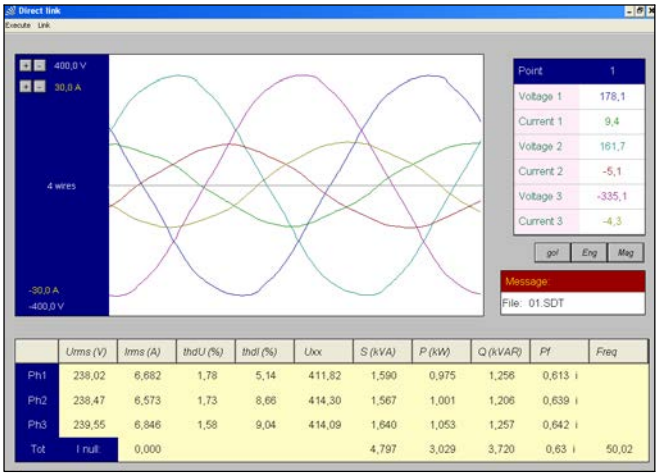

Fig. 1 *Voltage and current changes at fully open revolving valve of the centrifugal pump*

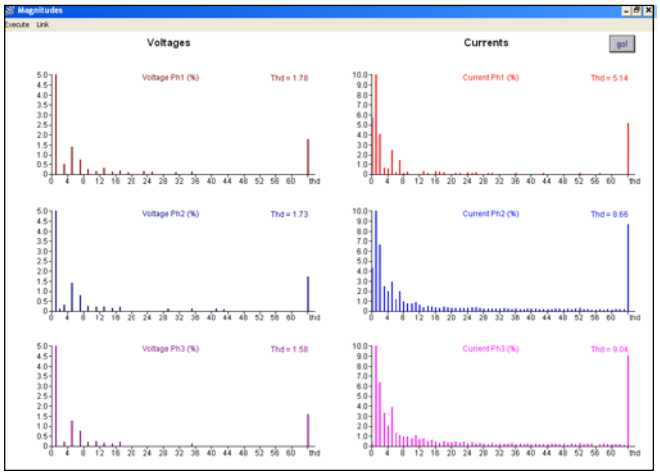

Fig. 2 *Observed harmonics at fully open revolving valve of the centrifugal pump*

4. Analysis of the results obtained for the centrifugal pump unit

The results obtained clearly show that a different load on the pump unit and the induction motor, respectively, changes some of its electrical characteristics. This results in a change in the power factor - PF, which has values in the range of 0.6 to 0.75 with a pronounced inductive character of the load.

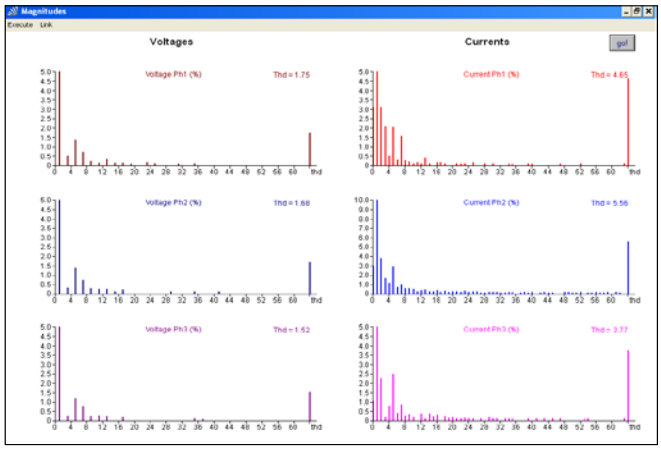

Fig. 3 *Observed harmonics at 1/3 open revolving valve of the centrifugal pump*

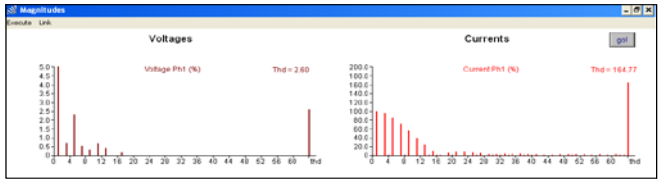

Fig. 4 *Observed harmonics for centrifugal fan at frequency of 50 Hz*

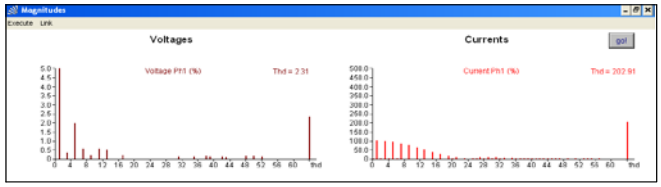

Fig. 5 *Observed harmonics for centrifugal fan at frequency of 30 Hz*

These values are typical of the squirrel-cage induction motors because they do not always work at a nominal load, largely due to the resistance of the drive mechanism. This leads to different values of the electrical energy quality indicators.

The results for the higher harmonics show that they are very pronounced with the serial number - 3, 5 and 7, they reach 9.04% for the current - THD_I and are too small for the voltage - THD_U = 1.50÷1.76. Nevertheless, the values of the higher harmonics are within the limits set in the ordinances, with the phase voltages and currents not altering their sinusoidal shape unacceptably.

5. Analysis of the results obtained for the centrifugal fan

Since the frequency control is fed by single phase, the results are only considered for the first phase *Ph1*. The measurements carryied out show that the frequency influence on the shape of the current is the most influential. With lowering the frequency and the motor speed respectively, some electrical performance changes. The odd harmonics of the current are highly pronounced (3, 5, 7, 9, 11, 13, 15, 17, 19, 21), the overall harmonic distortion reaches very high values at the lowest frequency of the supply voltage (*f*=20 Hz): THD_I = 219.05%. The power factor *PF* is also very low: *PF* = 0.4, with the predominant capacitive character of the load. This is largely due to power capacitors in frequency control that have high capacity and lack of filters at the input of the converter. Because of the low power, the frequency control does not affect the shape of the voltage curve and its harmonic composition.

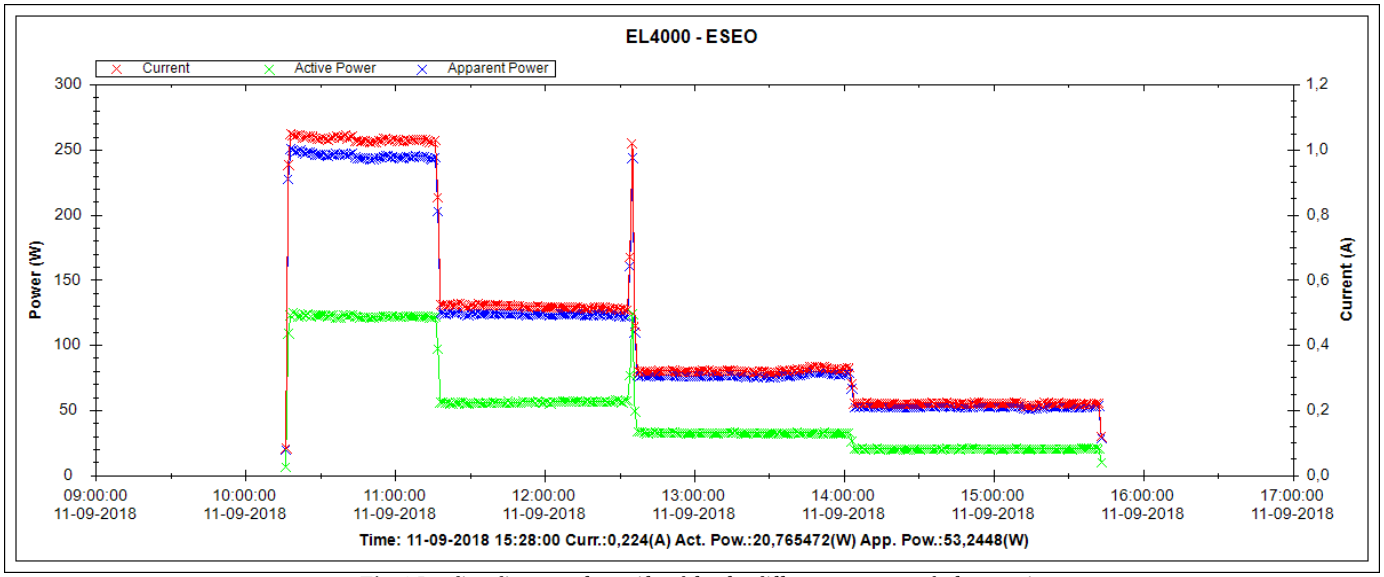

Fig. 6 *Loading diagram of centrifugal fan for different power supply frequencies*

6. Conclusions

The results obtained could be of great practical importance when considering to start and possibly implement the frequency control of induction motors for centrifugal equipment. There is more and more talk about the benefits (and deficiencies) of electric motors frequency control. Optional solutions implemented using a frequency converter can be successfully applied in laboratory exercises. It can practically examine the possibilities of the autonomous voltage inverter in order to acquaint and work with the students with a frequency regulator. The autonomous inverter provides great possibilities for exploring its co-operating with an squirrel-cage induction motor. This is a great advantage as most of the electric drives in the world are based on an induction motor controlled by frequency inverter.

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ORGANIC COMBINATION OF CONVERGING NBIC-TECHNOLOGIES AND SMART TEMP ADVANCED TECHNOLOGIES OF INDUSTRY 4.0

I. Matyushenko, Dr. Sc. of Economics, Professor, O. Azarenkova, PhD
Department of International Economic Relations, School of International Economic Relations and Travel Business, V.N. Karazin Kharkiv National University, Ukraine

azarenkova.olesia@gmail.com

***Abstract**: The paper is devoted to research of convergent technologies as a key factor in solving global problems in the new industrial revolution. It is shown that the concepts of the new industrial revolution, which today are widely used by Western scientists, also envisage the convergence of sciences and technologies and the creation of advanced manufacturing technologies on their basis. It is only possible to launch Industry-based trends in Industry 4.0 through the introduction of advanced manufacturing technologies based on convergent technologies. The approach to the periodization of scientific and technical development, which links the economic, technological and socio-political factors of development, as well as characterizes the structure of the sixth technological structure, the vision of the content of the new industrial revolution based on the organic combination of convergent NBIC-technologies with key factors, as well as approaches to solving global mankind issues are proposed.*

Keywords: NBIC TECHNOLOGIES, SMART TEMP, INTERNET OF THINGS

1. Introduction

From the last decades of the XIX century the research on periodization of main waves of innovation development the term "Industrial Revolution" simultaneously with the use of the concept of "technological structure" have become widely used. Initially, the industrial revolution meant only the process of transition from agrarian economics to an industrial society with a predominance of machine production, but today this concept has a much broader understanding.

At the same time, practically all developed countries took into account the difficult lessons of the crisis of 2008-2009 and revised their understanding of the role of industry and the priority of technological development. Already in 2011, in conditions of increasing competition on the external and internal markets for industrial production in the leading countries of the world, the state policy of these countries is becoming more and more clearly formed, aimed at developing the key factors of the new industrial revolution.

E. W. Drexler, the world-famous scientist-apologist for nanotechnology, believes that nanotechnology will be the basis for building a future civilization in the 21st century, emphasizing that the future will be connected not only with the proliferation of nanotechnological components, but with the transformation of the technological essence - the transition to what he calls atomically accurate production [13].

It is nanotechnology that becomes a connecting link between other revolutionary technological trends that have arisen in the last 20-30 years and allow us to obtain qualitatively new possibilities for convergence of these areas - to radically increase energy efficiency, to reduce the material intensity of the modern technosphere and, on this basis, enable mankind to exit Malthusian trap of limited resources of our planet and solve the problem of "the limits of growth" that faced modern civilization in the form of global problems. E. Drexler believes that this transition will not only be another technological improvement, but the fourth technological revolution - after agrarian, industrial and informational [13, pp. 96-97].

The concept of the Fourth Industrial Revolution, better known as Industry 4.0, was named in 2011 by the initiative of German businessmen, politicians and scientists led by C. Griffstaff (Siemens PLN Software), that identified it as a way of increasing the competitiveness of the manufacturing industry in Germany through enhanced integration of "cyber-physics systems" (or CPS) into production processes [14]. CPS means the integration of machines and human work connected to the Internet, as well as the process of creating a network of machines that will not only produce products with fewer errors, but will also be able to autonomously change the production patterns as needed, while remaining highly effective. At the same time, the driving force is integrated intelligence processes and products that generate so-called big data that completely change the production landscape and create new markets.

2. Results of Discussion

Industry 4.0 is a production that is equivalent to consumer-oriented "Internet of things", in which household items, from cars to toasters, will be connected to the Internet. This concept provides that further industrial development will be associated with the implementation of three related revolutionary trends until 2030, namely: (1) a revolution in the design and organization of production processes (technological and organizational reengineering industry, based on the total digitalization of production processes); (2) the transition to new materials (their integration into automated systems of design and production, the combination of the production of materials and the production of components); (3) reasonable environments (their mass implementation is expected in the 2050's and 30's) [5-12].

According to forecasts by 2030, the world's leading institutions (UNIDO, OECD, World Bank) and international industrial associations and research companies (in particular MIT, KPMG) can launch these trends in industrial production only through the introduction of advanced production technologies (APT) on the basis of convergent technologies, which are called "breakthroughs", emphasizing their revolutionizing influence on the structure of production. The general understanding of the APT is as follows: (1) technological substitution, leading to a qualitative improvement of existing or the creation of fundamentally new products; (2) automation of the production process, which introduces new requirements for the qualification of specialists; (3) customization of production as a flexible adaptation to the needs of the customer; (4) localization - reducing costs by saving on logistics and geographical proximity to the customer (customer); (5) economic efficiency, related either to a reduction in cost relative to mass production, or to resource savings, increased productivity, investment attractiveness and competitiveness [5-12].

Thus, APTs are associated with non-traditional methods of processing, new tools for control and management of production processes, as well as the use of new materials, automated and intelligent control and management systems for equipment, production processes and systems.

Specialists define the following priority areas of the APT [5-12]:

1) production process control systems, including state equipment sensors, raw material flow conditions and state (size, composition, etc.) of objects created (cultivated or grown);

2) multidimensional modeling of complex products, which allows to optimize their various parameters (strength, life

and, possibly, production process) and customize the object, modifying it for individual or small-scale production;

3) intelligent production management systems (optimization of external and internal logistics, modes of technological processes), including in robotics and in the "Internet of Things" area;

4) systems for the creation and transformation (cultivation) of material objects, including 3D printing; infusion technologies; promising methods of surface treatment and work with thermoplastics (growth technologies are key);

5) materials that are effective in creating promising actuators for growth technologies: composite and those that exhibit their properties in small-scale structures.

Summarizing analytical materials, it should be noted that today PVTs are, first of all, 3D-printing, "cloud" technologies, "Internet things", new materials, and robotics [15-17].

The concept of the convergence of NBIC-technologies as the basis for the new industrial revolution and on its basis - the convergence of knowledge, science and society has been developing since 2001, when the first presentation of the report by M. Rocco (USA) on the concept of NBIC-convergence, and since 2003, when the report of the National Science Foundation (NSF) of the United States "Convergent Technologies for Improving the Quality of Human Rights" was published [1]. In 2005, during a regular meeting of leading scientists dealing with NBIC convergence issues, a Delphi survey was first conducted to predict the main goals of NBIC-convergence and the expected results of their implementation, as well as how positive their impact on the scale would be. from 0 to 10 [17, 18]. In addition to the 20 ideas that were proposed in 2001, up to five further studies on this issue were conducted in the period up to 2012 and 80 other ideas were collected and, as a result, systematized and published in the final report of the National Science Foundation in 2013 year edited by M. Rocco and B. Bainbridge, [17]. We selected 40 possible ways to use the convergence of NBIC-technologies and predicted a probable period of time when they could be implemented. Average estimates (median) on a five-year scale, from 2015 and up to 2070, fairly describe the implications of using the main ideas of NBIC-convergence. At the same time, M. Rocco and V. Bainbridge acknowledge that the experience of holding meetings and conferences on the topic "Technology Convergence" for the period 2001-2013 has proved the need for regular foresight research among scientists and engineers involved in this issue.

The report outlined the main provisions for the convergence of knowledge, technology and society, including the main principles of convergence of human activity, including for the creation of knowledge and technological innovation, and also proposed a transformational approach to achieving social benefits, mechanisms and possible systems solutions for challenges to society in the next decade, among which: (1) challenges creating new knowledge, industries, professions; (2) the struggle against population growth, massive urbanization and globalization; (3) the functionality of national security; (4) improvement of life prosperity and human potential; (5) the development of individual and integrated health and education programs; (6) the fight against environmental problems; (7) maintaining a stable quality of life forever [17, 18].

In this case, the basic instruments of the process are precisely the NBIC-convergence, whose distinctive features are: (1) the emergence of a new, holistic science based on the material unity of the surrounding world; (2) the subject of the study of this science includes practically all levels of organization of matter: from the molecular nature of matter (nano) to the nature of life (bio), the nature of the mind (cognition) and processes of information exchange; (3) elemental structural elements are atoms, genes, bits and synapse; (4) intensive interaction between specified NBIC-scientific and technological areas; (5) significant synergistic effect; (6) the prospect of qualitative growth of technological opportunities of individual and social development of man [2-4].

Thus, according to the analysis of modern concepts of the industrial revolution, there is no single concept in relation to the content of the new industrial revolution, but they all focus only on individual constituent convergent technologies, namely: the concept of the APT revolution on nanotechnology; the concept of a combination of renewable energy and Internet technologies - on the digitization of sustainable development and alternative energy; the concept "Industry 4.0" absolves the so-called "reasonable" environment, based on the introduction of a new generation of Internet technologies and artificial intelligence in production processes; The concept of convergence of NBIC-technologies considers the possibilities of interdisciplinary research and development, but does not provide an instrument for their introduction into production. As a result, there is a need for in-depth study of the convergence of knowledge, technology and society and its application to solve global problems.

In the author's works [5-7] in connection with the implementation of the new industrial revolution in modern conditions, the assumption is made that Industry 4.0 technologies, combining Smart TEMP (T (technology) factors - intelligent technologies, E (environment) - reasonable environment, M (manufacturing) - reasonable production, P (products) - smart products), create new markets and industries, promote productivity and competitiveness of individual sectors and national economies. Based on the above, it is advisable to combine the key elements of the convergence concepts of NBIC-technologies and Industry 4.0 as well as to determine the ratio of relevant industrial revolutions and technological processes, as indicated in Fig. 1 [5, 6].

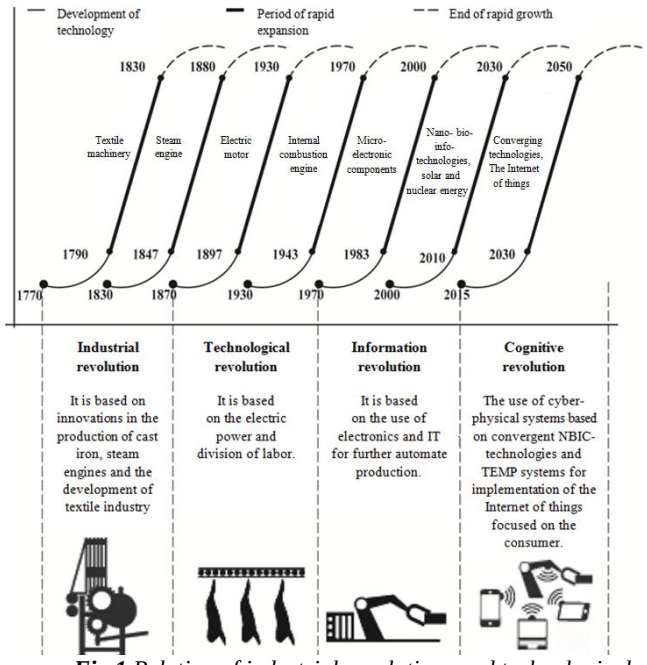

Fig.1 *Relation of industrial revolutions and technological waves [5-6]*

At the same time, the contours of the new technological system have already begun to be formed on the basis of the first convergent technologies and their explosive proliferation in 2010-2015. The fundamental abandonment of this technological wave from the previous ones is that human consciousness will become the same productive force as science has at one time become. The material basis and tool for implementing the convergent technologies of the new technological wave will be Industry 4.0 or Smart TEMP.

The study of global forecasts until 2030 showed that the main technological industries that will affect the development of the world economy will be: management of the course of the disease; regulation of population growth; genetically modified cereal crops; water resources management; bio- and solar energy; data processing solution; social networks; technology of "smart"

city; robotics; stand-alone vehicles; additive production / 3D printing.

Ukraine has great potential and competitive technologies in the aerospace industry, the production of new materials with specified properties, industrial biotechnologies, mathematical modeling and regulation of chemical, biochemical and biophysical processes, and intelligent production systems. In addition, Ukraine holds one of the leading places in Central and Eastern Europe in terms of the IT market and human resources. For example, in 2016, domestic IT industry, despite the crisis in the Ukrainian economy, showed growth at the level of 10-15%, and the volume of the market has grown to 3 billion dollars. All this shows the huge potential for growth for the industry. The key advantages of the IT industry and software development are that large investments in fixed assets are not required to increase production, since the IT industry's main asset is the human factor - programmers [19].

Fig. 2 shows the author's proposed directions for solving global problems based on the introduction of convergent NBIC-technologies as the nucleus of the development of the advanced production system Smart TEMP, which provides a number of tools [5-7, 12]:

- overcoming the global problem of slowing down scientific and technological progress, based on the introduction of convergent NBIC-technologies as the nucleus for the development and dissemination of Smart TEMP advanced production system;

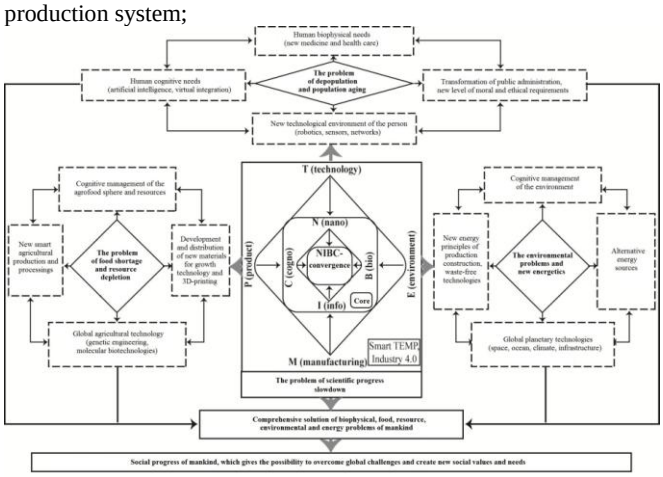

Fig. 2 *Directions of solution of global problems on the basis of introduction of convergent NBIC-technologies as the nucleus of development of Smart TEMP advanced production system [5-7, 12]*

- overcoming the problem of depopulation and aging of the population at the expense of: (1) satisfaction of the biophysical needs of man (new medicine); (2) the realization of the cognitive needs of man (artificial intelligence, virtual worlds); (3) new technological environment of the person (robotics, sensors-ethical needs;

- overcoming the global problem of food shortages and resource depletion by: (1) developing global agrarian technologies (genetic engineering, molecular biotechnology); (2) the creation of new intelligent agroprocessing and processing; (3) developing and distributing new materials for growth technologies and 3D printing; (4) cognitive resource management and the agro-food sector;

- overcoming environmental problems and creating new energy through: (1) global planetary technologies; (2) the transformation of public administration and the moral-energetic principles of construction of production, non-waste technologies; (3) alternative energy sources; (4) cognitive management of the environment;

- a comprehensive solution to biophysical, food, resource, environmental and energy issues as the foundation for social progress of mankind, which opens up opportunities to overcome global challenges and create new social values and needs.

At the same time, the main trend in solving global problems of humanity on the basis of convergence of knowledge, technology and society through the use of NBIC-technologies as the nucleus and fundamental tools for the development and dissemination of the advanced production system Smart TEMP is the support of converged technologies and the development of the advanced production system Smart TEMP at the expense of: 1) implementation of state and private programs, the driving force of which is openness and visualization; (2) accelerating the development of fundamental NBIC technologies and creating new Smart TEMP industries based on interdisciplinary research and innovation. It is a combination of converged technologies with industry-leading Industries 4.0 to provide material ground for solving other global problems.

Thus, for countries that wish to modernize the economy on a new technological base (such as Ukraine), identifying the priorities of scientific and technological research in the field of convergent technologies and creating on their basis the innovations in the framework of a new industrial revolution becomes today of great importance.

3.Conclusion

1. It is shown that the concepts of the new industrial revolution, which are widely used today by Western scholars simultaneously with the notion of "technology" for the periodization of the waves of innovation development, also envisage the convergence of sciences and technologies and the creation of advanced production technologies on their basis. It is established that in today's developed countries the concept "Industry 4.0" is increasingly prevailing, which involves the enhanced integration of "cyber-physics systems" into production processes, and the driving force of which is integrated intelligence processes and products generating "big data" that completely change the landscape. production and create new markets.

2. According to the results of the analysis of the research of authoritative world institutions and international industrial associations and research companies, it is established that the launch of industry-specific trends in Industry 4.0 can only be achieved through the introduction of advanced manufacturing technologies. They are based on convergent technologies, which include "Internet of things", "cloud" technologies", 3D printing, new materials, robotics, associated with non-traditional processing methods, new tools for control and management of production and technological processes, and using new materials, automated and intelligent monitoring and control equipment, production process and systems.

3. The approach to periodization of scientific and technical development, which connects the economic, technological and socio-political factors of development, as well as characterizes the structure of the sixth technological structure, is proposed. This approach provides a new scientific understanding of the relationship between industrial revolutions and technological developments in the economy of the future, which, along with the traditional ones, includes the notion of a cognitive revolution, based on the use of cyber-physics systems based on convergent NBIC technologies, it enables the transformation of economic processes based on the introduction of internet of things. In this case, the key factor of the core of the technological structure will be the state of convergence of NBIC-technologies. The core of the new sixth technological wave will form industries such as: nanomaterials and materials for growth technologies, nanoelectronics and nanophotonics, scanning nanotechnology, nanosystem technology, nanotechnology and 3D printing, genetic engineering, molecular biotechnology, cloud computing and multidimensional simulation, Internet applications, artificial intelligence. The carrier industries will be: medicine and pharmacy; agro-food complex on the basis of nanobiotechnologies;

microelectronics, robotics; information and communication industry; systems of creation and transformation (cultivation) of material objects; intelligent production management systems; education and scientific-practical research; new nuclear and thermonuclear energy; renewable energy; aircraft building and rocket and space complex; automotive, shipbuilding and machine tools; chemical and metallurgical complex.

4. The vision of the content of the new industrial revolution based on the organic combination of convergent NBIC-technologies with the key factors of the advanced system of Smart TEMP, which enables to change the system of production qualitatively through the enhanced integration of "cyber-physics systems" (or CPS) into production processes, is proposed. These technologies of Industry 4.0 combine the factors of the advanced system Smart TEMP (T (technology) - smart technologies; E (environment) - reasonable environment; M (manufacturing) - reasonable production; P (products) - smart products); create new markets and industries, contribute to the growth of labor productivity, the competitiveness of individual sectors and national economies.

5. The approach to understanding the correlation of the industrial revolution and the technological structure in the future economy, which includes the concept of a cognitive revolution based on use, and defines the structure of the sixth technological wave (the key factor of the nucleus is the state of convergence of NBIC-technologies, and the core will form sectors of the advanced production system Smart TEMP), as well as identified directions for solving global humanity problems, based on the introduction of converged technologies as a factor for the development and spread of Smart TEMP advanced production system.

6. The directions of solving global problems of humanity, which include the following main directions and tools for: (1) overcoming the global problem of slowing down of scientific and technological progress, based on the introduction of converged NBIC-technologies, are proposed; (2) overcoming the problem of depopulation and aging of the population at the expense of satisfaction of the biophysical needs of the person (new medicine and health); realization of cognitive needs of a person (artificial intelligence, virtual integration, etc.); new technological environment of the person (robotics, sensors, networks); transformation of the system of public administration, satisfaction at a new level of moral and ethical needs; (3) overcoming the global problem of food shortages and resource depletion by: developing global agrarian technologies (genetic engineering, molecular biotechnology); creation of new intelligent agricultural production and processing; development and distribution of new materials for growth technologies and 3D printing; cognitive management of the agricultural sector and resources; (4) overcoming environmental problems and creating new energy through global planetary technologies (space, ocean, climate, infrastructure); new energy principles of construction of construction, non-waste technologies; alternative energy sources; cognitive management of the environment.

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SMART SERVICES AS SCENARIOS FOR DIGITAL TRANSFORMATION

Antonova A.
Center of IST, Sofia University, Bulgaria [1]
a_antonova@fmi.uni-sofia.bg

Abstract: *Digital transformation, new business models development and business processes automation ranks among the key business concerns and company priorities. In this context, smart services propose new models for service automation, combining data, analytical components and physical infrastructure in unique customer offerings. The present research aims to present the smart services potential, exploring its characteristics, perspectives and fields of application. First, the paper makes an overview of smart services features and concepts, then, it determines smart services perspectives and last, it presents use cases and industry sectors for smart services implementation.*

Keywords: SMART SERVICES, DIGITAL TRANSFORMATION, INDUSTRY 4.0

1. Introduction

Within the framework of digital transformation and Industry 4.0 wider adoption, the role of companies is continuously changing from manufacturers and traders of mass products to data integrators and providers of complex and customer-oriented services. Many opportunities exists for companies to extend their value-creation offering and business models by developing focused and personalized services, by implementing Industry 4.0 technologies such as big data, cloud computing, Internet of Things, robotics, virtual reality and others. That is the reason smart services and smart service integration to be on the next frontier of Industry 4.0 ecosystem.

However, the development and smart service offerings requires new set of prerequisites such as technological advances: industry standards, cybersecurity, appropriate infrastructure and new business scenarios: organizational practices, new business models and customer-oriented business processes. In this context, the present research aims to identify the main features of smart services and to outline the companies' potential to develop and implement smart service scenarios on practice. The first part of the paper provides a short background overview of smart services, discussing its main concepts and perspectives. The second part defines the main layers and characteristics for smart service offering. Last, there are identified different application models and use cases for smart services implementation in new value-offerings. The present paper is partially supported by INTERREG project DIGITRANS - *Digital transformation in the Danube Region*.

2. Background

The common definition of smart services states that they combine digital services, data analysis and physical infrastructure within complex "smart product-service ecosystem". In this context, smart services are considered as individually configured systems, merging physical layer (infrastructure), digital services (access to computational capacity), and data (integrating contextualized and personalized data) [1]. Other definitions state that smart services are interconnected, data-driven and personalized, and "smart" stands for context-sensitive data and customer orientation. Smart services are digital services, adapted and delivered based on specific user requirements, and stepping on data analytics and contextual data [2]. They are individually configured and often delivered physically, covering digital services and physical products, usually performed on integrated platforms [3]. From data perspective, smart services are data-driven applications (set of traditional and digital services, integrating various data sources on technology platforms) [4]. Smart services come as result of the progress in machine intelligence, global connectivity and big data.

As alternative terms for smart services in literature are used: data-driven services, Internet of Services, Smart Web Services, intelligent or smart products, smart product-service systems, intelligent ecosystems and others.

Smart services advance on the increasingly blurring differentiation and convergence between physical products and services [5, 6], providing personalized customer offerings as "complex service packaging" [7]. Thus, smart services allow companies to use smart digital products as "distribution mechanisms for service provision" [5] extending their opportunities to digitally transform and personalize their customer offerings.

3. Smart services perspectives

The emergence of smart services is largely due to new intelligent or smart products, improved cybersecurity and encrypted data transfer, data analytics models and customer-oriented business models [8]. Smart services can be analyzed from three main perspectives – technology perspective (technology infrastructure), customer perspective (context of service delivery and value co-creation) and business perspective (value offering, based on integration of data and inter-organizational networking capacity).

-***Technology perspective*** covers technological architecture for smart services, including smart products or smart objects, assuring connectivity and infrastructure, such as sensors and actuators (IoT/IIoT), wearables or access to local physical devices. Technology perspective allows company to connect, to analyze and to adapt to specific customer preferences and context. Technology perspective consist of in-place technology infrastructure, determining the elements of the context and delivering physical components of the smart service.

-***Customer perspective*** builds on business scenarios and personalized user profiles. Extending data analytics and context recognition, companies can customize and adapt its smart service offerings to specific users based on preferences, patterns and experiences. Improving access and analysis to personal and general data statistics, models of use customization and recommendation services can further extend opportunities for value co-creation.

-***Business perspective*** aims to extend the capacity of the company to explore vertical and horizontal industry integration in order to enhance value-creation and value offering for its clients, by combining personalized features and general elements within smart service configurations. The business perspective integrates internal company resources and business processes with extended company ecosystem and network of partners, suppliers and end-customers.

The three general perspectives provide general understanding for the physical, customer and business layers, defining the smart service structure. In order to identify scenarios for smart service development, we will go deeper by examining the smart service platform model of Smart Service Welt [1].

Visually, the smart service system architecture covers five platform layers (fig.1), consisting of: 1) infrastructure and physical components, 2) smart products/smart objects, 3) data analytics, user profiles, 4) smart service platforms and 5) business models configuration. These five layers combine technology infrastructure (layer 1 and 2 – technology infrastructure and physical platform),

customer service infrastructure (layer 3 and 4: software platform – data, computational and analytical layer and service platform - smart service or customer layer) and business infrastructure (smart service integration layer- smart business model ecosystem and smart business processes).

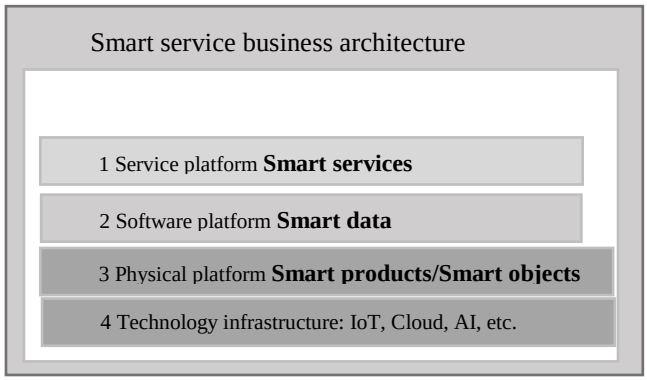

Fig. 1 *Smart service business architecture based on Smart Service Welt [1]*

3.1. Physical infrastructure (smart product)

Smart products or smart objects are the backbone of the physical infrastructure within the "smart service system". Intelligent (smart) objects (products) are able to sense its own condition and its surroundings and thus allows for real-time data collection, continuous communication and interactive feedback [9]. Furthermore "smart products" enable monitoring, optimization, remote control, and autonomous adaptation of products or objects [10]. Smart products use sensors (IoT) to obtain contextual data, exchange data with other actors (cloud technologies), store and process data locally (edge computing), make autonomous decisions, and act physically by means of actuators [1].

Smart products can include smart devices, smart objects, and cyber-physical systems. They embed hardware and software systems into physical goods that can connect digitally to other products and information systems. Smart products obtain contextual data from the field, analyze these data, automatically make decisions and take actions. The smart products (objects) may be associated with an individual customer (e.g., health monitoring), a group of customers (e.g., family home monitoring) or a firm (e.g., monitoring of industrial equipment) [9].

Some of the main features of smart products include [10]: unique identification, localization, connectivity, sensors, data collecting and computation (edge computing), actuators, interfaces, invisible computing. In this perspective, smart products act as service-distribution mechanisms.

It is important to underline that smart products can mediate the interactions between service providers and service consumers in two ways. First, when consumers use the products' embedded functionality as a self-service. This way, the smart products transfer the configuration of customer service. Second, smart products can act as point of interaction or interface between the end-users and the service providers. In this scenario, smart product transmits data on its use, condition, and context back to the service provider, who analyses these data to offer additional value propositions that fit the detailed contextual situation of the customer. The technology infrastructure and physical platforms, based on smart products (objects) (layers 4 and layer 3 from fig.1) can deliver different scenarios for remote and continuious services, routinized and technology-mediated interactions and personalized and contextualized customer services.

3.2. Customer orientation (smart service)

On one side, smart services rely on the application of specialized competences, through deeds, processes, and performances that are enabled by smart products. On the other side, smart services require customer orientation and customer focus. Therefore, for the design and development of smart services it is essential to understand the customer and his surroundings, to explore various data sources and to analyze, integrate and process these data into valuable personalized offerings. Within smart data software platform – layer 2 and service platform -layer 1 (fig. 1), smart services build on "smart data" concepts and integrate them in new user-oriented service modules, new diagnostic applications, new control and automation solutions. The customer perspective allows companies to extend the use of the growing volume of contextual data and to combine it in innovative ways creating on-demand, personalized solutions for customers [3].

- *Customer profiles*

Customers and customer experiences are the cornerstone for any smart service scenario. By defining and extending user profiles, smart service technologies can personalize and enrich the user experience by developing individual combination of service elements reflecting individual preferences and expectations. The customer profiling is defined by algorithm or user acquisition model. This model can combine both explicit and implicit user information, including on one side explicitly submitted user information and on the other side, by observing and tracking user preferences, service usage and behavior patterns. In order to rely on appropriate customer profiles, the user acquisition models scenarios should evolve and extend over time, upgrade user preferences, skills and competences, combining various types of data and measuring their relative weights.

- *Context recognition*

Customer orientation or service personalization requires on one side to understand the customer profile (personalization based on personal preferences) and on the other side - to recognize the specific context of service delivery (personalization based on external conditions). The context is determined in plan recognition module that integrates historical data (plan libraries), input observations and potential plans, adapting the service delivery pattern to local conditions.

The smart services main feature is the individual approach to customers based on their context and personal preferences. The service platforms can develop and support individual profiles and context recognition patterns using various artificial intelligence technologies (such as chatbots, image or text recognition), allowing development of scenarios for three types of personalized services:

1. Interactive configurations: customized smart services, adapted both to the customer profile (explicit data and implicit preferences) and to the service delivery context (taking into account the context).

2. Recommendation systems: customized service models, supporting decision-making and choice options, based on personal preferences, past data and environmental/contextual information.

3. Personalized interactive processes: application of different models of service interactions, so that the services are tailored to the individual preferences and context/environment data.

Smart services usually support customers for taking decisions and selecting one or another solution, based on personal preferences, evaluation criteria and decision-making patterns, conformed to the specific context. Smart service platforms have to facilitate the decision-making process, but in the same time, they have to provide relevant explanations of its own logical models. In the same time, the smart service platforms have to allow the end-users to apply and customize other solutions that may differ from the system recommendations.

3.3. Business infrastructure (smart service integration)

Smart services often require individual organizations to extend its capacity by delivering boundary-objects that integrate resources, data and activities provided by different actors from the ecosystem

[10]. As customer-oriented, platform-based and service-oriented business models are expected to replace traditional product-oriented business models, development of new smart services will require new mechanisms for value adding and value integration.

Within business perspective, companies should define new opportunities for re-integration of resources and processes from the ecosystem in order to improve or extend its value offering. For example, it can exploit open data, work in open innovation processes, collaborate in open communities or rely on open source infrastructure.

In the concept of the Smart Service Welt [1], business models stand as the outermost layer of smart-service architecture functionality (fig.1), supporting digital transformation and directly affecting inter-organizational business processes and workflow configuration. In this context, the most important elements of Smart Service business model are [8]:

- Content or the specificity of the smart service, how it is created and used and what is the customer added-value;
- Customer or focus of the smart service, customer preferences and level of satisfaction;
- Platform or the technology infrastructure, supporting the delivery, personalization and access to smart services;

The role of the business ecosystem is crucial for smart service configurators and integrators. As different social and economic actors use different data, resources or services, the possibility for networking, partnerships and exchange of digital assets and physical infrastructure can extend the capacity and value co-creation potential for smart service providers.

3.4. Smart service characteristics

The characteristics and elements of smart services vary, but usually they are considered as: data dependent, agile and customer focused, cross-company and cross-sectoral delivered[12].

The smart services classification in [8] distinguishes the following five characteristics: 1) smart services are the connection between the physical and the digital world, 2) they upgrade the value creation and economic efficiency; 3) they provide extension of products and services with a digital layer; 4) they transform the product into a part of service-offering; 5) they require transformation from product-centred to customer-centred business models.

The elements of the services consist of the following dimensions [13]: service structure, service delivery process, service outcome and service business model. In this context, the components of smart services are physical delivery, digital services, technology-based services and data-driven services.

The characteristics of smart services, defined by [11] are:

(1) Smart services rely on embedded information and communications technology that allows data transmission and information generation.

(2) Smart services integrate and are enabled by big data analytics.

(3) Smart services are automated (at least partly) and they are perfectly aligned with human interaction. Such automated service actions are only possible by the integration of smart components like cognitive systems.

(4) From a customer perspective, smart services allow for greater customization of services by reacting on environmental-conditions or customer requests (smart services adapt based on users data).

Finally, smart services elements include physical infrastructure or smart and connected products, they rely on encrypted and secured data transfer, they are developed based on data analytics and data-based intelligence, they are developed on new business models and new mindsets and customer-driven business scenarios.

4. Discussion and conclusions

The successful generation and development of smart service scenarios within companies rely on different factors such as analysis and optimization of organizational processes (communication and coordination processes), good governance and management structure (sufficient resources, access to capacity, competent decisions), appropriate culture (rewarding creativity and trust). Development of smart services start with focus on customers and trigger additional digital transformation processes. The expected benefits from smart service implementation come in two main directions: source of new revenues and cost optimization:

- Smart services can provide additional revenues, improved efficiency, increased visibility & cost reduction, enhance customer base, relationship and satisfaction, larger mobility and independence, stronger interconnectedness, faster decision making. Delivering intelligent customer service can improve customer interaction, customer data collection and analysis, customization and customer value improvement. All these characteristics can lead to: increased innovation, turnover and profit, increasing customer loyalty, creating competitive market advantages, higher employee productivity, satisfaction and qualification.

- Implementing smart services in organization can lead to savings, process optimization, dependency, virtualization and process automation, flexible combining, and enhanced functionality. This would increase the efficiency of processes, reduce resources and waste, solve problems at an early stage.

High complexity for the development of smart services requires systematic approach for defining complex "product-service systems". Smart service ecosystems aims to link data and information connecting different sources, smart objects and products, contextual information, user profile and additional data. Therefore, customers can have different concerns, related to smart services wider adoption.

It is important to state that customers perceive smart services as highly risky if they are invisible, feature a high level of automated decision-making or enable the service provider to access sensitive information [9]. The increased risk perception is mainly driven by the fear of privacy violations and concerns about data security [14]. Different levels of perceived embeddedness might trigger different emotional responses in consumers. The customer concerns about smart services dramatically increase with the increasing of the embeddedness of the technology in their lives and bodies. Research has identified that technology characteristics, customer characteristics and context specific perceptions such as privacy concerns are the main factors affecting the perception and adoption of smart services [9].

Some of the other smart service challenges include [8]:

- Technology (lack of smart service standards and interoperability issues),
- Data (data management, data protection, cybersecurity, data ownership and security),
- Business (high initial investment and uncertain return on investment models, need for new business models and new business logic, differing from traditional markets),
- Competences (lack of practical experience, skilled workforce and management experience);

Smart services have the potential to digitally transform many industries and companies' business models. Combining data, customer focus and data analytics with new hardware applications such as autonomous cars, robots, drones, wearables, IoT/IIoT, smart city infrastructure and others, smart services can provide many value offerings. Examples of smart industry services, smart urban services, and smart senior care services are already provided in the research of [9]. Other smart services use cases are explored as well in education, in health care, utilities, retail, manufacturing and

transport [8]. ICT companies and leading service providers already promote successful use cases for smart services and customization opportunities within smart factory, smart mobility, smart city, smart farming and smart agriculture, smart energy (FIWARE platform), smart trade, logistics, smart predictive asset management and maintenance, smart industry (SAP Leonardo system). Therefore, smart services have the potential to enable next scenarios for customer-oriented digital transformations.

5. Acknowledgement

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ОБЕЗШУМЯВАНЕ НА ПУЛСАРЕН СИГНАЛ ПОСРЕДСТВОМ УЕЙВЛЕТ ТРАНСФОРМАЦИЯ

Проф. д.н. Иван Гарванов, Руска Ийнбор, Николай Гешев
Факултет по информационни науки, Университет по библиотекознание и информационни технологии, България

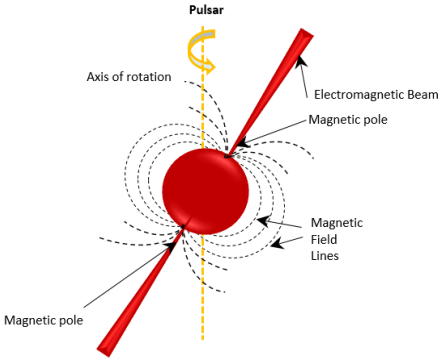
i.garvanov@unibit.bg, ruskadi@yahoo.com, inkious@yahoo.com

Резюме: *В настоящата статия е изследван алгоритъм за обезшумяване на пулсарен сигнал посредством уейвлет трансформация. Сигналната обработка включва три основни етапа: уейвлет трансформация, прагова обработка и обратна уейвлет трансформация. Предложеният алгоритъм е тестван върху модел на сигнал от пулсар B0329+54, като е изчислен коефициентът на корелация даващ връзката между оригиналният и обезшуменият сигнал.*

Ключови думи: УЕЙВЛЕТ ТРАНСФОРМАЦИЯ, ОБЕЗШУМЯВАНЕ НА ПУЛСАРЕН СИГНАЛ

1. Въведение

Пулсарите са въртящи се неутронни звезди, които излъчват широколентови електромагнитни сигнали [1]. Периодът на повторение на пулсарните сигнали е същият като периода на въртене на пулсарите. Периодичността на повторение на пулсарните сигнали е стабилно във времето и е сравнимо с точността на атомните часовници. Сигналите от пулсарите се различават един от друг по вида на техните профили. През последните години се появяват различни идеи за използването на тези сигнали в науката и индустрията. Има предложения за използването им като естествени навигационни маяци, подобно на GPS сателитите за навигация на Земята [2-4]. Измервайки времето на пристигане на импулсите, идващи от най-малко три различни пулсари, могат да бъдат определени координатите на приемника. Преди няколко години практическата реализация на идеята за навигация с пулсари беше трудно реализуема, поради малкия брой на известните пулсари, и поради липсата на технология за тяхното бързо откриване. През последните години ситуацията се промени значително. След откриването на първия пулсар през 1967 г. до този момент са открити и изучени повече от 2000 броя пулсари, (фиг. 1) [1].



Фиг. 1 *Модел на пулсар*

Сигналите от пулсарите могат да се използват и за естествена охранителна система на земята от падащи метеорити и астероиди използвайки принципа на радио бариерите [5]. Летящата цел при пресичане на бариерата образувана от даден пулсар и радиотелескоп на земята е възможно да задейства система за ранно предупреждение от наближаващо космическо тяло.

Основното ограничение за използването на пулсарните сигнали е много малкото отношение на сигнала към шума (SNR) от -40 dB до -90 dB [2, 3]. Това от своя страна води до следващият сериозен проблем, а именно голямото време за обработка на пулсарните сигнали. За да се открие сигнал от даден пулсар е необходима няколкочасово некохерентно натрупване на сигнала [6].

В настоящата статията се предлага алгоритъм за обработка на пулсарен сигнал с цел намаляване на шума на приемника и увеличаване на отношението сигнал към шум. Тази обработка е базирана изцяло на уейвлет трансформацията и включва три основни етапа: уейвлет трансформация, прагова обработка и обратна уейвлет трансформация. Алгоритъмът за обезшумяване е тестван върху модел на сигнал от пулсарен B0329+54. Ефективността на обезшумяване а оценена посредством средно квадратичната грешка и коефициента на корелация даващ връзката между оригиналният и обезшуменият сигнал, при различни стойности на SNR и при прилагане на мек и твърд праг за обработка.

2. Уейвлет трансформация

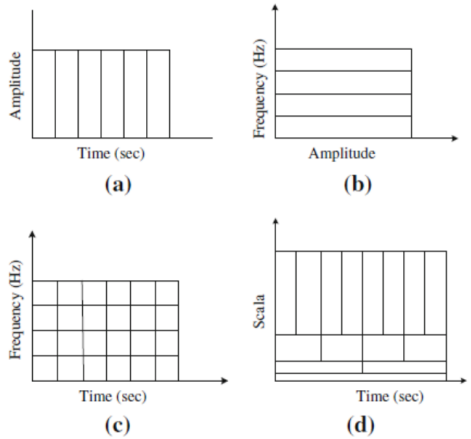
Уейвлет трансформацията (Wavelet Transform) представлява разлагането на непрекъснати във времето сигнали (функции) чрез уейвлети (вълнови функции) на честотни елементи [7]. Уейвлетите са бързо затихващи трептения или такива с крайна дължина. За разлика от преобразуването на Фурие, непрекъснатото уейвлет преобразуване осигурява възможност за построяване на време-честотно представяне на спектъра на изследвания сигнал, при което се достига много добро локализиране и по време, и по честота. Това свойство е от съществено значение за анализа на пулсарните сигнали. Уейвлет трансформацията представя най-добрата времева разделителна способност за нискочестотни и високочестотни компоненти като по този начин преодолява недостатъка на краткото преобразуване на Фурие (STFT) за определяне на една времева честота. Време честотното представяне на сигнала е показано на фигура 2 [7].

Широчината на прозореца се променя при уейвлет трансформацията, което е една от най-важните характеристики на уейвлет трансформацията. При уейвлет анализа е от съществено значение да се обърне внимание на: функцията за мащабиране и вида на вълната майка. Съществува голямо разнообразие от семейства елементарни вълни, които са доказали, че са особено полезни при обработката на сигнали. В практиката се използват различни уейвлети при разлагане на сигналите, като вълничките на Morlet, Meyer, Coiflets, Haar, Daubechies, „мексиканска шапка“ и други [7, 8]. Уейвлетите се определят посредством: мащабиращ филтър, мащабираща функция или уейвлет функция (уейвлет-майка). Уейвлет функцията $\psi(t)$ е функция с нулева средна стойност [7].

$$\int_{-\infty}^{\infty} \psi(t)dt = 0 \qquad (1)$$

Уейвлетите от дадено семейство $\psi_{a,b}(t)$ се определят чрез функцията $\psi(t)$ (майчин уейвлет) и мащабиращата функция $\varphi(t)$ (бащин уейвлет) във времевата област. Те са мащабирани и

транслирани копия на вълната-майка $\psi(t)$, която обикновено е бързо затихващо трептение или такова с крайна дължина.



Фиг. 2 *а) Прозорец с време-амплитудно разделяне на сигнала, b) честотно-амплитуден спектрален прозорец получен с Фурие преобразование, c) честотно-времево разпределение на сигнала с помощта на STFT, d) прозоречна техника с уейвлет трансформация*

Непрекъснатата уейвлет трансформация (Continuous Wavelet Transform - CWT) на дадена функция $f(t)$ може да се представи по следния начин:

$$Wf(a,b) = \frac{1}{\sqrt{a}} \int_{-\infty}^{\infty} f(t)\bar{\psi}\left(\frac{t-b}{a}\right) dt \qquad (2)$$

Където a и b са параметрите на мащаба и позицията или вълната-майка е мащабирана с коефициент a и транслирана с коефициент b. Чрез подходящ избор на параметрите a и b на уейвлет функцията могат да се отделят като ниско-, така и високо-честотните компоненти на сигнала и да се анализират локалните му особености. Базирайки се на изследванията в [9] и с цел получаване на най-добро представяне на сигнала на пулсар B0329+54 в настоящето изследване е избрана вълната-майка да бъде Daubechies 5, където цифрата показва броя на минимумите и максимумите във функцията (фиг. 3).

Фиг. 3 *Профил на Daubechies 5 уейвлет.*

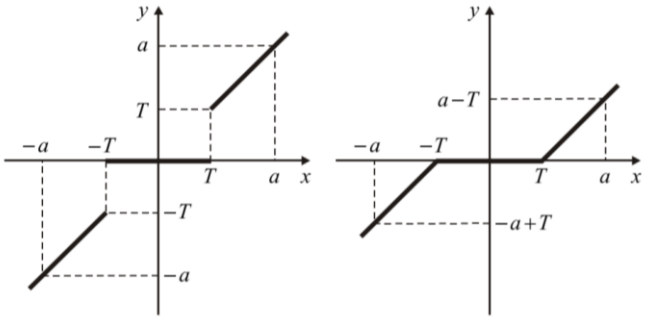
3. Алгоритъм за обезшумяване на сигнала

Обезшумяващият алгоритъм (Denoising Algorithm) се прилага за премахване на шума от полезният сигнал [7]. Ако приетия сигнал се състой от полезна и шумова съставляваща, както е дадено в уравнението

$$y[n] = x[n] + d[n] \qquad (3)$$

където $x[n]$ е полезният за нас сигнал, който ние искаме да открием на фона на бял Гаусов шум $d[n]$.

Основата на тази техника е използването на прагови функции с различни форми, въз основа на които се осъществява ограничаването на детайлизиращите коефициенти. Задавайки определена стойност на прага е възможно да се "отреже" стойността на сигнала под този праг, можете значително да се намали шума и да се свие сигнала. Праговите функции който разглеждаме в настоящата статия и най-често се използват в съвременните алгоритми за филтриране са показани на фигура 4 [7]. Изборът на прагови стойности при уейвлет трансформацията е много важна задача. Ако праговата стойност е много голяма или много малка, сигналът може да не бъде открит акуратно.



Фиг. 4 *Прагови функции за обработка на коефициентите на преобразуване: а) твърда прагова функция; b) мека прагова функция*

Твърдият праг (фиг. 4*a*) се описва със зависимостта [7]

$$y(x) = \begin{cases} x & if\ |x| \geq T \\ 0 & if\ |x| < T \end{cases} \qquad (4)$$

Величината T може да заема стойности, които ще бъдат разгледани по-долу в статията като x и y са входящите и изходящите коефициенти на уейвлет трансформацията.

На фиг. 4*b*) е представена функцията за мек праг (мека прагова оценка), която се задава с израза [7]

$$y(x) = \begin{cases} sgn(x)(|x| - T) & if\ |x| \geq T \\ 0 & if\ |x| < T \end{cases} \qquad (5)$$

Функцията *sing*(x) определя знака на коефициента x.

$$sgn(x) = \begin{cases} 1, & if\ x > 0 \\ 0, & if\ x = 0 \\ -1, & if\ x < 0 \end{cases} \qquad (6)$$

Основната разлика между функциите на мекия праг и твърдия праг е, че първата (функцията за мек праг) не съдържа скок (празнина) в точката определена от праговата стойност T. С други думи, меката функция на прага, за разлика от твърдата, е непрекъсната. Благодарение на това обстоятелство, в случая на мека прагова обработка се получава по добро обработвате на зашумен сигнал в близост до точката на прекъсване. Трябва да се отбележи, че намаляването на стойностите на коефициентите при разлагане по праговата стойност, в случай на мека прагова обработка, като цяло, за голям брой сигнали оказва отрицателно влияние върху окончателната оценка на качеството на възстановения сигнал. Следователно, като цяло, както е показано експериментално, по-добри по отношение на числената оценка на качеството на възстановения сигнал е твърдата прагова оценка. В случая на мека прагова обработка цифровото оценяване на качеството на възстановеният сигналът е близък до последния в случая на твърда прагова обработката и е необходимо да се избере подходяща стойност на прага T.

Алгоритъмът за обезшумяване от [7, 9] на сигнала се състой от няколко стъпки:

1. Нивата на приетия сигнал се разделят чрез уейвлет трансформация. След което, коефициентите на уейвлет на приетия сигнали се изчисляват до желаното ниво.

2 Дисперсията (σ^2) на шума се изчислява с помощта на уейвлет коефициентите [10].

$$\hat{\sigma} = \frac{med(|W_{j,k}|)}{0.6745} \qquad (7)$$

където $med(.)$ е медианата. Това уравнение може да се използва и за оценка на средно квадратичното отклонение на бял Гаусов

шум с нулево математическо очакване, който се явява адитивна смес с полезния сигнал.

3 Праговата стойност се изчислява, като се използва дисперсията на шума.

$$T = \sigma\sqrt{2\log(n)} \quad (8)$$

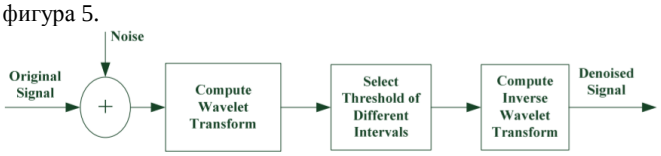
където T е праговата стойност, а n е броя на семплите в обработвания сигнал. Тази формула се отнася за случая на едномерен сигнал.

4. Праговата обработка се прилага посредством уравнения 4 или 5 след изчисляването на праговата стойност T от 7.

5. Оригиналният сигнал се реконструира, използвайки обратната уейвлет трансформация чрез получените коефициенти.

4. Интервално-зависим прагов метод

Зашуменият сигнал се разлага с помощта на детайлни и апроксимационни коефициенти. Нискочестотните компоненти се характеризират с големи коефициенти, а компонентите с висока честота с малки коефициенти. Уейвлет коефициентите, които са по-малки от праговата стойност, се премахват. В резултат на това оригиналният сигнал се филтрира от зашумения. Праговите стойности се получават поотделно за всяко ниво на уейвлет трансформация [7, 9]. Тъй като високочестотните и нискочестотните съставляващи на сигналите имат различни характеристики като средна стойност и стандартно отклонение, то интервално-зависимата прагова стойност се изчислява отделно за всяко ниво и всеки интервал е обезшумен. В тази статия са тествани зашумен сигнал от пулсар с цел оценка на ефективността на този метод. Блоковата диаграма на интервално-зависимия прагов метод е показана на фигура 5.



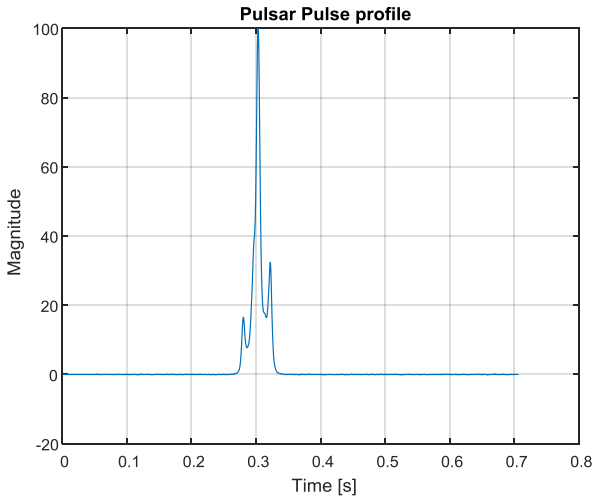
Фиг. 5 *Блокова схема на интервално-зависим прагов метод*

Алгоритъмът на уейвлет базирания интервално-зависимо обезшумяване е описано в [7]: Стъпка 1: Декомпозиция на зашумен сигнал с помощта на уейвлет трансформация. Стъпка 2: Изчисляване на дисперсията на шума за всяка вълнова скала използвайки уравнение 7. Стъпка 3: Изчисляване на прага на всяко ниво използвайки уравнение 8. Стъпка 4: Високата и ниска прагова стойност се изчисляват, като се използва интервално-зависим праг на метода в различните интервали, като се използва уравнение 4 или 5. Стъпка 5: Оригиналният сигнал се реконструира от запазените коефициенти, като се използва обратната уейвлет трансформация. Зашуменият сигнал, използващ уейвлет трансформация, се разлага на 8 нива. След това, вместо да се приложи постоянна прагова обработка на всички нива, то се определя праг за всяко ниво. Коефициентите на уейвлета за шума се елиминират. Оригиналният сигнал се получава от запазените коефициенти. Най-важната характеристика на този метод е да се определи прага за всяко ниво поотделно. Тази функция подобрява ефективността на алгоритъма.

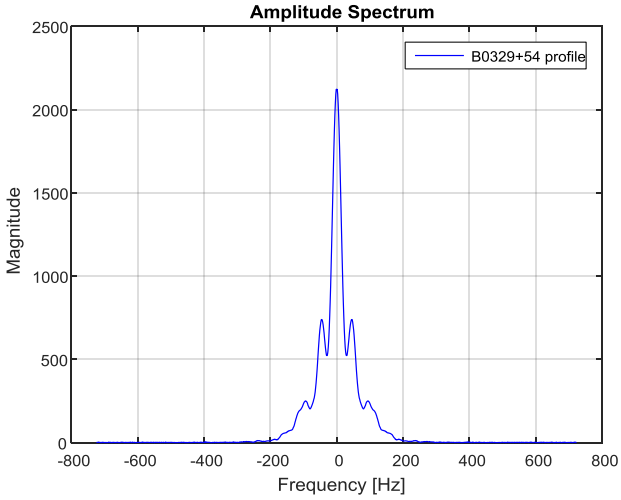
5. Резултати от изследването

За изследване на предложеният обезшумяващ алгоритъм в настоящата статия е моделирана последователност от десет импулса от пулсар B0329+54. Профила на сигнала от този пулсар има вида показан на фигура 6 и е получен от центъра Lovell telescope in Jodrell Bank. Продължителността на периодът на повторение на сигнала е T=0.714518664 s. Профила на сигнала е получен в резултат на 40105 интегрирания на сигнала, което е около 8 часа. Спектъра на този пулсарен сигнал е показан на фиг. 7 и е получен в резултат на прилагане на Фурие трансформация на сигнала.

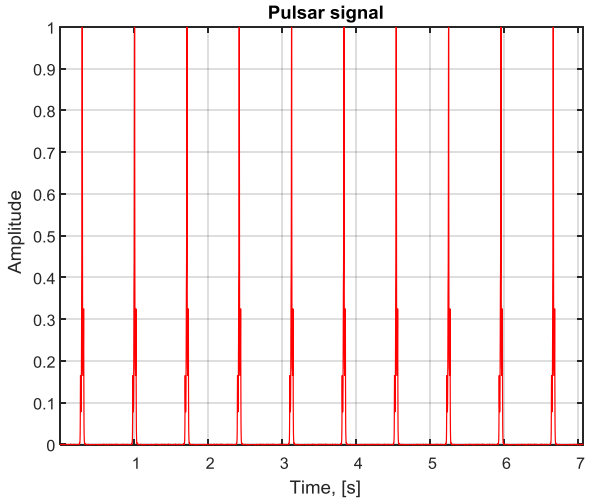
Моделираната последователност на нормирани десет импулса от пулсар B0329+54 има вида показан на фигура 8. След зашумяване на този сигнал с бял Гаусов шум, така, че SNR=-10dB, се получава смес на сигнал и шум, която е показана на фигура 9.



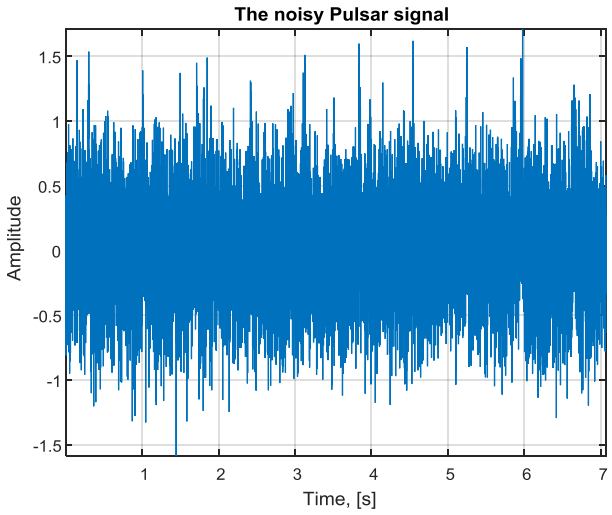
Фиг. 6 *Профил на пулсар B0329+54*



Фиг. 7 *Спектър на пулсар B0329+54*

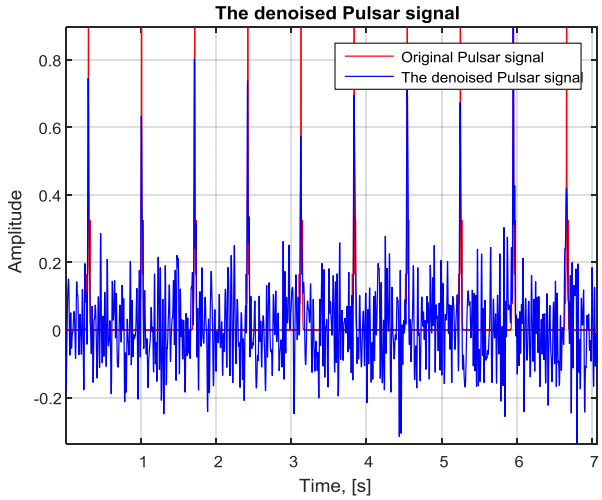


Фиг. 8 *Моделирана последователност от импулси от пулсар B0329+54*



Фиг. 9 *Смес на моделираният пулсарен сигнал и бял Гаусов шум (SNR= -10dB)*

Прилагайки алгоритъма за обезшумяване на сигнала се получава резултат, който е показан на фиг. 10. От него се вижда, че алгоритъма работи успешно и може да се използва за обезшумяване на пулсарни сигнали с цел тяхното откриване на фона на изключително зашумена радио среда. По време на всички изследвания е използвана вълната на Daubechies 5 поради общата и прилика с пулсарният сигнал. Зашуменият сигнал, използващ уейвлет трансформация, се разлага на 8 нива.



Фиг. 10 *Оригинален и обезшумен пулсарен сигнал*

За сравняване на оригиналният и получен обезшумен пулсарен сигнал е използван корелационен коефициент (Таблица 1).

Табл. 1: *Коефициент на корелация и средно квадратична грешка*

Праг	SNR [dB]	СКГ [%]	Коефициент на корелация
Твърд	-3	0.23	0.91
	-5	0.25	0.86
	-10	0.35	0.81
	-15	0.49	0.75
	-20	0.66	0.69
Мек	-3	0.23	0.89
	-5	0.26	0.85
	-10	0.35	0.80
	-15	0.51	0.73
	-20	0.69	0.64

,

Корелационни коефициенти показваш степента на близост между двата сигнала и средно квадратичната грешка получена от несъвпадението на оригиналният и обезшумен пулсарен сигнал. Очевидно е, че получените резултати са добри и за двата прага (мек и твърд), както и за всички стойности на SNR. При твърд праг и SNR = -3 dB, изчислената стойност на коефициента на корелация е 0.91. При стойност на SNR = -20,6 dB, то коефициента на корелация е 0,69. Този алгоритъм може да се ускори ако се имплементира на FPGA [11].

6. Заключение

От получените резултати се вижда, че изследваният обезшумяващ алгоритъм дава добри резултати и е възможно да се използва за ускоряване на процеса на откриване на пулсарните сигнали в практиката. Получените коефициенти на корелация са задоволителни дори и при силно зашумен полезен сигнал. Средно квадратичната грешка е под 1% и е по-малка при слабо зашумен сигнал.

Благодарност

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CREATION OF A LABORATORY OF CYBER-PHYSICAL SYSTEMS: INTERDISCIPLINARY INTEGRATION

Iureva R. PhD [1], Vasilkov S. PhD.[1], Kremlev A. PhD[1], Margun A. PhD [1], Kirsanova A. [1], Vlasov S. PhD [1], Penskoi A. PhD [1], Timko A.[1]
Faculty of Computer Technologies and Control – ITMO University [1]
raddayurieva@gmail.com

Abstract: *The paper is devoted to a problem of an interdisciplinary interaction of researchers in a framework of big and ambitious projects implementation. This problem is of immediate interest in the modern scientific community since it is necessary to solve problems from various fields of scientific directions. For the implementation of breakthrough interdisciplinary projects and for the interaction of experts from different scientific fields, ITMO University decided to establish an interdisciplinary Laboratory of cyber-physical systems.*

Keywords: CYBER-PHYSICAL SYSTEMS, INTERDISCIPLINARY RESEARCH, R&D, LABORATORY FOUNDATION

1. Introduction

Nowadays we are on the verge of a technological revolution that will fundamentally change the way we live, work, and interact. By its scale, scope, and complexity, such as transformation will differ from all the changes that humanity has previously experienced [1].

While we do not know how events will develop, one idea is clear: a universal involvement, the participation of all stakeholders on an international scale, from the public and private sectors to the scientific community and civil society. To implement this idea in practice at the early beginning of the academic year 2017/2018 it was decided to create Interdisciplinary laboratory on cyber-physical systems (CPS) as far as interest on this kind of systems is growing well, but at the same time, it is one of the most interdisciplinary fields in modern science. Here finds the connection not only physics and cybernetics (as one can see from the title of laboratory), but also information security, mechanics, information systems, sociology and what not. The main aim of the laboratory is research and development in the field of CPS used in industry and science and everyone's life [10]. Another goal of the laboratory is the transfer of the accumulated experience and knowledge gained in applied projects to students during the educational process.

When solving complex scientific and applied problems, it is necessary to involve specialists from various fields. Universities have a great potential for forming interdisciplinary teams [2]-[5]. Nevertheless, practice shows that interaction between departments and communication of individual scientific groups is difficult to implement for several objective reasons. To create an interdisciplinary team, the idea of selectively attracting young specialists from various departments of the faculty was proposed, so that they, on the one hand, became the nucleus of a new scientific laboratory, on the other, became conductors between their divisions.

The second section of the paper describes the foundation of interdisciplinary research laboratory of cyber-physical systems on the basis of ITMO University. Interaction of the laboratory with commercial companies on projects involving different specialists is described in the third section. The fourth section devoted to the educational activities of the laboratory and transfer of commercial projects experience and knowledge to the students.

2. Foundational Works

The managers of plants and factories not only reconsider the principle of the assembly line but also actively create a network of machines that will not only produce products with fewer errors but also be able to autonomously change production templates in accordance with the need while remaining highly effective. As far as the development of Industry 4.0 starts, scientists all over the world began to discuss how much work we should do to deal with all problems, which CPS defines (Fig.1).

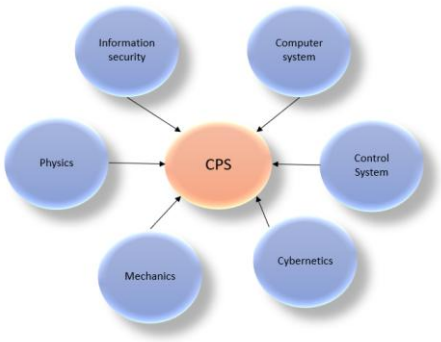

Fig. 1. *Integration of different sciences in CPS*

So, to create the Laboratory it was decided to lead competitive admissions among young PhDs which include projects launch before the scientific and technical council of ITMO University. Presenting competitors talked to each other, discussed the problems which were risen, showed the depth and the breadth of knowledge and experience, that helped to figure out who would be the most useful in future scientific and research work. Finally, among 17 young participants (not older than 35 years) were chosen five best presentations from different scientific fields.

Special area was selected for the laboratory. In cooperation with designers, it was changed into convenient spaces for teamwork in scientific, research, experimental and educational projects. The spaces and zones, allocated for certain works and activities, are shown in the Fig. 2.

For the laboratory, three interconnected locations were identified with the possibility of designing additional architectural and design solutions for the interior. Thus, the spaces were divided into three parts (Fig.2): workspace, meeting hall and conference room. At the same time, there is a separation with a flexible sliding partition in the conference room, as not only lectures will be held there, but also conferences, practical and experimental work.

The main advantages of this zoning:

- flexible use of hall space for 10 to 50 people seminars while carrying out experiments with samples of large dimensions, practical work of students, the possibility of constructing graphics large schemes on a huge marker wall;
- an office of the main staff with the arrangement of tables for teamwork;
- a meeting room, a bar-style zone combined with a coffee break, with the possibility of presenting and fixing individual results on a slate wall;
- a workshop, where students study how modern instruments and robotic devices work;
- a visual increase in the space between the hall and the office due to the vitrescence of a large area.

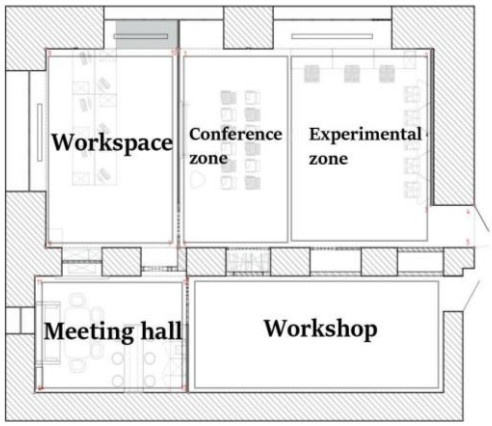

***Fig. 2**. Laboratory plan*

3. Interdisciplinary Research, R&D Projects

Despite the growing popularity of so-called inter-organizational collaboration and academy-industry, the study of interdisciplinary cooperation is in its early beginning, and much is still unknown about the interdisciplinary impact of research and development projects. Interdisciplinary R&D projects respond to growing complexity of either technology or different scientific branches. Interdisciplinary R&D team, such as presented one, involving individuals from different disciplines is more effective than many isolated mono-disciplinary teams, as they always minimize redundancy, balance diversity, and complementarity, and capitalize on synergies in information, knowledge, cultures, and techniques. The intersection of different breadth and depth levels of knowledge results in much higher comprehension of specific fields.

***Fig.3.** CPS laboratory meeting hall*

Certainly, CPS brings advances either in health care, traffic flow management or electric power generation, technogenic security, and delivery, as well as in many other areas. Speaking about CPS, we can't help mentioning that its meaning includes also:

- IoT, IoS and Industrial Internet;
- "Smart" Anything (e.g., Grid, Cars, Buildings, Houses, Manufacturing, Hospitals, Appliances);
- Multiagent systems;
- Industry 4.0;
- Big Data;
- Fog and Cloud computing;
- M2M.

All these systems mean the integration of definitely all science branches. That's why all research and development work is held collectively by scientists of the laboratory which is a very accessible as the requirements presented to the developing system do not contradict each other from the point of view of different areas of knowledge. For example, from time to time while developing new systems engineers forget about information security until the last stages when changes in construction or algorithms are too expensive or even impossible. Interdisciplinary research reduces such blunders to naught.

***Fig.4.** The Laboratory of CPS Lecture hall*

Since its foundation in October 2017, the laboratory has already worked on several projects on smart technologies. A great number of plants and companies is interested in the development and implementation of technologies Industry 4.0. Now the laboratory is working on the common project connected with a locomotive assembly and digital factory with a company of digital manufacturing. The idea is in the modernization of locomotive assembling schedule to improve the level of effort (time expenditure, human resources, and input requirements). The first task to be solved is the automatic generating of a schedule for starting details production. This schedule is necessary for the coordination of work with production departments and the timely purchase of details, as well as the prevention of large stockpiles. The developed algorithm is going to ensure the generation of a schedule for launching production units (production option without regard to restrictions).

During the implementation of this project, specialists of various qualifications were involved, such as technologists, programmers, and mathematicians.

The task of technologists was to build and systematize knowledge base for all production operations and requirements for them (including production resources, personnel and time costs). The developed knowledge base is a systematized initial information for solving the problem of scheduling. The task of mathematicians is the development of optimization algorithms to reduce costs. Algorithms to optimize production time of locomotives' lot and optimize the cost of production of a locomotives' lot were synthesized. The team of programmers was engaged in the development of application software based on information received from technologists and mathematicians' algorithms. The results of the project were positively evaluated by the customers. The project was implemented under the supervision of two PhD. Three graduate students and two students were the main project performers.

***Fig.5.** Example of Gant diagram generated by software*

This project received a significant expansion. On its basis, Software to generate a detailed production plan for departments and individual tasks for each employee with the possibility of planning for several years ahead automatically was developed on its basis (Fig. 5). High performance has become a feature of the software. Long-term planning is several orders faster than such well-known solutions as Siemens Plant Simulation. Developed optimization algorithms allow determining the dependence of the lot production time on the given production resources and personnel. These algorithms make it possible to determine the enterprise's need for resources to produce lot within a required time.

At the moment we are working on expanding the functionality: optimization to reduce inventory and details stored in warehouses and between operations; development of algorithms for detecting problem zones in the production chain and automatic generation of proposals for their prevention; development of a planning algorithm for the start-up of several lots of different products at the same time; generation a heterogeneous schedule of staff to reduce production costs.

The number of project executors has increased significantly to achieve all tasks. A lot of master students and graduate students is involved in the project. Thus, we can conclude that the described project became a good basis for interdisciplinary cooperation in the field of "smart" enterprises.

Nowadays negotiations on cooperation and research with companies from the railway, automotive, instrument-making, and energy industries are carrying out.

Another major project of the laboratory in cooperation with the industrial company to develop flight simulator for pilots training (Fig. 6). Flight simulator is a complex cyber-physical system consisting of a virtual environment that imitates all physical processes occurring with a real aircraft under different conditions; pilot's environment, consisting of a mobile chair simulating the load on the pilot, and the real controls of the aircraft; systems of drives that provide movement of the pilot seat in accordance with the indices of the virtual environment; mechanical parts that ensure the reliability of the entire structure.

Implementation of such a project required the involvement of the following specialists: constructors, electronic engineers, programmers, drive specialists, automatic control specialists, flight physics specialists. Thus, this project is significantly contributed to the organization of interdisciplinary work on the direction of cyber-physical systems. Participation in the projects is described above allowed a lot of students and graduate students to get the experience of cooperation with representatives of the real commercial companies and to participate in the implementation of complex interdisciplinary projects. These factors significantly increase the value of graduates in the labor market [10].

Besides within the constraints of this collaboration was held so-called "Techno Challenge" in smart welding - special kind of brainstorming session where not only specialists but also students of the different level were able to take part. It was dedicated to virtual reality, artificial intelligence, and computer vision. The participants were given the task to solve problems in advance and then on challenge day they had the feedback from heads and leading engineers of plants and factories. The best participants were going to have a chance to make a pact with those giant companies who found their projects and solutions interesting and advanced.

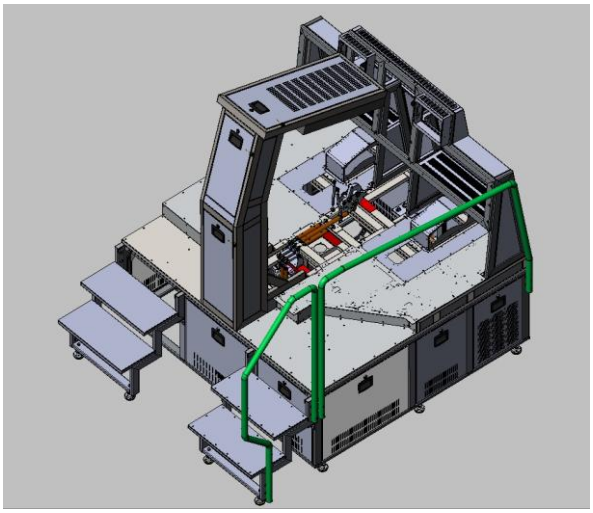

Fig.6 *Flight simulator 3D model*

Another one project is building on corners of the computer engineering, computer aid systems, control engineering, and system dynamics discipline. It is a complex project in which we are developing the original reconfigurable real-time computational platform for developing CPS which are based on adaptive robust control algorithms and artificial intelligence with high requirements on latency and computational volume; developing problem-oriented programmable ASIC and dynamically reconfigurable IP-core [12]-[13]. The key features of this project are:

- the orientation on model-driven engineering, not on software engineering practices;
- automation of most of the development stages, including algorithm design and functional simulation, prototyping and complex verification, complex automatization of cross-layer testing and synthesis of a target system;
- deeply computational platform reconfiguration on hardware, software and tool levels, transparency of CAD system workflow.

In this project, we already have an end-to-end demo for hardware acceleration of several system dynamic models. Right now, we work on demos with identification algorithm for a non-linear continues system.

4. Training Course

Currently, a new paradigm for the results of education is being established, based on the formation of general cultural and professional competencies of undergraduate, graduate and postgraduate students. In the basic legislative documents on education, the democratic and humanistic nature of the transformations in the sphere of education aimed at improving its quality is emphasized [2]-[4]. Accordingly, these documents set the task of preparing modern competitive professionals in all areas of society.

On the one hand, interdisciplinarity is an obvious trend, and on the other hand - so-called "evident challenge", the challenge for both science or education. Without any doubt the current scientific and educational achievements in the field of individual disciplines are high enough, but it should be noted that in order to find an answer to the complex questions that society, technology and science face for the new millennium, are required specialists who have been trained simultaneously in various and from time to time rather distant from each other spheres. This means that it is time to revise the existing principles and approaches to the educational process and the preparation of students in higher education. The interdisciplinary approach to education is directly related to the formation of such important skills as ability and readiness to work in a team, the skill of critical thinking, tolerance, etc. - much of

what is not directly related to professional training in the sense of organizing the educational process, but in fact is the first requirement of an employer in the conditions of dynamics and constant changes in a labor market. The new industry requires a new staff quality. Modern engineers have to be ready to work in conditions of increasing complexity of technological processes and equipment, rapidly changing requirements for competitive products, to take revolutionary decisions, to perform intellectual exploits.

The content of the training course presented by the interdisciplinary laboratory is 2-3 sessions on CPS within the competence and scientific interests of the laboratory staff: system design, information management and processing, computing platforms, communication and information protection, sensors, etc. All lectures and lab sessions are held CPS laboratory indoors. Masters who successfully complete this course may experience significant benefits, including but not limited to the ability to reason, to act with assurance and to think beyond one's own needs. Strong reasoning capabilities are valuable in each career field, and compassion may serve to enhance all areas of life.

Each student workplace has network access' data port, and computers in the lab can be shared by students in the class. There are also laptops which allow students to move back and forth from their experiment's place to a workplace to analyze data. These increased capabilities are critical to conducting experiments such as computational prediction and modeling of physical phenomena. The lab design also provides equipment and instrumentation sharing, and collaborative student efforts to cover sub-disciplines or to pair less experienced students with senior ones.

Also, the laboratory staff developed two new training courses: «Design of future things» for bachelor students and «Cyber-physical systems» for master students.

During studying the discipline "Design of future things," students are taught the actual trends in the design of modern devices, explain differences in traditional approaches. Teachers bring examples of interdisciplinary projects and their organizational structure as well as systems for monitoring the projects' implementation. Students receive practical recommendations on information security and data processing, basics of technical systems automation and are studying the problems of modern microprocessor systems designing and the concept of digital enterprises. Students of different directions teamed up to develop a model of the perspective device for successful completion of the discipline [6], [7]. The developed model is presented to technical specialists in different fields.

During studying the discipline "Cyber-physical systems" master students are taught the design of cyber-physical systems and the use of a systematic approach in the framework of interdisciplinary work. Students are taught the basics of control systems and the info-communication components of cyber-physical systems, the regulatory foundations of their operation and the design of industrial cyber-physical systems. The project approach is also used for discipline completion.

The training of the above disciplines will give future specialists experience of interaction with representatives of other professional areas. Project approach will allow them to gain experience in development of complex interdisciplinary projects [8], [9], [11].

5. Conclusions

The need for expanding the scientific worldview is largely promoted by the scientific and technological revolution, which requires a more profound and intensive insight into the laws of nature and interaction. Interdisciplinary interaction is a distinctive feature of modern science and other types of intellectual production. Today the solution to a major problem is impossible without the interdisciplinary interaction of scientists.

Within the framework of the Laboratory of CPS, the efforts of researchers will be concentrated in such areas as robotic and intelligent systems, Industry 4.0, space infrastructure and technologies, nanoengineering and cybersecurity, digitalization and Industrial Internet of things

The paper describes the organization of a laboratory for interdisciplinary research and how it can be a good basis for attracting students of various specialties to complex applied projects, to give them practical experience in the real sector of the economy. Also, based on such a laboratory, an educational process can be organized in the way to train the latest technology trends on the basis of a project and an interdisciplinary approach.

Acknowledgments

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COMPUTER-AIDED SOLUTIONS TO SUPPORT THE OPERATION OF A MANUFACTURING COMPANY, WITH THE USE OF PERSONALISED IT SOLUTIONS

M.Sc. Bernat P. PhD.[1], Prof. PhD Eng. Zaborowski T., Dr. h. c.[2]
University of Applied Science in Nysa, Poland [1]
Polish Academy of Sciences Branch in Poznan, Institute for Scientific Research and Expertises in Gorzów Wlkp., Poland [2]
piotr.bernat@pwsz.nysa.pl

Abstract: Computer-aided information flow affects the operating efficiency of manufacturing companies. Personalised IT solutions (PITS) may appear to be helpful. The article discusses the rationale and requirement for the use of computer-aided solutions at manufacturing companies and the practical applications of such solutions in selected areas. Computer-aided management of technical documentation (CAMTD), computer aided items design (CAID) and total productive maintenance (CATPM) and options of further work have been proposed. These solutions were prepared in the form of DBMS systems. The final solution will be to integrate PITS into the IT system supporting the information flow in the production company.

Keywords: COMPUTER AIDED, PRODUCTION, COMPANY, DBMS, PERSONALIZED IT SOLUTIONS (PITS)

1. Introduction

The use of computer-aided solutions at a production company, including the use of CaX [8] techniques, may cover all of the company's basic processes or selected areas or tasks. The flow of information may be supported by integrated management systems (IMS), production management systems (PMS) or personalised IT solutions PITS) [2]. MES's (Manufacturing Execution Systems) in production management can be used to integrate several functional areas [13]. The choice of the solution to be implemented will depend on a number of factors, particularly the capacity of the production company, which is linked with the size of the company.

Industry 3.0 focused on the computerisation of certain functions or areas of significance for the delivery of basic processes [3], while industry 4.0 places emphasis on the integration of computerised processes [14]. An important aspect is the automation of design, production and distribution processes, which requires the use of computer-aided solutions [16].

To be able to improve communication between its units (such as production sites or departments) as well the management of information flow [10] and, as a result, the management of its resources [7], the production company under analysis should employ adequate functional solutions. Such solutions may include computer-aided solutions [9], which can take the form of personalised IT solutions (PITS). A company without such solutions in place will find it difficult to deliver its processes efficiently, control them precisely and respond to events quickly.

If the resources necessary to deliver processes are limited, solutions designed to support the processes are needed. However, before any such solution is implemented at a particular company, it is necessary to identify the company's needs.

Even a company with an integrated management system in place will have some room for PITS's, as the company's IMS will normally cover between 70% and 80% of the company\s \processes. For the remaining processes, the company will need solutions that reflect its specific requirements as well as future changes. One area where this may be the case is production maintenance, including product, system and process improvement, and this will require the integration of data from various sources [1]. Therefore, it is advisable for manufacturing companies to monitor, on an ongoing basis, their requirements for computer-aided solutions.

The purpose of the work was to find solutions to improve the operation of a production company. The work was based on the assumption that computer-aided solution would improve the operating efficiency of the company under analysis and that employing a dedicated procedure to identify the company's needs would help design and develop dedicated IT solutions for certain areas or functions. Different options and methods were employed to find the final solution.

The analyses in the area of computer-aided solutions were conducted in 2017-2013 at a medium-sized company manufacturing industrial fittings. The products offered by the company are catalogued. [12].

All production is preceded by its preparation [3]. The analyses were focused on finding solutions to support the company in the production preparation process and to ensure the efficiency of production. One example of the work as part of the analyses is computer-aided preparation of production documentation, which is discussed in [11].

2. Prerequisites and means for solving the problem

The full information flow covers production preparation and preparation with accompanying activities. In the area of technical production preparation (TPP), the important aspects include not only the discipline of technology, design and engineering computations, protection of machinery and equipment, but also the procedures and regulations that apply to the company's products and the company itself, which should be taken into account.

The company under analysis had an IMS in place. Therefore, the analyses included three development options: (1) keeping the company's IMS in place, (2) replacing the IMS in place with a production management system (PMS) or (3) supplementing the IMS with other solutions (PITS) based on the company's needs and, as far as practicable, compatible with the IMS [15]. The second option would be the best one for the company under analysis, as it means moving away from a large IT system that is not working at its full capacity and implementing a solution that will support the company's basic process, i.e. production, and integrating it with the other processes. This means that the company's resources and processes would be interconnected by an IT solution to control and manage the company's production. However, following consultations with the company and based on an cost/benefit analysis, the third options was chosen, i.e. to implement dedicated solutions to support certain areas or tasks.

For the flow of technical product documentation, it is necessary to ensure that the flow of such documentation is controlled, that such documentation is archived and that hard copies of it can be digitalised into a database. It was, therefore, necessary to prepare a dedicated solution that reflected the needs of the technical department in this respect. A DBMS was proposed as a way to support the flow of documentation. [6]

The first stage in the technical production preparation process is product design. In this process, the customer's requirements (such as standards) must be taken into account. The solution was to support the design of the face and flange of a valve (these two parts are components of the body of the valve). It was also important for the designers to visualise the results of the design work in a CAD environment and to ensure efficient archiving of the 3D models of

the designed products. The solution to this problem was a DBMS [4].

The efficiency of the company's production process is also linked with its machine park. The maintenance of machinery and equipment is normally the responsibility of the company's production maintenance team, although it may be the case that this responsibility is assigned to a particular person or a company's technical team. This area generally includes day-to-day and scheduled maintenance of machinery and/or the keeping of operation/maintenance records. Once again, a dedicated DBMS can be the solution. [5]

In all the above cases, it is necessary for the company to be able to gather the required information systematically, with access, archiving and processing being not less important. It was decided that DBMS's were an effective response to the user's needs and, therefore, the solution proposed to the company was based on a DBMS.

3. Solution of the examined problem

3.1. Managing technical documentation

In the case of PITS's, the challenge was to organise the system for managing the company's technical documentation to ensure that the documentation is archived systematically and that searching for the necessary documentation was a smooth process. Based on the analysis of the company's needs, it was necessary to design a solution that would incorporate a standardised, continuous document numbering system and provide the company with full information on the flow and status of its documents. Therefore, the proposed solution (Figure 1) should allow the company to (a) register new documents, (b) search for existing documents and (c) register the flow of documents. In other words, the company can use the solution to register new documents and, subsequently, to archive them and find them quickly in the database.

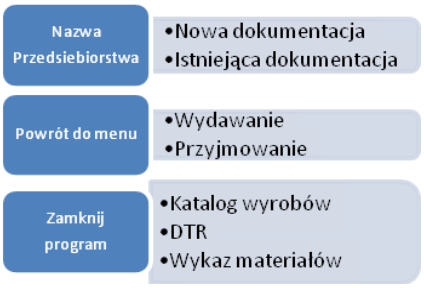

Fig. 1 *Elements PITS-CAMTD.*

It was also necessary for the company to be able to use its (a) product catalogue, (b) operations and maintenance (O&M) manuals and (c) list of materials. (Figure 1)

The documentation was divided into three types: design documentation, process documentation and assembly documentation (Figure 2), divided by content.

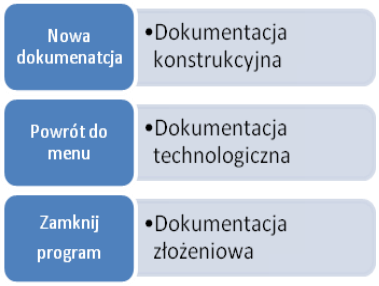

Fig. 2 *Documentation catalog.*

The solution also allows the user to access the company's product catalogue (Figure 3) to search for a product in the catalogue or to register a new one, to view all the products or only new ones.

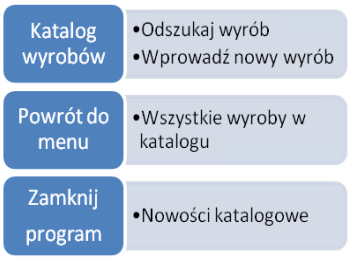

Fig. 3 *Product catalog.*

One aspect of efficient management of documents is the ability to control the flow of document, is a challenge. The proposed dedicated solution allows the company to control the release and return of documents. The information provided by the system includes who a document was released to or returned by, the release and return dates, the type of document and the number of copies.

As regards O&M documentation, it is necessary for the company to be able to archive such documents, to register new ones and to find existing ones. The solution offered the option to keep English-language documents and templates of O&M documents that could be downloaded and edited.

The search criteria are the same, regardless of the required resources, e.g. O&M documents or the product catalogue.

3.2. Design work support

As regards the product design process, it was necessary to design a 3D model generator for flanges. Such a generator (Figure 4), which is part of the dedicated solution, allows for defining the parameters of the flange and face of the valve and for viewing standardised values.

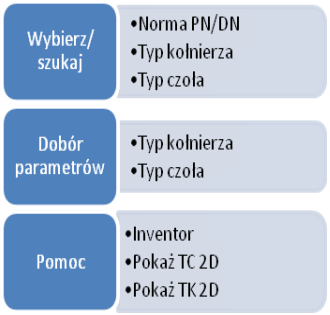

Fig. 4 *Generator of flanges*

When the selected parameters of the flange are approved, the modelled part can be visualised in 3D using the selected graphic design software (Figure 4) and 2D documentation can be produced.

In the process of designing the solution, the challenge was to think of a way to archive 3D models efficiently and to work in groups, i.e. to make such models available to other users, and allow for such models to be exchanged between work group members. Therefore, it was necessary to ensure that the solution allowed the user (a) to create a model of a flange, (b) to search for an existing model and (c) to change the settings. The response was a PITS-CAID solution, which is shown in Figure 5.

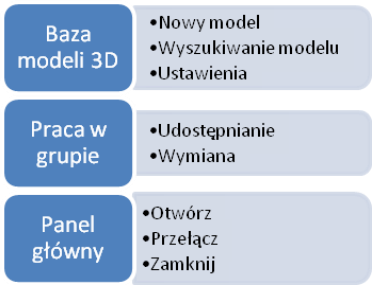

Fig. 5 *The main panel IRI.* *Elements PITS-CAID.*

The company also required a solution that would provide it with (a) access to a group of standards in respect of certain parameters and (b) access to the application (i.e. the solution) anywhere within an LAN.

The last step in the process was to prepare a standard file to allow the user to install the application on the user's workstation.

3.3. Production maintenance

In the case of total productive maintenance (TPM), the fundamental purpose was to ensure efficient and effective management of the company's technical resources (machinery and equipment).

The response was a solution based on the processing of information in this area. Therefore, the proposed dedicated solution should allow the user (a) to gather information on the company's machines, (b) to keep machine operation records, (c) to issue machine maintenance requests and (d) to generate reports, which was provided (as shown in Figure 6) by means of a computer aided total productive maintenance (PITS-CATPM) solution.

Fig. 6 *Elements PITS-CATPM.*

The PITS-CATPM solution (Figure 6) was divided into five 'thematic groups' (modules), i.e. machines, maintenance requests, personnel, orders and reports.

The Machines module is used to enter and store information on the company's machines and to keep machine operation/maintenance records. The Maintenance Requests, module allows the user to issue day-to-day maintenance requests or scheduled maintenance requests and to monitor the maintenance work. The module can include information identifying the request, the machine(s) covered by the request and the personnel responsible for performing the requested maintenance work.

The Reports module is a report generator (Figure 7). The user can both view and print reports. The Reports module can also be used to generate various useful reports/summaries.

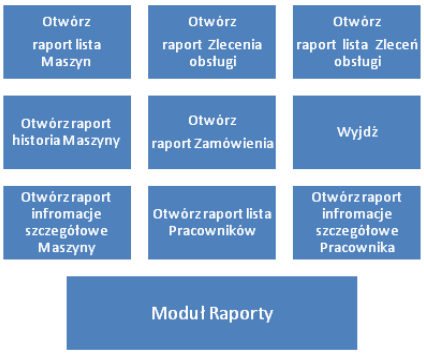

Fig. 7 *Module Reports.*

The Orders module allows the user to generate orders for spare parts necessary for the requested maintenance work. The user can keep a record of the necessary spare parts and use the module to easier calculations of spare part purchases. The Personnel module contains information on the company's personnel.

4. Results and discussion

Computer-aided management of production at the operating level requires, *inter alia*, the use of solutions for automated exchange of data between IT systems in a way that reflects the user's specific needs and requirements. The response could be a production management system (PMS) or the integration of a number of standalone IT systems (e.g. PITS's), in which case it is necessary to address the question of compatibility [3].

The analysis included the option to implement a PMS. A PMS reflecting the company's needs and requirements would improve the quality of the computer-aided management solutions in place at the company. The process of designing such a system would be a complex and multi-stage process. The preparations for the process would take a long time and require remodelling the flow of information within the company. Issues might occur both before and during the implementation of the system, as well as during the initial period of its operation.

Another possibility is the design of a PITS based on an analysis of the company's needs, with the option to allow for the exchange of data between the PITS and the IMS in place at the company. In the case of catalogue-based production, a PITS allows the user to coordinate its production work based on the process-oriented approach. As long as the company's hierarchical organisation is maintained to ensure the stability of its operation, this allows the company to adopt, for certain processes, solutions based on modules, i.e. particular operational units.

One example of this approach is an enquiry from the company's customers about a non-standard product for which online reporting by a few departments is required. The computer-aided solution would cover the company's sales, technical, purchasing and production departments. The response to the company's requirements in this example would be a system for identifying non-standard solutions and allowing for a flow of documents in line with decision-making procedures.

The 2007-2013 analysis of the company's operation included the flow of information, with special emphasis on decision-making processes and the resulting flow of documents. It was, therefore, necessary to ensure control of the flow of information and of decision-making for different areas or tasks. For example, the suggestion was that standard orders should be separated from non-standard ones in customer service, In particular, the latter may be very difficult to deal with. Handling such orders requires the use of a dedicated solution to control the flow of documents. Also, the time needed to design the requested product should be reduced and the production process made more efficient. These activities are the responsibility of the company's technical department and can be supported by a computer-aided solution. Therefore, the proposed solution designed to support the work of the technical department (covering document management, design work and production maintenance) needs to be supplemented with a PITS for non-standard orders.

Based on the analyses of the company, the response could be a PITS for "the identification of non-standard order processing" that would allow for data to be exchanged electronically between the company's units involved in the production of such orders. The solution should allow the company (a) to archive input data and the documents produced in the course of work, (b) to access such resources from multiple workstations operated by such units of the company and (c) to control the production of the order. Databases with product indexes and (spare) part indexes.

Implementing such a solution would help improve the flow of information in the processing of non-standard orders, resulting in improved customer service. This, however, would require further work on a computer-aided solution, i.e. a PITS.

5. Conclusion

The exchange of information within a manufacturing company requires the use of an information system supported by IT solutions. Such solutions may include integrated management systems, production management systems or personalised IT systems. They can be used to support the flow of information within the organisation or in respect of a specific process, area or task. In addition, the designers should take into account the scalability of the IT system or the addition of applications for new tasks in response to the company's needs identified through analyses.

The company under analysis had an IMS in place and used a PITS based on previous analyses. However, five years later, new analyses revealed that both the IMS and the PITS needed some upgrading. This shows that the analysis of a company's needs to decide what IT support the company requires should be a continuous process, based on the PDCA (Plan-Do-Check-Act) cycle.

The technical department of virtually any company needs solutions designed to improve the flow of information. The problems such departments usually encounter are related to product design, production planning or production maintenance. The response to such problems should include efficient preparation of technical documentation for the product to be made, efficient flow of such documentation and the provision of technical resources to ensure uninterrupted production. These issues were addressed by the proposed PITS solution for the company's technical department, as it covered technical document management, design work and production maintenance.

PITS's cover certain operating areas and provide support for defined processes. They help to improve the flow of information to the extent of the support provided by them. PITS's are dedicated solutions designed to offer specific functionalities and to be used in a specific operating environment. PITS's can be operated from multiple workstations. Although the input data in such systems is stored in one place, the data can be accessed by multiple users. In such a case, it is necessary to define access priorities. As a result, a member of the company's personnel will have access, to the extent of their authorisations, to the PITS from their workstation.

In the case of the company under analysis, the PITS's in place allow the company to gather and systematically store and process information according to the company's needs. They could also be used at other companies, provided the required software and hardware are available.

The analysis of the three options shows the directions and possible actions as regards industry 3.0 computer-aided solutions for companies, as well as within the context of industry 4.0. Regardless of the option, there is room for PITS's.

The proposed approach to supporting the operation of a manufacturing company with IT solutions is in line with the efficient business management philosophy. Efficient use of the proposed solutions will depend on many factors, including the human factor, i.e. the users of the solutions. However, the directions for development within the context of industry 4.0 leave no doubt as to whether the use of computer-aided solutions is justified or even.

Acknowledgment

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STANDARDS FOR MONITORING AND CONTROL OF CYBER-PHYSICAL SYSTEMS

Prof. Dr. Batchkova I. A., Eng. Tzakova D. L., Eng. Belev Y.A.
Dept. of Industrial Automation, University of Chemical Technology and Metallurgy
Bul. Kl. Ohridski 8, Sofia, Bulgaria

idilia@uctm.edu, dtzakova@gmail.com

Abstract: *The Industry 4.0 initiative imposes new requirements on cyber-physical systems in terms of interoperability, response time, communication capabilities, and more. A major approach to addressing these requirements is through the development and use of standard reference frameworks, architectures and models as well as the widespread and joint application of open industry standards. The aim of the article is to analyze the use of standards under the Fourth Industrial Revolution as well as to present and analyze some of the most applied standards in the field of monitoring and control of cyber-physical systems, such as AutomationML, OPC-UA, IEC-61449, IEC-61512. The reference architecture RAMI 4.0 was used to establish relationships and interactions between them.*

Keywords*:* CYBER-PHYSICAL SYSTEM, INDUSTRY-4.0, IEC-61499, AutomationML, OPC-UA, IEC-61512, IEC-62264

1. Introduction

The rapid development and broad penetration of information and communication technologies in the industry has led to the emergence of new industry development strategies with a view to enhancing its competitiveness, such as: the German Initiative "Industry 4.0" [1], the American "Smart Manufacturing" [2], the Chinese "Made in China 2025" [3], the Japanese IVI (Industrial Value Chain Initiative) [4], the Italian "Industrial National Plan 4.0" [5], etc. All of them aim "The complete transformation of the whole sphere of industrial production through merging of digital technology and Internet with conventional industry". Recent studies have shown that digitization of products and services can add more than 110 billion Euros a year to Europe in the next five years [6]. Successful implementation of all these initiatives is possible with the use of Cyber-Physical Systems (CPS) technologies, which are considered to be new types of systems that expand the capabilities of the physical world through computing, communications and control, and upgrading the electronic automation. The most important key topics in research, development and implementation are:

- Modeling, Simulation and Verification of CPS;
- Development and application of software process models in the development of CPS (Modeling of the development life cycle of CPS;
- Reference Frameworks and Architecture of CPS;
- Development of semantic service oriented architectures of CPS;
- Distributed control of CPS using advanced methods and algorithms;
- Interoperability in CPS and between them;
- Data analysis (big data) and decision making.

An important role for successfully dealing with the tasks in the above mentioned directions and integration of the received solutions is played by standardization. The development and adoption of standards reduces the risk to enterprises and encourages the adoption of new technologies, products and production methods. Standards for CPS include reference architecture, common services and functional models, semantics, security and safety standards, and standard interfaces for system-to-system interactions [7]. A survey on the "Prospects for Industrie 4.0" [8] confirms the importance of standardization for adoption of Industry 4.0. It is identified that the first greatest challenge connected with implementing the vision is the standardization as shown in Fig.1.

The main objective of the investigation proposed in this paper is to summarize and analyze the knowledge about standardization processes and standards needed in the field of monitoring and control of CPS. It is necessary to draw conclusions on the applicability of the existing standards in the field for the purposes of the Industry 4.0 initiative and to analyze the possibilities for their extension and joint use. The paper is organized in 4 parts. After the introduction, in part 2 a short overview of standardization processes in the context of Industry 4.0 is proposed. Part 3 presents an analysis of the most important standards for monitoring and control of CPS, based on different reference architectures, meta-models and models. Finally some conclusions in respect to interoperability of applications for monitoring and control are drawn.

Fig.1: *Challenges for the implementation of "Industry 4.0" [8]*

2. Standardization in the context of Industry 4.0

The major advantage of using standards is that they reflect the state of the art of research and technology development and promote mutual understanding and consensus among partners. Studies show that the contribution of standards to annual GDP growth varies from 0.3 to 1%. For Germany this impact is estimated at 1% of GDP, for France - 0.8% and for the UK only 0.3% [9].

The main shortcomings in standardization are related to the existence of too many standards and the lack of interoperability between them internationally, with the main reasons for this being the different culture, language and areas of use. Overcoming these shortcomings requires cooperation and coordination, the so-called harmonization process. In this regard, the White Paper on "Modernizing the Standardization of Information and Communication Technologies (ICT) in the EU" was adopted in 2009, where it stated that: "Standards are needed in the digital society to ensure the interoperability of networks and systems. In a digitally-driven society, ICT-related solutions are used in every economic sector as well as in our everyday life. These solutions, applications, and services must be able to communicate with each other, i.e. they must be interoperable. Interoperability requires standards"[10]. At a meeting of the European Commission in February 2010, the Expert Group on the Review of the European Standardization System (EXPRESS) presented its report

"Standardization for a Competitive and Innovative Europe: Vision 2020" [11]. In a document dated 4 February 2011, the European Council, on the basis of [11], confirms that standardization is an important framework for promoting private investment in innovative goods and services and that standardization processes need to be accelerated, simplified and modernized. This is an essential sign of the European economy that European standardization continues to adapt to the rapidly changing global reality and economic environment. In June 2011, the "Strategic Vision for the Development of European Standards by 2020" is published. It aims at improving and accelerating the sustainable growth of the European economy [9].

The basis for addressing the above-mentioned standardization issues is the use of standardized reference frameworks and architectures that help achieve interoperability at standards level. One of the most well-known reference architectures for Industry 4.0, which successfully launched these processes, is the reference architecture RAMI 4.0 [12]. The reference architectural model RAMI 4.0, shown in Fig.2, is three-dimensional and describes the crucial aspects of Industry 4.0. The "Hierarchy level" axis includes the hierarchy levels defined in the ISO/IEC-62264 standard, including all different functionalities in the factory. In the RAMI 4.0 the functionalities are extended to the "product" according IEC-61512 standard and to "connected world". The left horizontal axis represents the life cycle of the facilities and products, based on the IEC-62890 standard and the vertical axis represents the six layers for decomposing into its properties. The reference model allows a step-by-step migration from present into the world of Industry 4.0. RAMI 4.0 integrates different user perspectives and provides a common understanding of Industry 4.0 technologies. It is a foundation for the following next steps towards Industry 4.0: thing identification, unified semantics and common syntax for data, defining of QoS components, communication connections and protocols.

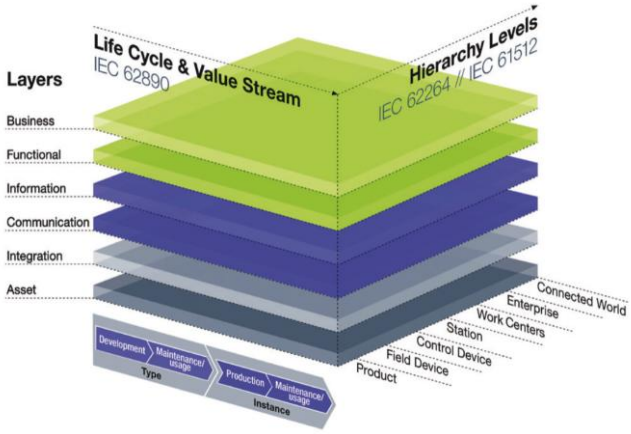

***Fig.2**: Activity model of quality operations management [12]*

The areas in which the interoperability of different standards based on RAMI 4.0 can be successfully launched are summarized and shown in Fig.3. With respect to monitoring and control of cyber-physical systems, the standards of great importance are from the following fields: "Engineering" (IEC-62714, IEC-62424, IEC-61131, IEC-61499), "Communication Layer" (IEC-62541) and "Hierarchical Levels" (IEC-61512, IEC-62264). They will be presented and analyzed in Part 4 of the paper.

3. Main trends in monitoring and control of CPS

The structural and behavioral complexity of cyber-physical systems poses great challenges in terms of the methods and environments for their design and analysis. It is necessary to develop the theoretical foundations of CPS, as well as to create software platforms with appropriately defined levels of abstraction, architecture, languages for modeling different aspects of CPS and transformations between these models. Especially important are methods that have to integrate the discrete dynamics of the computing part with the continuous dynamics of the physical part and the stochastic nature of communications, which must be expanded to cover a wider context. There are three main approaches to designing the CPS: Networked control systems, Hybrid control systems and Distributed hybrid control systems.

***Fig.3:** Key domains for standardization*

The fundamental requirements for introducing CPS in industry are specified by [13] as follows:

- Adaptable to heterogeneous environments: integration with cutting-edge information systems, smart-devices and the existing environment (from old PLCs to smart object embedded in computing power).
- Capable of working in distributed networks: they should gather, transfer and store in a reliable manner all the information provided by smart sensors and actuators through the use of the IoT.
- Based on a modular open architecture: the interoperability has to be ensured across different platforms provided by several vendors along the value chain.
- Incorporate human interfaces (HW & SW based): integration of user-friendly and reliable service to make decision makers aware about the real time situation of the factory.
- Fault tolerant: given by the encapsulation of models to activate prediction control loop and correctness of automation systems.

4. Short analysis of standards for monitoring and control of CPS

4.1. IEC-62714 Standard (AutomationML)

The IEC-62714 Standard or also known as AutomationML (AML – Automation Markup Language) is an international and free of charge standard proposing neutral data format based on XML for storage and exchange of engineering information about industrial automation systems [14]. It covers information about the plant structure (topology, geometry and kinematics) and the plant behaviour (logic). The standard ensures a common understanding of exchanged data through explicit common semantics for all data to be exchanged. AML covers the data contents from different information sets as shown in Fig.4, combining the following data formats:

- CAEX (IEC-62424) – for description of system hierarchies and attributes of system elements and devices;
- COLLADA (Standard of KHRONOS Group) - describing geometry und kinematic information;
- PLCopen XML (Standard of PLCopen for modelling of IEC 61131 projects) for describing of behavior information models.

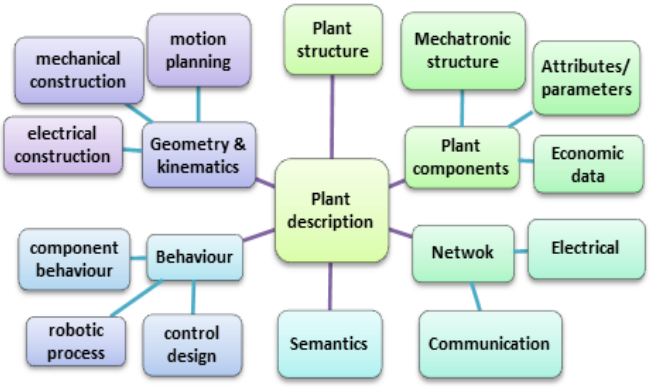

Fig.4: *Basic information sets covered in IEC-62714*

4.2. IEC-62541 (OPC-UA)

The IEC-62541 Standard [15] or OPC-UA (Open Platform Communication – Undefined Architecture) is a new generation of OPC that replaces DCOM communication specific TCP/IP protocols enabling OPC in any operation system and can be implemented in all languages. OPC UA offers a fully networked, object-oriented concept for the namespace, including metadata for object description. The OPC UA specification defines a service-oriented architecture (SOA) with a set of services described in Part 4 of the standard. The information models in OPC UA form a layered structure, shown in the Fig.5, where the lowest level is the base Information Model. Above the base model the service-specific information model extensions for Data Access, Alarms & Conditions, Programs, Historical Access and Aggregates are located. Above the composition of general information models, the companion specifications are defined. The next layer are companion specifications which are domain-specific information models On the uppermost level of the OPC UA structure, highly specified information models are defined by different companies or vendors for use in their specific products. The composition of information models can be extended.

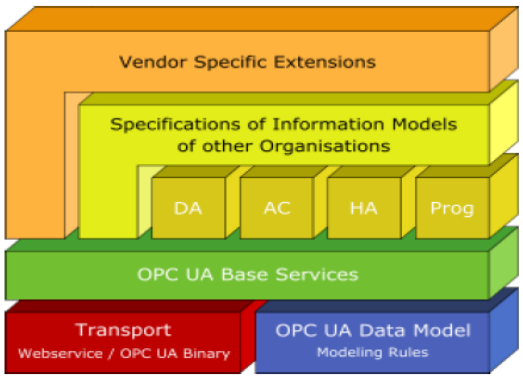

Fig.5: *Layered structure of information models in OPC UA [16]*

4.3. IEC-61499 standard

The IEC 61499 standard [17] defines different reference models supporting the design of distributed control systems at physical, logical and conceptual levels and from different viewpoints. The key models of an IEC 61499 based distributed control system are system, device, resource and application models as shown in Fig.6. All these models are based on the Function Block (FB) concept. Three different kinds of FBs are defined: basic (BFB), composite (CFB) for encapsulation of complex functionality through networks of BFB and service interface function block (SIFB) for providing interfaces for unidirectional (publish/subscribe) and bi-directional (client/server) communications as well for resource or device management. An application model is a network of FBs and may be executed by one or more devices, including one or more resources. Resource models provide support for program execution by their scheduling part, communication and process interfaces. A device is a control unit having one or more processors that defines specified function for the purposes of automaton and has two types of interfaces - process and communication in order to communicate with the process and other devices on the network respectively. The system model consists of a number of devices, with global or local communication links between them. From the above said it is clear that combining encapsulation of functionality, component-based design and event-driven execution and distribution accelerates and facilitates significantly the dynamic reconfiguration of control systems.

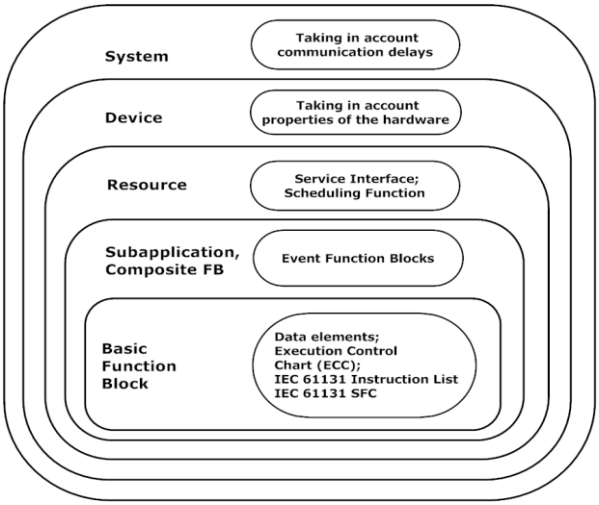

Fig.6: *Basic models in IEC61499*

Extra for the configuration purposes the so-called Management SIFBs are also considered in the standard. They enable the management of devices, resources and applications as it is possible to define and use 6 operations - create, initialize, start, stop, delete and query and to provide notification of changes in availability and status of data types, function block types and instances, connections among function block instances (IEC TC65/WG6, 2005). Thereby IEC 61499 provides the basic interfaces to support dynamic reconfiguration, but the mechanisms to do it are still under development.

4.3. IEC-61512 Standard

The IEC-61512 Standard [18] or also known ISA S88 provides a guideline for design of batch control systems. It defines basic terminology and a set of descriptive models. The main idea is to separate product knowledge from the equipment used. To describe a batch process in different grades of detail from chemical and control engineering points of view, the standard proposes a set of seven models as shown in Fig.7.

Taking the process view, design starts with a process model containing the (abstract) chemical knowledge of the process to be realized. From general recipe to control recipe this model is stepwise substantiated (i.e. adapted to the batch plant). The resulting control recipe describes which actions have to be taken in which order to reach the desired process. The control view (or equipment view) is described with the physical control model, dealing with sensor and actuator signals, and its abstractions, equipment control and control recipe. The control recipe is the meeting point of the two points of view. It is also the starting point for the proposed approach and will be explained in detail in the following. As all models in S88, the control recipe is built in a hierarchical way. Phases are considered as elementary steps in the control recipe and cannot be decomposed. A phase describes a basic function of the given plant such as dosing, stirring or heating. Collections of phases performed in a specified order (sequential and/or parallel) are operations.

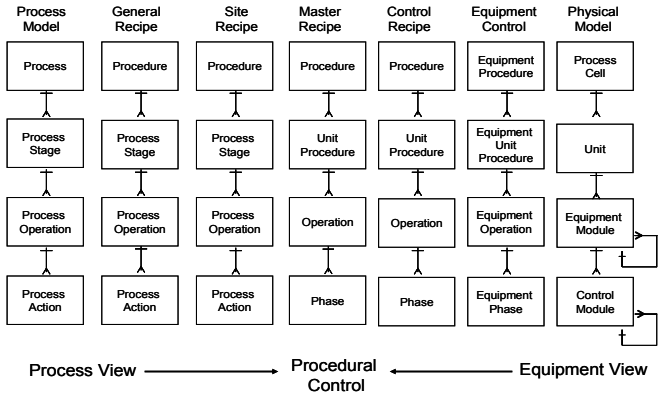

Fig.7: *Process and equipment view of IEC-61512 [18]*

4.4. IEC-62264 Standard

ISO/IEC 62264 (ANSI/ISA-S95) series of standards [19, 20] offer the technology and a vendor independent way to exchange data and information. These standards are an agreement between leading companies (SAP AG, Eli Lilly, The Foxboro Co., Hewlett-Packard, Honeywell, Rockwell Automation, IBM Corp., Oracle Corp., ABB etc.) to create a common framework and guidelines for design and integration of systems. The standard ISO/IEC 62264 facilitate to separate business process from production processes and to separate the exchanged information from specific implementation of manufacturing systems and specific implementations of the business systems. The standard provides standard models and terminology for describing the interfaces between the business systems of an enterprise and its manufacturing-control systems (Fig.8). Activities related to manufacturing operations management (Level 3) integrate planning and logistics (level 4) and control functions defined on Level 2.

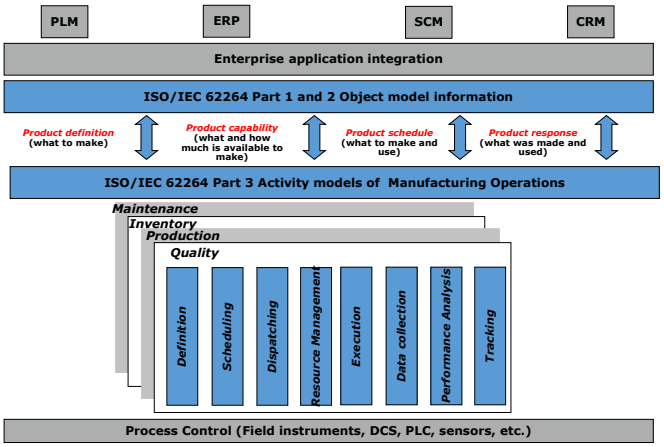

Fig.8: *ISO/IEC-62264 Manufacturing Architecture [21]*

5. Conclusions

The CPS require the development and use of new methods and techniques for design and integration, based on the use of open industry standards related to the achievement of full integration of heterogeneous products and systems from different perspectives and points of view. None of the standards discussed in this paper is able alone to address the challenges faced by monitoring and control in CPS. The use of RAMI 4.0 reference architecture ensures compatibility of the presented standards and significantly improves the performance and quality of the development.

Industry 4.0 vision requires revision of the approaches for development and use of CPS concerning the decentralization in order to integrate the Cyber-Physical Systems (CPS) with cloud computing infrastructures, and to empower decentralization using edge computing that moves some part of computing from the cloud to its edge nodes, supporting real-time interactions and scalable analytics, or the application of new disruptive key enabling technologies in factory automation like DLT (Distributed Ledger Technology) and Smart Contracts (ISO-20022) changing the paradigm of messaging. All thise new trends in the development of CPS will impose new challenges to ensure the interoperability at the level of standards.

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INNOVATION POTENTIAL OF AUGMENTED TECHNOLOGIES IN INDUSTRIAL CONTEXT

Asst. Prof. Dr. Eng. Nedeltcheva Galia Novakova

Sofia University, Faculty of Mathematics and Informatics, 5 James Boutchier Str., 1164 Sofia, Bulgaria
g.novak@fmi.uni-sofia.bg

Abstract: *The goal of this paper is to provide a resource that can be used by the Augmented Reality research community and practitioners to understand the most recent potentials for application of the innovative Augmented Reality technology in various industry. Firstly, it is described mainly the role of the Augmented Reality in logistics and maintenance. Secondly, the paper provides an overview of research papers in the period 2008-2018 in the field of Augmented Reality for facilitating and supporting industrial applications.*

By efforts of research, review and classification the author outlines both opportunities and challenges for spreading the Augmented Reality applications in smart manufacturing environments that will provide the baseline for further discussion and research in this direction.

Presenting this survey the author aims at creating an active community that further discusses the future development of Augmented Reality particularly in Supply Chain Management. Future steps will be taken in research workshops and online community work.

Keywords: AUGMENTED REALITY, INNOVATION, INDUSTRIAL CONTEXT, MANUFACTURING

1. Introduction

With the constant development of new technology – digitalization and integration with all sorts of internet platforms, various cloud services and artificial intelligence with machine learning, the ever-brewing competition and rivalry drives many companies to reconsider the management of their Supply Chains and invest in better, more innovative ones. Even if their goal is not to aim for the top places, taking the time to arrange their raw materials, manufacturers, distributors and even logistics details, in the best way possible, can really save the company from a lot of financial and material losses.[1]

Digital manufacturing consists of different steps which not only create the digital data, but also steps that compress the content so that it is easily and more quickly distributed and delivered, steps that ensure the quality of the content.

Digital logistics nowadays is replacing the old way of distributing physical goods that carried the same digital information by implementing virtual distribution using different platforms and cloud technologies that can be accessed on demand.

Many innovative technologies are appearing and companies are taking advantage of integrating them into their current Supply Chain Management (SCM) systems, or altogether replacing them for better, faster and more reasonable ones.

In this paper, we will look into the innovation of the Augmented Reality technology in industry that more and more companies are either implementing or integrating to secure their future on the market or as the top leading companies in their respective fields.

2. Background on Augmented Reality

Famous companies who have introduced AR to their commerce webstores are eBay, which has focused on car enthusiasts for now, who are said to be able to see how different auto equipment would look like on their personal vehicles; IKEA has allowed its customers to use their own smartphones or tablets while browsing furniture to help them visualize them in their own homes using only the phone's camera and IKEA's application. DHL have been using virtual reality glasses to speed up the warehouse picking up process, which help ensure that the proper product is being picked up and thus minimize losses by eliminating human error and at the same time shortening the time for checking the products with a slower device.

Augmented Reality (AR) is a novel human–machine interaction that overlays virtual computer-generated information on a real world environment. It has found good potential applications in many fields, such as military training, surgery, entertainment, maintenance, assembly, product design and other manufacturing operations in the last ten years. This research aims to provide a survey of developed and demonstrated AR applications in manufacturing activities. The intention of this survey is to provide researchers and engineers, who use or plan to use AR as a tool in manufacturing or in Supply Chain Management (SCM), a useful insight on the state-of-the-art AR applications and developments.[2]

Various solutions based on Augmented Reality have been proposed by the research community. Particularly in maintenance operations Augmented Reality tools have offered new perspectives and have promised dramatic improvements. On the other hand, Augmented Reality is an extremely demanding technology and at present it is still affected by serious flaws that undermine its implementations in the industrial context.[3]

AR technology is particularly suited for maintenance industry, as it can be easily implemented in several processes. AR can enhance the user's view of the surrounding scene with different content that include visual animations, sounds, written instructions or static images. Using AR can potentially reduce the numbers of errors during maintenance tasks. In fact, AR provides information that is generally not easily available or whose retrieval is relatively demanding. In general, many processes in manufacturing, aviation and automobile industry have to deal with assembly tasks. During

maintenance operations, mechanics have to deal with a large amount of different parts that represents a large proportion of search time: standard manuals or handbooks can lead inexperienced operators to frustration and poor performance.[3]

Training specialized workers is an expensive voice in any kind of industry. In the case of aviation, it takes up to 2000 hours for inspectors to be completely trained. AR can remove restrictions of time and location, leading to a much faster transfer of knowledge and a better understanding of the maintenance processes. Hence, from an economical point of view, industry can use AR to lower processes' operational costs and thus sustain their growth and innovation.

The main factor retarding the full deployment of the new technology has been until now the human one, because the gap between technology and human resources culture has grown, not reduced. [4]

3. *Application of AR technologies*

The goals of our study is to investigate the following research questions:

RQ1: What is the state of the art of the scientific literature on the innovation potential of Augmented Reality in manufacturing in journal articles from 2008 to 2018, as well as

RQ2: Is AR the future of Supply Chain?

To address these questions, we performed a systematic study of scientific publications on Augmented Reality in manufacturing.

It is acknowledged that AR technologies are well applicable in many different industries like Automotive, Aeronautics and Aviation, Robotics and Automation, Software, Construction industry, Transportation, Marine, Dentistry, Electronics, as well as Education. In Figure 1 the distribution of typical industrial fields of AR application are graphically represented.

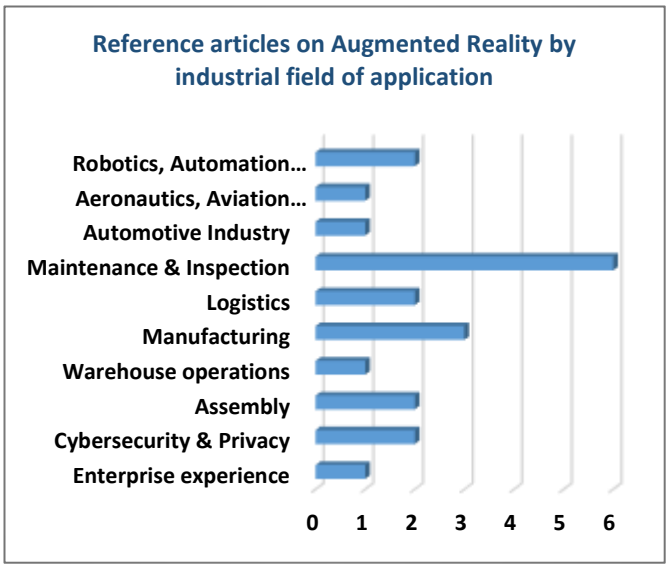

Fig. 1 *Distribution of reference articles on AR by industrial field of application*

Table 1 summarizes the articles being reviewed on Augmented Reality per year of publication and facet type.

Table 1: *Referenced articles on Augmented Reality per year of publication* and facet type

Facet type	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Research method	1		1	1	1	1
Implement ation field	1					1
Industry type						
Facet type	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Research method	1	1	1	2	2	
Implement ation field	1	1	1	4	2	
Industry type	1			2		

Figure 2 depicts the distribution of articles on AR both by year of publication and facet type.

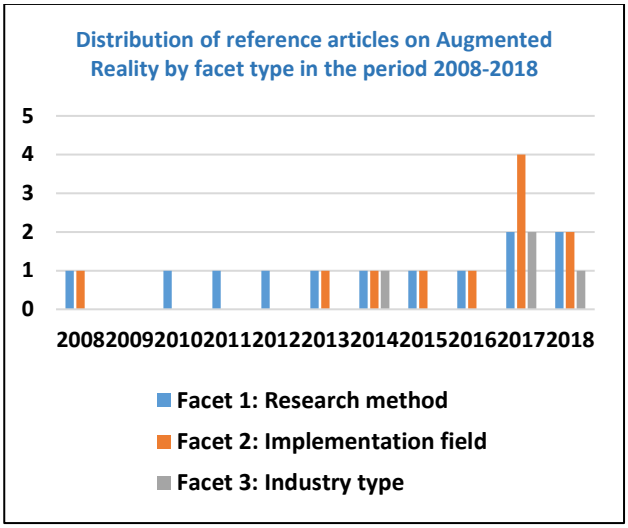

Fig. 2 *Distribution of the number of reference articles on AR per year of publication and facet type*

4. *Main advantages and disadvantages of AR systems in Industry*

AR technology is extremely flexible and, particularly in maintenance industry, it can be easily implemented in several processes. Thanks to the additional knowledge provided by AR, the number of errors during maintenance tasks can be greatly reduced. In fact AR provides information that is generally not easily available or whose retrieval is relatively demanding. In general many processes in manufacturing, aviation and automobile industry have to deal with complex assembly tasks, which execution involves a large amount of different parts. In these situations standard manuals or handbooks can lead inexperienced operators to frustration and poor performance.

From an economical point of view, industries can use AR to lower processes' operational costs and thus sustain their growth and innovation: training specialized workers is an expensive voice in any kind of industry.

In the case of aviation, it takes up to 2000 hours to fully train a maintenance inspector. AR can remove restrictions of time and location, leading to a much faster transfer of

knowledge and a better understanding of the maintenance processes.

Main disadvantages of AR systems

Even though AR is a promising technology, it still presents some disadvantages that may jeopardize its actual implementation in real maintenance applications. In fact, a bulky, relative low resolution prototype with fixed focus cameras or a small field of view HMD can become an actual occlusion to work execution, and so seriously influence the perception of the AR technology and the advantages introduced. Another important aspect that should be considered is the weight of the hardware: the average weight of high-end HMD is 700 grams, while normal reading glasses weight around 100 grams. When the process that we want to improve takes more than one hour, the user may get tired and perform the work poorly: it thus become very important to take breaks between steps of the process, unavoidably resulting in important delays. To avoid wearing a heavy HMD, we may use an LCD screen, but this would diminish the quality of AR experience and would force the user to wear a helmet or a belt holding the cameras so that they could keep objects of interest inside their field of view: such a solution is very uncomfortable and would hardly be accepted by operators. Also the range of movement plays an important role in the development of AR applications: since HMDs are usually not wireless, the displacement of the user is limited by the extension of the wire. Another characteristic that is limiting the spread of the technology to new markets is the cost, because high ranges vision glasses are between 500 to 5000 dollars, depending on resolution, transfer speed and comfort for the user. To open the technology and make it more attractive to public, these hardware limitations must be surpassed: companies like Microvision, Vuzix or Lumus are already working and improving current AR systems, trying to overcome the flaws that are slowing down the spreading of AR.[3]

A different kind of problem is given by the computational cost of AR applications: the amount of polygons that can be drawn at 25 frames per second on a single frame is limited by the computing hardware of an AR system. Usually a 3D CAD model with more than 100000 polygons already represents an interesting challenge.

Even if hardware is continuously improving, especially thanks to the availability of extremely performing parallel CPUs, this still constitute a limit when the AR application has to deal with complex environments or has to draw several detailed objects.

Research on how to take advantage of Augmented Reality applications and technologies in the domain of manufacturing has brought forward a great number of concepts, prototypes, and working systems. Although comprehensive surveys have taken into account the state of the art, the design space of industrial augmented reality keeps diversifying. Within our classification framework we collected and classified relevant publications in terms of implementation area facet as shown in Table 4. This facilitates initial research activities as well as the identification of research opportunities [5]. Thus, we lay the groundwork, but forthcoming workshops and discussions shall address the refinement.

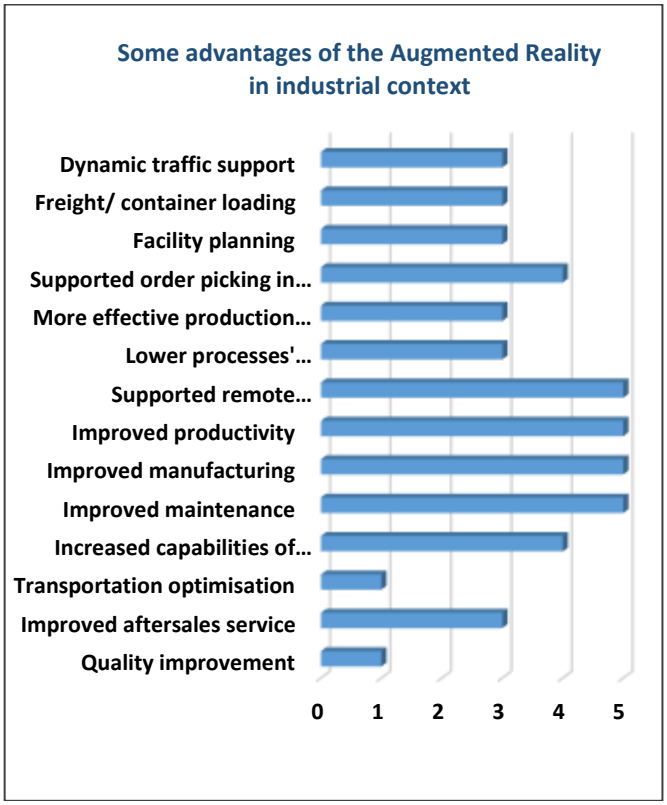

Fig. 3 *Advantages of Augmented Reality in an industrial context*

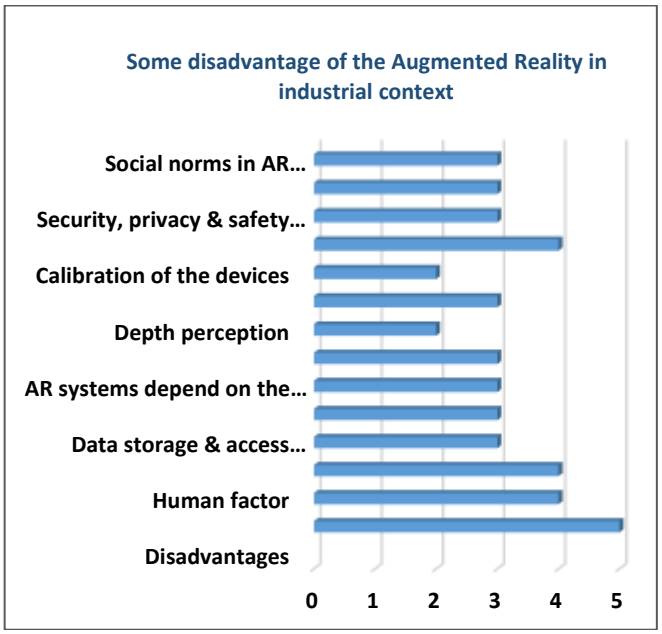

Fig. 4 *Disadvantages of Augmented Reality in an industrial context*

In Figure 3-4 are summarized the main advantages and disadvantages of the AR in an industrial context.

5. Is Augmented Reality the future of Supply Chain

AR technology is particularly suited for maintenance industry, as it can be easily implemented in several processes [3]. AR can enhance the user's view of the surrounding scene with different content that include visual animations, sounds, written instructions or static images. Using AR can potentially reduce the numbers of errors during maintenance tasks. In

fact, AR provides information that is generally not easily available or whose retrieval is relatively demanding. In general many processes in manufacturing, aviation and automobile industry have to deal with assembly tasks. During maintenance operations, mechanics have to deal with a large amount of different parts that represents a large proportion of search time: standard manuals or handbooks can lead inexperienced operators to frustration and poor performance.

Training specialized workers is an expensive voice in any kind of industry. In the case of aviation, it takes up to 2000 hours for inspectors to be completely trained. AR can remove restrictions of time and location, leading to a much faster transfer of knowledge and a better understanding of the maintenance processes. Hence, from an economical point of view, industry can use AR to lower processes' operational costs and thus sustain their growth and innovation.

As defined in the industry report on Augmented Reality by DHL, Augmented Reality refers to the layering of computer simulation models over the physical layout of current surroundings. In a sense, this is the hallmark of virtual reality, but AR refers to using this information to improve the efficiency of today's processes as they relate to the supply chain.

Most common forms of Augmented Reality involve some sort of glass, visual display for a wearer to use in the process of increasing productivity and performance. For example, smart glasses in the warehouse are considered a form of Augmented Reality Supply Chain, explains SupplyChainDigest. The wearer is able to overlay a computer simulated image into the physical space.

By 2017, Augmented Reality is estimated to have a value of just over $6 billion. Evidently, this trend is growing at one of the fastest paces in the market, 100 percent annually. One of the largest sectors we will see grow is in the "Industrial" sector, meaning application for both an Augmented Reality Supply Chain to include manufacturing, distribution, and logistics [4].

Augmented Reality is currently being used to provide a sense of scene recognition during order picking processes. Most traditional order picking processes involve paper-pen picking or picking through voice-automated systems. However, this continues to result in inefficiencies.

At any time, employees in a given warehouse must typically perform multiple actions in order to successfully pick an order. For example, the picker must locate the correct product, scan the product, and deliver the product to the loading dock. However, scene recognition and Augmented Reality allowed a camera-operated system to autonomously identify where a product is located if it is the correct product, and how to move to the next product at a faster pace. All of this information is displayed to the user of the Augmented Reality-enabled device.

On the consumer-end, Volkswagen has created a vehicle that can display the current speed, status updates, and other information on the windshield of the vehicle for improving the safety of the driver. Yet, truck drivers spend up to 60 percent of their time away from facilities locating the correct order in the truck, not driving, explains Karolina Maziliauskaite (Maziliauskaite, 2015). This is unacceptable. AR could be used to help a driver rapidly identify exactly where the shipment is located within the truck, cutting the amount of time spent not driving drastically. The applications of augmented reality in the future of the supply chain are limited only by the imagination. Since AR allows a non-tangible aspect of business to take place on top of the physical parts of business, AR will dramatically change how consumers and businesses view typical processes within the standard supply chain, thus creating an augmented reality supply chain.

For example, the process of item repair and reverse logistics (aftersales services) could be made much simpler. AR could be used to help an entry-level tech immediately identified incorrect circuits and problems within a given product. On the other hand, Augmented Reality could be applied to a video stream from the consumer of a current product's condition. This video could be applied to the AR aspect on the business-end or customer service-end of the Augmented Reality Supply Chain to immediately identified what is wrong with the product. As a result, the consumer does not lose any time in bringing the product into the store, the Supply Chain partner does not lose any time in analyzing the problems with the product, and the consumer is able to obtain a repair or replacement at a faster pace. The level of consumer service is increased, which helps to propel the entire supply chain forward.

AR is not without its faults. These brief descriptions of AR rely on some sort of power source, and wearing a battery pack on the head is simply impractical. As explained by Roland Martin (2015) [8], the biggest challenge to the widespread use of AR is low battery life. The solution to this problem must rely on using technology and innovation to define a new way of getting power to the systems rapidly and efficiently, without imposing a burden on the employees. Ultimately, Augmented Reality may be used to figure out a way to create a smaller, more durable battery to power AR-enabled devices. Essentially, the applications of AR are continuing to expand.

Consumers are demanding more from the modern Supply Chain, and the level of competition between different Supply Chain service providers is growing. However, AR will be one of the defining forces of the modern supply chain in 2016, where the augmented reality supply chain will start to shape. Once, the use of radio frequency-driven headset seemed like the best solution to supply chain management and the use of technology. However, the use of technology is taking on a new level through augmented reality, and it will only continue to grow as society becomes more apt and reliant on advanced technologies. [6]

With this overview on the recently available scientific articles on the Augmented Reality applications in an industrial context web try to give contribution to understand better the present and future technological impact on SCM processes.

A new wave of Artificial Intelligence applications can approach and solve many problems of Planning and Control of Supply Chain, in the past approached only through off line mathematical models combined with inter-functional team work. [4]

We can conclude that Augmented Reality is a promising driver for industrial applications and it is a breakthrough technology that could considerably ease execution of complex operations.

6. Conclusion

The work to be done at research and implementation levels is enormous to assure a full exploitation of the AR technological potential for SCM. The main factor retarding the full deployment of the new technology has been until now the human one, because the gap between technology and human resources culture has grown, not reduced. Demonstration

systems, prototype systems and productive systems are still required. [4]

AR is a breakthrough technology, but at present it is still affected by serious problems that jeopardize its implementation in industrial environments. In this article we have presented the main advantages that AR can offer to industrial processes, with particular attention to maintenance operations. AR could seriously improve human performances, and this can lead to great benefits not only from an economical perspective: a better maintenance on a car or an airplane does not only mean cheaper costs, but also higher reliability and thus, less failures and subsequent accidents. [3]

Main flaws that are heavily hindering AR spread in the industrial background were detailed: valid solutions to these flaws are needed to make AR a more competitive technology. Better materials, faster algorithms, smaller hardware are demanded and the research community must take charge of this need and offer valid solutions.

How to get to the most relevant information with the least effort from databases, and how to minimise information presentation are still open research questions.

AR systems will depend heavily on the available types of content. Scientific and industrial applications are usually based on specialised content, but presenting commercial content to the common user will remain a challenge if AR is not applied in everyday life. [7]

Our research investigation gives us the opportunity to identify broader lessons and key challenges to inform the research and practitioners about the potential use of AR technologies in industrial context with focus also on the whole Supply Chain. The study highlights important security and privacy challenges that emerging AR technologies will raise. [9]

Supply chains will continue to evolve and become more integrated with the information technologies. It can be said that it is a concurrent evolution, and with the evolution of the IT, the evolution of the SCM will also take place and leading companies will make sure that they do not get behind, so they are more and more applying in their operations disruptive technologies like the Augmented Reality.

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ЕФФЕКТИВНИЕ ПУТИ ПОВЫШЕНИЯ ДОЛГОВЕЧНОСТИ МЕДИЦИНСКИХ ПАР ТРЕНИЯ

R.S. Turmanidze[1], S.Ye.Sheikin[2], G. Z. Popkhadze[3]
[1,3]Georgian Technical University: inform@gtu.ge, popxadzegiorgi@gmail.com
[2]Bakul Institute of Superhard Materials NAS of Ukraine: sheykin2003@ukr.net

Abstract: *The article is devoted to the development of promising ways to increase the durability of friction pairs in the endoprosthesis, and to the peculiarities of mechanical processing of spherical components of the hip joint endoprosthesis.*

Keywords: single crystal sapphire, anisotropy, grind ability, endo-prosthesis, precision grinding, forming and spherical surface.

1. Введение

Эндопротезирование суставов является эффективным методом восстановления работоспособности человека при неизлечимых заболеваний или травм.

При этом операция эндопротезирования тазобедренного сустава является наиболее распространенной операцией костной хирургии. Ежегодно в протезировании тазобедренного сустава нуждаются 500 -1000 больных 1 млн. Население. При этом, на каждые 3-4 первичных операции проводится 1 ревизионная. Эндопротез тазобедренного сустава состоит из ножки, головки, ацетабулярного чашки и обоймы (рис. 1). Совершенно очевидно, что долговечность эндопротеза является основным критерием его качества и определяется в значительной мере служебными свойствами применяемых материалов, важное место среди которых занимают износостойкость и триботехнические характеристики. То есть, исследования, направленные в этом направлении являются

Рис.1. *Ендопротез тазобедренного сустава человека*

чрезвычайно актуальными [1, 2 и др.].

Шарнирное сочленение с таким сочетанием материалов до настоящего времени наиболее широко распространено в ортопедической практике и может сохранять работоспособность в течение 20 лет и более [1,3].

Шарнирное сочленение (пара трения) является важнейшей частью изделия, которое в значительной степени определяет его долговечность. J. Charnley в 1958 г. [4] предложил использовать в качестве материала головки эндопротеза сплав CoCrMo, а ацетабулярного чашки - хирулен (сверхвысокомолекулярный полиэтилен (СВМПЭ) - ultrahigh molecular weight polyethylene (UHMWPE).

Сегодня для изготовления компонентов пары трения используют различные материалы и их сочетания. Для сферических головок используют сплав CoCrMo, различные виды керамики, реже - титановые сплавы (как правило, GRADE 5). Для ацетабулярного чашки наиболее часто применяют UHMWPE [1, 3]. Однако с точки зрения биосовместимости эти материалы не являются лучшими (рис. 2) [4].

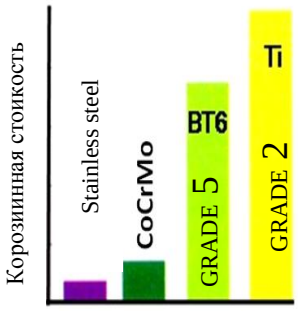

Рис.2. *Биологическая совместимость материалов*

Как видно из металлов и сплавов с биологической точки зрения лучшим для изготовления головки протеза технически чистый титан (GRADE 2) [1, 3, 4]. Однако основными его недостатками, препятствующими применению в практике эндопротезирования, являются низкие механические и трибологических характеристики. Это не позволяет использовать детали из технически чистого титана для изготовления компонентов пар трения без изменения рабочей поверхности, результатом которой должно быть оптимальное сочетание прочности и адгезионной инертности. На наш взгляд получить такое сочетание возможно использованием технологии термодиффузионного азотирования (ТДА) [5 и др.].

Перспективной альтернативой эволюционному развитию традиционного эндопротеза головки бедра G. Pezzotti с соавторами в своем обзоре нерешенных проблем и тенденций дальнейшего совершенствования искусственных суставов (2014) [6] считают принципиально другое технологическое решение – гибридные эндопротезы головок бедра с сердцевиной из металла и внешним слоем из оксидной керамики. Эта идея реализована например в продукте с коммерческим брендом Oxinium™ (Smith & Nephew, Memphis, US), в котором сочетается основа из металла (сплав Zr-2,5Nb) и прочный керамический слой (керамическая оксидная пленка m-ZrO2 толщиной 5-6 мкм на "буферной" обогащенной кислородом прослойке металла толщиной 3-5 мкм). Однако, как подчеркивает M.N. Rahaman с соавторами (2010) [7], оксидированный цирконий не может быть использован в соединениях с твердыми несущими поверхностями типа керамо-керамических (Al2O3-Al2O3) из-за появления повреждений, царапин и сколов керамического слоя. Этими же авторами проведено исследование двухслойного эндопротеза головки бедра (рис. 3), в котором внешний слой выполнен из плотной мелкозернистой керамики (Al2O3), в то время, как конусное отверстие для фиксации головки выполнено в ее металлической сердцевине из ниобия (Nb) (рис . 3 б) [2]. В качестве доказательства целесообразности такой конструкции, авторы ссылаются на прогнозную модель зон распределения максимальных контактных напряжений растяжения в

соединении с шейкой ножки эндопротеза, полученную методом конечных элементов C. Affolter с соавторами (2009) [8].

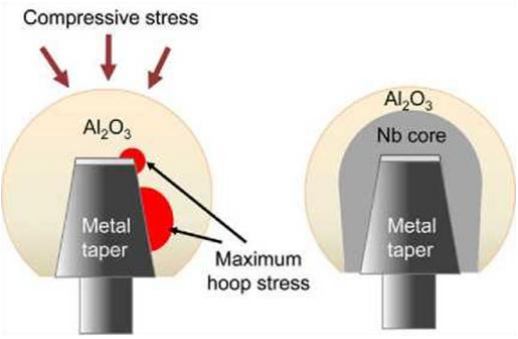

Рис. 3. *Схематическое изображение эндопротеза бедренной головки из керамики Al_2O_3 на металлической конусной шейке ножки искусственного сустава: а) сплошная керамическая головка, б) двухслойная головка (Al_2O_3 + Nb) [2].*

2. Методики

Выбор технологических режимов ТДА осуществляли по результатам триботехнических испытаний, которые проводили на машине торцевого трения по схеме плоскость-кольцо (рис. 3) [5].

Азотирования образцов проводилось в смеси газов азота и аргона. Как показывают рентгеноструктурные исследования, выполненные на приборе ДРОН-3Г, после азотирования в поверхностном слое идентифицируются три компонента: α-Ti, TiN и незначительное количество Ti2N [5].

Режимы триботехнических испытаний назначали соласно стандарта ASTM F732-82. Скорость скольжения металлического образца по контртело составляла V = 0,057 м / с, контактное давление q = 3,54 МПа. Шероховатость рабочей поверхности металлического образца составляла Ra 0,8 мкм, контртела с хирулен (ISO5834-2) - Ra 3 мкм. Триботехнические характеристики пары трения оценивались по 2-м параметрам - коэффициент трения и удельного интенсивности износа хируленового компонета - объем износа площадки 1 мм2, отнесен к пути трения (мм3 / км).

Для сравнения в тех же условиях испытывались также образцы из сплава CoCrMo (HV4,5 ГПа) производства ПО «Моторсич», керамики ZrO2 и из нержавеющей стали [10].

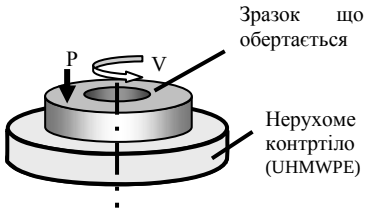

Рис.4. *Схема «Кольцо-пластинка»*

В качестве рабочей жидкости использовали лекарственное препарата «Артифлекс хондро» [9,10], что представляет собой 10% водный раствор хондроитин сульфата, который является важным структурным компонентом хрящевой ткани.

Результаты триботехнических испытаний (рис. 5) показали, что титановый сплав GRADE 2 (ВТ 1-0), модифицированный Термодиффузионное азотированием, может на одном уровне конкурировать с аналогами из керамики (например, ZrO2), а также в несколько раз превосходить металлические аналоги CoCrMo . Характерно, что после прохождения пути трения 200 км, что соответствует ~ 23 млн. Циклов нагрузки [11,], износ титанового компонента не обнаружено.

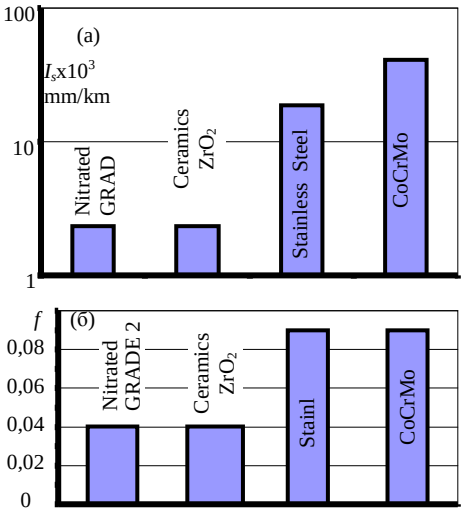

Рис. 5 *Коефициент трения в паре между азотированним титаном GRADE 2 (R15) и UHMWPE (а) и величина интенсивности износа компонента UHMWPE (б) при количестве циклов 3 часа работы машины*

При испытании пары "неазотований GRADE 2 / UHMWPE" наблюдалось практически мгновенное схватывание титана с хирулен и повышенное значение коэффициента трения.

Трибологические испытания керамических елементов проводили на установке Т-20 с трибосистемой типа "шар-по-диску " (рис. 6). Трибосистема состоит из неподвижного плоского диска из испытываемого материала и шара из материала контртела, вращающегося с заданной скоростью n. Диск прижимается к шару с определенной нагрузкой Р. При испытаниях измеряется сила трения, линейный износ диска. Температуру процесса не фиксировали, но поддерживали постоянной., Рабочую жидкость подавали капельным путем на поверхность вращающегося шара. (рис. 6).

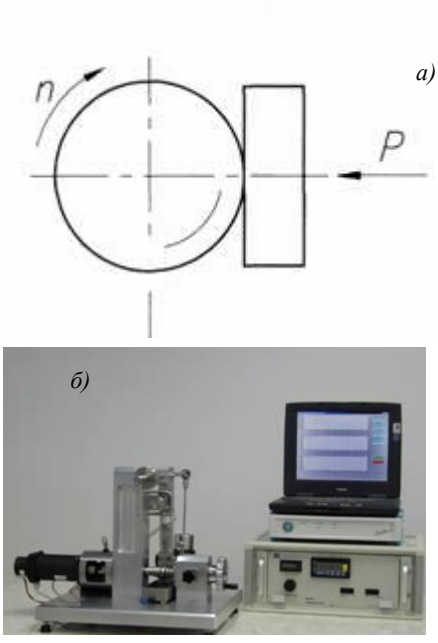

Рис. 6. *Схема вращательного трения а) и установка Т-20 (б).*

Результаты трибологических испытаний показаны на рис. 7-8 в виде графиков кривых отношения силы трения к силе прижима и линейного износа дисков из исследуемых материалов по ходу 3-х часов трения. На рис. 8 показаны фотографии пятен износа на поверх-ности диска из сапфира, тетрагонального диоксида циркония 3Y-TZP и (Y,Ce,Hf)-TZP.

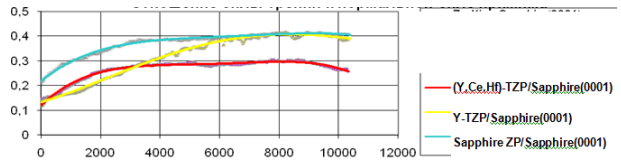

Fig. 7. *Експерименталные результаты сзмерения коефициента трения сапфира с разными материаламы в течении три часа работы машини*

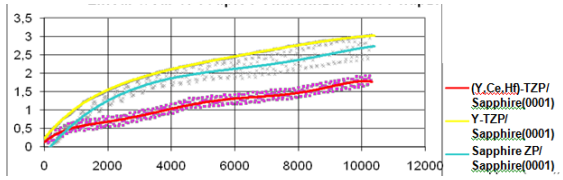

Fig. 8. *Результаты износа при трении сапфира с разными материалами в течении три часа работы машини*

3. Технология механической обработки сферического компонента тазобедренного сустава из титанового сплава GRADE 2.

Полученные результаты свидетельствуют о том, что GRADE 2, модифицированный ТДА, может быть успешно применен для изготовления деталей пар трения эндопротезов, поэтому разработка технологии их изготовления является актуальной задачей. Необходимо отметить, что до настоящего времени такая технология создана не была. Причиной тому является крайне неудовлетворительная обрабатываемость титана GRADE 2 абразивными методами. Технологический маршрут обработки сферических головок с GRADE 2 должен включать предыдущие операции прецизионной обработки, задачей которых является получение точности изделий, и финишные операции (полировки), задачей которых является получение шероховатости поверхности Ra 0,05 мкм, что соответствует ДСТУ ISO 7206-2- 2005 .

Практика изготовления керамических головок эндопротезов показала, что для получения требуемой точности изделия достаточно эффективной показала себя схема свободного притирки (рис. 9).

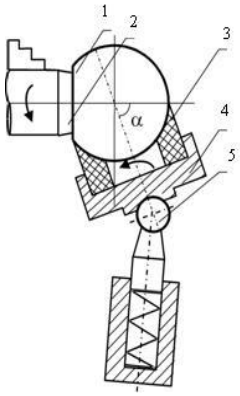

Рис. 9. *Схема профилного притирания*

Однако проблемой для обработки заготовок из чистого титана, остается отсутствие инструмента, обеспечивающего стабильное снятия припуска и получения поверхности изделия, соответствует требованиям к шероховатости. Попытки применить абразивные инструменты на традиционных связях приводили к схватывания в зоне взаимодействия инстумента заготовке и, как следствие, резкого увеличения шорскости.

Избежать перечисленных негативных явлений при обработке титана возможно применив абразивные композиты, связи которых способна к снижению модуля упругости при увеличении механической нагрузки на абразивные зерна. Необходимым свойством обладает связи на основе композита - епоксиакрилатнои смолы, наполненной порошком карбоната кальция. При ее применении группа наиболее выступающих зерен, не скалывая, может погружаться в связи на большую глубину. При оптимальном составе композита зазор между связкой и обрабатываемой поверхностью стабильный и достаточный для надежного предотвращения схватывания. Инструменты (притиры) на основе разработанного композита (рис. 10) испытаны при обработке сферических изделий из GRADE 2 в лабораторных условиях ИСМ НАН Украины.

На рис. 11 приведена зависимость интенсивности съема припуска с заготовки от силы прижима инструмента при разной его зернистости. Видно, что наиболее интенсивное снятия припуска обеспечивает инструмент зернистостью 200/160. Его задачей является устранение погрешностей формы заготовки после токарной обработки. Практика показала, что для получения дальнейшей полировкой шероховатости Ra 0,05, обусловленной техническими тебования, необходимо предварительной обработкой получить Ra 0,25 мкм. Для получения этого значения шероховатости достаточно 3-х переходов с применением инструмента с алмазами зернистостью 200/160, 63/50, 20/14 (рис.12). При этом отклонение формы изделия, изготовленного по разработанной технологии, не превышает 6 мкм, удовлетворяет стандарту.

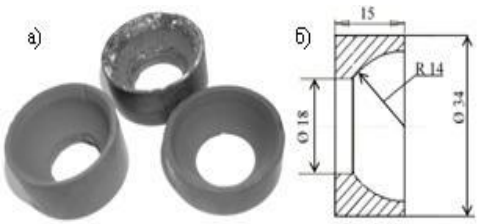

Рис. 10. *Притиры для обробки титановой заготовки:*
а) фото инструментов;
б) сечение инструмента

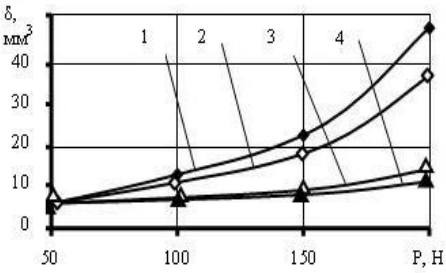

Рис. 11. *Зависимость интенсивности износа материала в зависимости от усилии прижима при разной зернистости алмазного порошка:*
1) 200/160; 2) 125/100; 3) 63/50; 4) 50/40

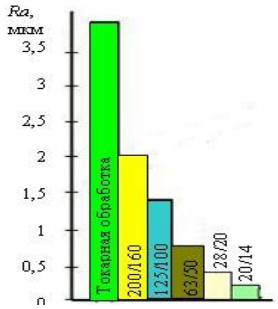

Рис. 12. *Величина шероховатости при разной зернистости алмазного инструмента*

Для полировки головок применена полировальная паста, разработанная в ИСМ НАН Украины. Паста имеет интенсивное механо-химическое воздействие на обрабатываемую поверхность. В ее основу введен активный комплексообразователь, способный избирательно извлекать атомы титана с оксидированных пленок на поверхности, поэтому обработка проходит без образования дефектов в низших слоях.

Использование полировальной пасты с оптимальным содержанием комплексообразующего агента позволила формировать полированной поверхности ВТ1-0 с наибольшей производительностью (вследствие большого содержания в ривноважений оксидной пленке). При этом шероховатость сложившейся поверхности минимального размера неоднородностей оксидной пленки.

Результаты замеров параметров шероховатости поверхности после полировки приведены в таблице 4.

Таблиця 4

S q	S sk	S ku	S ku	S ku	Sku	S ku	S ku	Sku
0.0725	0.0725	0.0725	0.0725	0.0725	0.0725	0.0725	0.0725	0.0725

Видно, что по шероховатости поверхности изделие также соответствует требованиям стандарта. На рис. 13 приведена фотография головок с GRADE 2, изготовленных по разработанной технологии в ИСМ НАН Украины.

Рис. 13. *Головки ендопротезов из титана ВТ 1-0*

4. Выводы:

1. По сопротивления истиранию, антифрикционным свойствам пара трения «Азотированный GRADE 2 / UHMWPE» существенно превосходит традиционную для практики эндопротезирования пару «CoCrMo / UHMWPE». Трения в паре «азотированная GRADE 2 / UHMWPE» ниже на 25%, износ - на 60%. После прохождения пути трения 200 км, что соответствует ~ 23 млн. Циклов нагрузки, износа титанового компонента не обнаружено. Это позволяет утверждать, что модификация поверхности титанового сплава ВТ 1-0 позволяет реально конкурировать с керамическими компонентами в паре трения с UHMWPE.

2. Искусственные композиты на основе модифицированных эпоксидных смол и синтетических алмазов, представляющие собой трехуровневые адаптивные системы и позволяют проводить обработку технически чистого титана по схеме свободного притирки без схватывания и шаржирования обрабатываемой поверхности, обеспечивая шероховатость до Ra 0,25 и точность до 0,008 мм (в соответствии с ГОСТ Р ИСО 7206-2-2005).

3. Применение разработанной в ИСМ НАН Украины полировочной пасты позволяет получить шероховатость рабочей поверхности головки с ВТ1-0 Ra 0,05 мкм, что соответствует ДСТУ ISO 7206-2-2005.

4. Трибологические характеристики тетрагонального диоксида циркония (Y,Ce,Hf)-TZP в паре с контртелом из сапфира существенно лучше характеристик пары сапфир/сапфир (сила трения ниже в 1,3 раза, линейный износ – в 1,5 раза).

Размер пятна износа в направлении трения на диске сапфира 0001 (800 мкм) меньше, чем у дисков тетрагонального диоксида циркония: (Y,Ce,Hf)-TZP – в 1,1 раза (900 мкм), 3Y-TZP – в 1,5 раза (1200 мкм).

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CONFORMAL COOLING CHANNELS IN INJECTION MOLDING TOOLS – DESIGN CONSIDERATIONS

Ognen Tuteski M.Sc., Atanas Kočov PhD, Jasmina Caloska PhD, Zoran Spiroski PhD

"Ss. Cyril and Methodius" University in Skopje, R. Macedonia - Faculty of Mechanical Engineering

ognen.tuteski@mf.edu.mk; atanas.kochov@mf.edu.mk;

Abstract: *This scientific paper presents the research conducted for defining the characteristics of the conformal cooling systems used in molds for injection molding processes (IMP). By utilizing laser-sintering additive manufacturing (AM) technologies, this type of cooling systems could be used to minimize the cooling and cycle times in the IMP's and provide a homogeneous cooling necessary to maintain a consistent quality of the part. The paper also presents an overview of the AM technologies used in manufacturing conformal cooling molds and the main guidelines for designing these cooling systems.*

The research shows that the efficiency of these channels is based on the channel system's design; and for plastic parts with a lower complexity the improved temperature distribution compared to conventional cooling systems could be negligent.

The research is conducted by using Finite Element Analysis (FEA) and CAD modeling to compare different conformal shapes, as well as their cooling efficiency on a plastic part. The simulation studies are done to determine the temperature distribution in each case study. These trials are done to assess the productivity benefits that arise from the use of conformal cooling channels compared to conventional channels that utilize baffles and bubblers.

KEYWORDS: INJECTION MOLDING, CONFORMAL COOLING, 3D PRINTING, RAPID TOOLING, LASER SINTERING

1. Introduction

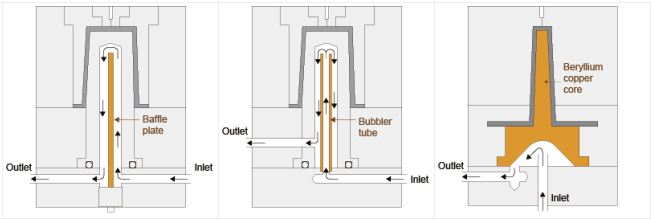
In thermoplastic injection molding, the mold performs three basic functions: forming molten material into the product shape, removing heat for solidification, and ejecting the solid part. Of the three, heat removal usually takes the longest time and has the greatest direct effect on cycle time. Despite this, mold cooling-channel design is often done after the feed system, mold mechanism, and ejection system designs are already finished. Consequently, many cooling designs must accommodate to the available space and machining convenience rather than the thermodynamic needs of the product and mold.

Cooling in cavity geometries is typically accomplished by drilling cooling channels around the part cavity. The need to drill these cooling lines and avoid the part ejector system limits the size and number of cooling circuits and their proximity to the molded part. Short and independent circuits yield the best temperature control performance. Parallel cooling circuits as opposed to series cooling circuits are considered a better cooling method. Short parallel circuits do not allow the coolant to heat up in the mold and offer more consistent and uniform temperature control.

Cooling of the core insert is the greatest problem in most injection molding applications. Often, no cooling is employed in the core itself. Cooling only occurs in the mold base through the core mount. With no core cooling, eventual heating of the core is unavoidable. Cooling of slender cores is often accomplished by using **inserts** made of materials with high thermal conductivity, such as copper, beryllium-copper or high-strength sintered copper-tungsten materials. When these inserts are press-fitted into steel tools, an additional heat transfer interface is created. When used in contact with the polymer melt, reductions in tool lifetime may be noted.

A baffle is a common cooling method in those cases in which the coolant is directly channeled through the core. A baffle uses a flat or spiral divider in a hole running through the center of the core. The inlet and return flow are separated. This method provides maximum cross sections for the coolant to flow through. The divider must be mounted exactly in the center of the hole to ensure that the coolant does not bypass the hole.

The most effective cooling of slender cores is achieved with **bubblers**. An inlet tube directs the coolant into a blind hole in the core. The diameters of both have to be adjusted in such a way that the resistance to flow in both cross sections is equal. Bubblers are commercially available and are usually screwed into the core. One problem with baffles and bubbler cooling systems is that the necessary hollow center can result in a structurally weak core insert [7].



a) baffles *b) bubblers* *c) metal inserts*

Fig.1.1 *Conventional cooling strategies for injection mold cores (Source: polyplastics.com)*

2. Rapid tooling technologies

Rapid Tooling involves all additive manufacturing procedures that lead to final parts used as cores, cavities, or inserts for tools, dies and molds. Two sub-levels must be distinguished: direct tooling and prototype tooling

The primary advantage of RP and RT is its ability to create almost any shape or geometric features, even those complex shapes that would be virtually impossible to machine. With additive fabrication, the machine reads in data from a CAD model and lays down successive layers of different materials, and builds up the physical model from a series of layers. Those layers are joined together or fused automatically to create the final shape matching the CAD model.

The possibility of direct-metal rapid tooling (RT) from high quality steel is not commonly used in the injection molding industry today. However, the RT industry is in an expansive phase and new applications are evolving continuously. RT technologies can be divided into different types and [10] Menges, G et al [10] suggest the following classification:

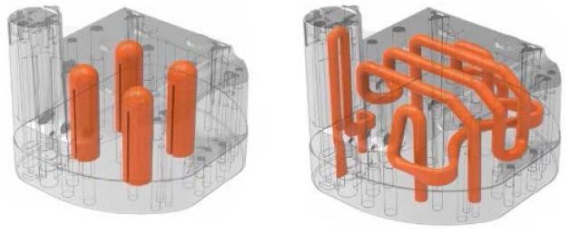
- conventional removal and coating processes;
- material additive processes;
- master mold processes; and
- hybrid processes

L-E. Rannar, lists some of the competitive methods in the RT market today [9]:

- 3D Keltool, by 3D systems.
- EBM, electron beam melting, by Arcam.
- DLF, direct laser forming by Trumpf.
- DMD, direct metal deposition, by the POM Group.
- DMLS, direct metal laser sintering, by EOS.
- LAM, laser additive manufacturing, by Aeromet.
- LaserCusing, by concept laser.
- Laser consolidation, by Accufusion.
- LENS, laser engineered net shaping, by Optomec.
- ProMetal, by ProMetal RCT.
- RSP, rapid solidification process, by RSP tooling.
- SLM, selective laser melting, by MCP Group.
- SLS, selective laser sintering, by 3D Systems.
- Solid phase laser sintering, by Phenix systems.
- Stratoconception by CIRTES.

3. Conformal cooling

Over the last decade, conformal cooling has been proposed as a solution for controlling injection molding temperatures. Mold inserts can be built with internal cooling channels that follow the contour of the cavity beneath the surface (Fig. 3.1, b). Because the form of the channels follows the contour of the mold, the method is called conformal cooling. Due to the increased heat extraction, the productivity of a plastic injection mold can be increased significantly. In addition, cooling and heating channels can be designed to obtain an integrated heat management system and thus much more effective tools. Improperly designed cooling systems often result in two undesirable outcomes. Firstly, cooling and cycle times are much longer than what could have been achieved. Secondly, significant temperature gradients arise across the mold, causing differential shrinkage and warpage of the moldings. To operate effectively, cooling systems must be carefully designed to manage the heat flow throughout the mold without incurring undue cost or complexity.



a) b)

Fig. 3.1 *Conventional cooling channel core with bufflers (a) vs. conformal cooling channel design (b) (Source: 3dsystems.com)*

In recent years, a lot of case studies have been done proving the effectiveness of cooling channels for parts with complex geometry. One of those studies featured by 3DSystems with is for a core with a tapered helix that is positioned on the inside of a spacing cone used for industrial assemblies (Fig 3.2).

Fig. 3.2 *A Bastech mold core insert with conformal cooling channels prototyped using 3D Systems' Stereolithography (SLA) technology and printed in maraging steel on the ProX® DMP 200. (Source: 3dsystems.com)*

The conformal cooling mold maintained a lower temperature throughout the run and reduced cycle time by 14%. This design can also be applied to molds made by materials other than metals, but as it stands now, metal based AM technologies are still the standard when it comes to designing conformal channels for larger production series molds.

3.1. Design for conformal cooling

In order to remove a molded part from the mold, the material must be sufficiently cooled to provide ejection without distortion. Adequate mold cooling can be considered to have occurred if the part surface is hard enough to prevent ejector pins from penetrating. Cooling-channel placement determines cooling efficiency and uniformity. Positioning the channels too close to the cavity surface can cause cold spots and uneven cooling. If they are too far away, cooling becomes more uniform but less efficient.

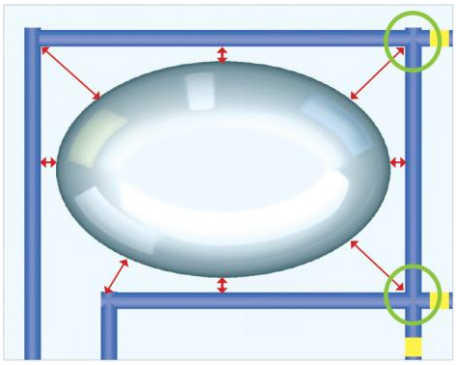


Fig. 3.3 *Conventional tooling mold temperature control. Uneven distances to the cavity surface throughout the length of the channels (Source: [5])*

As shown in Fig 3.3, uneven distances to the cavity surface leads to an uneven heat conductance. The areas with the threaded plugs limit the coolant flow (marked with green). These locations are susceptible to accumulation of dirt deposits which lead to pressure losses that result in a steady decline of the general flow in the cooling circuit.

The use of conformal cooling channels optimizes the molding process by providing a constant temperature gradient throughout the mold all the while increasing the total surface area of the cooling circuit. This also results in savings in manufacturing the inserts.

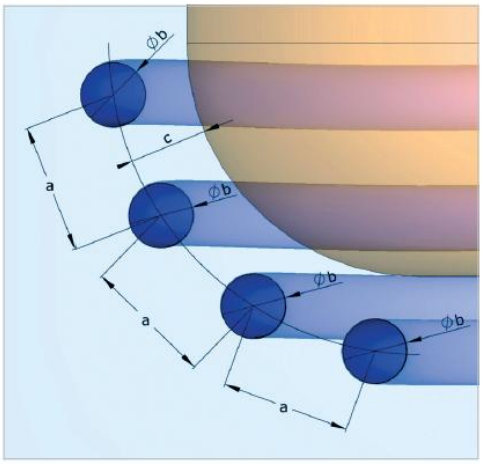


Fig. 3.4 *Optimal design of a conformal cooling channel system (Source: [6])*

The ultimate objective is the creation of a mold temperature control system, which enables a constant and adapted temperature level for the material, during the running injection molding process on each point of the molding surface. In order to achieve this result, the channel diameter should be chosen depending on the distance between the heating/cooling channel and the cavity. Provided that the design for the mold part is correct, the product can recrystallize

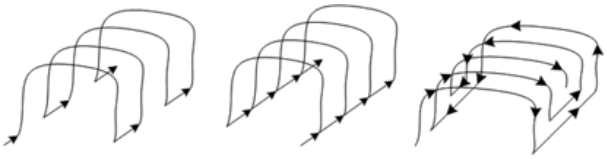
uniformly and efficiently in the mold after the injection phase, which improves the quality and reduces the cycle time.

Table 3.1: *Conformal cooling channel diameter based on the wall thickness (Source: [6])*

Wall thickness [mm]	**Hole diameter [mm] (b)**	**Centerline distance between holes [mm] (a)**	**Distance between the center of the holes and the cavity [mm] (c)**
0 ÷ 2	4 ÷ 8	(2÷3) · b	(1,5 ÷ 2) · b
2 ÷ 4	8 ÷ 12	(2÷3) · b	(1,5 ÷ 2) · b
4 ÷ 6	12 ÷ 14	(2÷3) · b	(1,5 ÷ 2) · b

The design guidelines used for conventional cooling circuits can also be applied to conformal cooling channels. Some of the recommended dimensions are given in the schematic in Fig 3.4 and the recommended hole diameters based on the average wall thickness of the plastic part are shown in table 3.1. Selective laser sintering techniques can build cooling channels down to a diameter of 1 mm, but such small channels can only be put into service using specific coolant fluids in order to avoid clogging.

According to Park and Pham [7], there are three basic techniques that can be used when designing conformal cooling channels: zigzag, parallel, and spiral. (Fig. 3.5).



a) zigzag type b) parallel type c) spiral type

Fig. 3.5 *Basic shapes used in designing conformal cooling channel systems (Source: [7])*

Depending on the geometry of the part, these methods may be used in combination or on their own. The zigzag pattern, also known as a series cooling path, cools regions of the part one after the other rather than at the same time. Cooling in series is generally not preferred unless parts are small enough that the delay is negligible. The parallel channel design allows for different areas of the mold to be cooled at the same time, but requires a lot more coolant. The spiral conformal cooling channel design is often used with parts that have curvature or spherical elements.

The general opinion is that when designing conformal cooling channels, it's always recommend to use an injection molding simulation software package in order to identify different temperature zones within a mold so that the conformal cooling channels can be separated and optimized within each region.

The freedom offered by additive manufacturing opens a lot more possibilities when it comes to optimizing the coolant flow in the cooling circuits. One of those possible optimizations is to change the cross section of the channels in order to improve the coolant flow. In a study done by Manat et. al. [5], the efficiency of a conformal cooling system is studied by using different cross sections. The cooling channels had a different number of fins as shown in Fig. 3.6.

In that study, the novel cooling channel design showed a decrease in total cooling time by up to 6.5 sec for channels with seven fins compared to the cooling channels with circular cross sections and the cooling efficiency in term of the heat flux increased by 22.6 %.

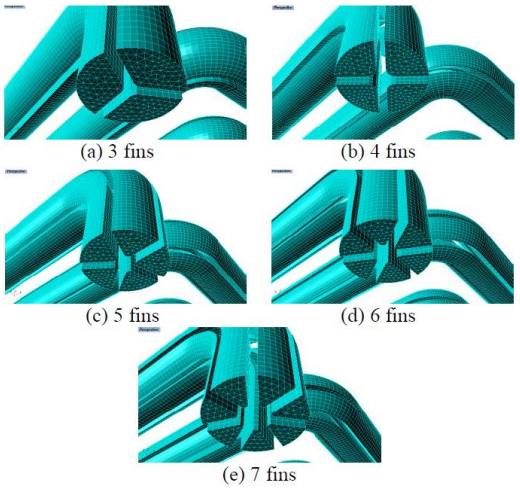


Fig. 3.6 *Conformal mold cooling by using fin concept (Source: [5])*

3.2. Case study of the viability using FE analysis

This study investigates the impact of the conformal cooling circuits on a plastic injection mold for parts with a simple shape. The analysis of the cooling efficiency is done by comparing 3 different circuit geometries, one conventional and 2 conformal channels that correspond to the spiral and linear type mentioned in [7] (Fig.3.5). All of the shapes are shown in table 3.3**.** Every channel has a circular cross-section with a diameter of 8 mm that corresponds to the recommendation found in table 3.1 for a wall thickness of 4 mm. The injection molding software used for the simulation was Solidworks Plastics. The simulation was done using a virtual mold to account for a more accurate heat transfer. All of the relevant information concerning the part and mold properties, as well as the process parameters are given in table 3.2.

Table 3.2 *Material properties and process parameters*

Part properties	
Material	PA66+30% Glass fiber
Dimensions	Ø 39 x 164 mm
Volume	84,15 cm^3
Weight	115,73 g
Thermal conductivity (polymer)	0.27 W/(m-K)
Specific heat (polymer)	$2.2 \cdot 10^7$ erg/(g-C)
Virtual mold properties	
Mold material	Steel – 420SS
Density	7,73 g/cm^3
Thermal conductivity	$2,5 \cdot 10^6$ erg/(sec-cm-K)
Specific heat	$4,62 \cdot 10^6$ erg/(g-C)
Process parameters	
Fill time	10 sec
Pressure holding time	12.59 sec
Mold open time	5 sec
Injection pressure limit	100 MPa
Max. injection flow rate	194 cc/s
Average Coolant Flow Rate	150 cc/s
Melt temperature	295 °C
Mold temperature	60 °C
Ejection temperature	220 °C
Glass transition temperature	235 °C
Coolant temperature	25 °C
Ambient temperature	30 °C

Table 3.3: *Material properties and process parameters*

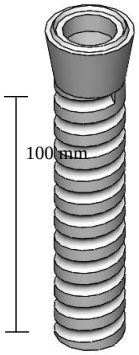
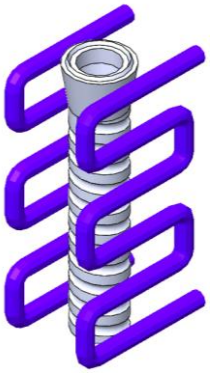
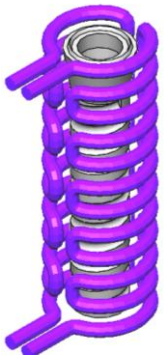
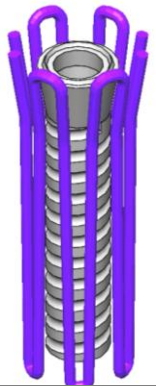
Conventional cooling circuit	Conformal cooling – Spiral type	Conformal cooling – Linear type
			

Table 3.4: *Summary results*

	Conventional cooling circuit	Conformal cooling Spiral type	Conformal cooling Linear type
Total cycle time	71.09 sec	70.44 sec	70.09 sec
Pure cooling time	46.95 sec	46.00 sec	45.65 sec
Averaged part temperature	161.63 °C	163.00 °C	162.50 °C
Averaged mold cavity temperature	44.42 °C	40.45 °C	40.40 °C
Averaged mold cavity heat flux	2.33 J/cm2-sec	2.40 J/cm2-sec	2.38 J/cm2-sec
Averaged cool channel heat flux	1.71 J/cm2-sec	1.16 J/cm2-sec	1.46 J/cm2-sec

4. Conclusion

Rapid tooling has numerous advantages and applications and few of them have been covered in this paper. The use of CAD technologies allows the use of modular dies and specially fabricated inserts. It reduces the high cost of skilled laborers and die makers and significantly improves lead times. Still there are some challenges to overcome when moving forward. The main shortcoming of rapid tooling is the potentially reduced tool life compared to conventional tools. The parts produced by RT still need to be machined, as in most cases the initial surface finish is not good enough. Currently, metal based AM processes are the only viable technologies for large series of injection moldings, mainly because of conformal cooling circuits. Conformal cooling designed for plastic injection molding is a valuable alternative in improving the plastic part quality and in reducing cycle times and energy consumption. However, due to the high manufacturing costs linked to addictive manufacturing techniques, its application is still in its infancy.

This paper presented two conformal designs and compared them to conventional cooling channels. Even though the temperature distribution throughout the part improved, the reduction in the cycle time was not significant. We suspect that the reason behind this is the low degree of complexity of the tested model. Previous research showed that conformal cooling tends to be valuable when the product has deeper regions from which linear cooling channels are unable to achieve a significant heat transfer due to low accessibility. In these cases, as previous research showed, the cycle times are reduced by up to 20% when using conformal cooling channels.

Conformal cooling, however, adds new layers of design and production complexity to the mold making process, placing it beyond the means of most shops. The investment in AM machines is not always justified, especially when manufacturing simpler injection molded parts. In those cases, the use of conformal cooling is not needed and conventional channels manufactured with drilling can be used to get similar results. In some cases RT is still slower than traditional manufacturing due to its incomplete integration and the number of available materials that can be used is limited.

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INFLUENCE OF CARBON NANOTUBES AND GRAPHENE ON THERMAL AND ELECTROMAGNETIC PROPERTIES OF PLA NANOCOMPOSITES

Assist. Prof. Angelova P.[1*], Prof. D.Sc. Dr. Kotsilkova R.[1], Prof. Dr. Kuzhir P.[2]

[1] Institute of Mechanics (OLEM), Bulgarian Academy of Sciences, Bulgaria
[2] Institute for Nuclear Problems, Belarusian State University, Belarus
polq_s_angelova90@abv.bg

Abstract: *This work investigate electromagnetic and thermal properties of poly(lactic) acid-based composites with graphene nanoplates (GNP) and multiwalled carbon nanotubes (MWCNTs), produced by solution blending method. It was found that the MWCNT carbon nanotubes are an effective filler for both absorption and reflection of electromagnetic waves in the GHz and THz frequency domains. The higher aspect ratio of carbon nanotubes, compared to industrial MWCNT, is the cause of better electromagnetic characteristics of nanocomposites prepared by solution blending method (SB). The DSC analysis of the samples shows that the glass transition is around 60^oC, followed by cold crystallization with enthalpy and melting temperature around 150^oC. The TGA analysis show, that the thermal stability of PLA polymer is improved by addition of 6% MWCNTs and GNP.*

KEYWORDS*: BIODEGRADABLE POLY(LACTIC ACID) NANOCOMPOSITES, GRAPHENE, CARBON NANOTUBES, ELECTROMAGNETIC PROPERTIES, THERMAL STABILITY*

1. Introduction

Poly (lactic acid) (PLA) is a plant-derived biodegradable polymer, which can be obtained from natural source such as corn starch and may be a sustainable alternative to petrochemical-derived polymers [1]. As a thermoplastic and aliphatic polyester, PLA has been used to produce beverage packages, biomedical supplies, food wares, vehicle interiors, films, and fibers [2,3]. Unfortunately, some significant disadvantages of PLA such as relatively poor mechanical properties, slow crystallization rate, and low thermal stability hinder its applications for more demanding requirements [4,5].

Carbon-based fillers such as carbon nanotubes (CNTs), nanofibers (CNFs) and graphene possess excellent electrical conductivity together notable mechanical and thermal properties [6,7,8]. When such nanoparticles are introduced in host polymeric matrices, the interesting properties of these latter (like easy processability and shaping possibilities, resistance to corrosion, flame, moisture, etc.), are enhanced giving rise to nanocomposites that recently have gained great attention from both academicians and industries. In fact, these innovative composites can leverage many of combined properties leading to develop new materials for several applications ranging from aeronautic, automotive, plastics, semiconductor and electronic industrial sectors [9,10].

In the present work we investigate binary and ternary composites based on PLA with graphene nanoplatelets and multiwall carbon nanotubes, produced by solution blending techniques. The electromagnetic interference (EMI) shielding effectiveness are determined by material absorptivity, surface reflectivity, and multiple internal reflections. Polymer films incorporating graphene and other nanocarbon fillers were recently studied as a light coating material to protect micro- and nano-devices in a harsh electromagnetic environment, due to the promising electromagnetic shielding efficiency of the carbon nanostructures [11,12]. The electromagnetic shielding of a composite material with carbon nanofillers, such as graphene nanoplatelets and carbon nanotubes, are studied mainly depend on the filler's intrinsic conductivity, dielectric constant and aspect ratio [13]. Thermal analysis are used to determinate thermal stability and degradation of the polymer and nanocomposites.

2. Materials and methods:

The poly(lactic) acid polymer (PLA) Ingeo 700 1D was used for the solution blending samples. Graphene nanoplates (GNP) and multiwall carbon nanotubes (MWCNT) produced by Times Nano, China were used for preparation of nanocomposites. The PLA types and different grades of GNP and MWCNTs are shown in Table 1.

Table 1. Typical properties of row materials used in this study

CNTs	GNPs
OD: >50nm	Layers <20
Length 1-5μm	Size D(0.5)=5-10μm
Purity: >95%	Purity > 99.5wt%

2.2. Methods of preparation of solution blending:

The TNGNP and MWCNTs were supplied from Times Nano, China. Ten types of compositions, combining different proportions of TNGNPs and MWCNTs were produced at maximum 6 wt% filler contents. The compositions were produced in laboratory OLEM, Bulgaria, Sofia.

Procedure for nanocomposite preparation: The PLA700 1D was dissolved in chloroform in ratio 1:3. Suspensions of graphene (TNGNP) and MWCNTs were prepared in 200 ml. chloroform by ultrasonic mixing and added to the dissolved PLA. The final mixture was mechanically stirred for 60 minutes and dried in a vacuum oven for 24 hours at 70 ^oC. Compositions with 1.5%, 3% and 6 wt% of TNGNP, and MWCNT and their combinations, in PLA were prepared by this solution blending technique.

2.3 Methods for characterization:

2.3.1 THz frequency range:

THz measurements were carried out using a commercial THz time-domain spectrometer shown on Fig. 1 [1]. A 1050±40 nm wavelength pumping laser having 50–150 fs pulse duration and more than 40 mW output power at approximately 80 MHz pulse repetition rate was used to excite a photoconductor antenna and produced THz radiation up to 2 THz. The layout of the system is shown on Fig. 1(b). The spectrometer, THz emitter and detector consists of a micro strip antenna integrated with a photoconductor (low temperature grown GaBiAs) and silicon lens. The THz detector output is proportional to the instant electrical field strength of the THz pulse during the ultrashort pumping pulse. The Fourier transformation of waveform of electrical field of THz radiation gives the spectral content (E(x)) of THz radiation.

2.3.2 GHz frequency range:

The microwave measurements were provided by a scalar network analyzer R2-408R [fig.2] at room temperature and normal pressure. The scalar network analyzer is designed for measurement of the transmission factor and reflection factor module Voltage Standing Wave Ratio (VSWR) of waveguide devices and components in frequency range from 25.96 GHz to 37.5 GHz.

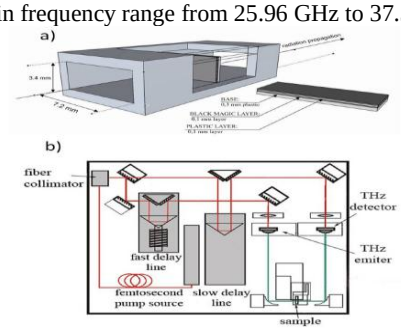

Fig. 1 The equipment for THz frequency range measurement

The frequency sweep bandwidth range can vary from the full frequency range of the instrument to 1500 MHz. Basic error limit of the frequency setting does not exceed ±0.2% in normal conditions. The frequency stability of the oscillator was controlled by a frequency meter and was as high as 10^{-6}. The power stabilization was maintained in the level of 7.0 mW ± 10 μW. EM attenuation was measured in the 0 db to -40 db.

The scalar network analyzer ELMIKA R2-408R

Fig.2 *The equipment for GHz frequency range measurement*

2.3.3 Differential scanning calorimetry (DSC Q20):

For the thermal properties measurements, a differential scanning calorimeter, DSC Q20, bought from the American company TA Instruments, shown in Figure 3, was used.

Technical characteristics of DSC Q20 (TA Instruments)
Temperature range - from room temperature to 725 ° C
Temperature Accuracy +/- 0.1°C
Temperature precision +/- 0.05°C
The experiments are carried out in an air atmosphere or in nitrogen.

The conditions under which the current DSC test was carried out were: a temperature range of 20 to 200 °C in a nitrogen atmosphere with a heating step of 20 ° C / min.

(a) (b)

Figure 3 a) DSC Q20 (TA Instruments), b) pan

2.3.4 Thermogravimetric analysis (TGA 50):

For the thermal properties measurements, a differential scanning calorimeter, TGA Q50, bought from the American company TA Instruments, shown in Figure 4, was used.

Technical characteristics of the TGA Q50 (TA Instruments):
Temperature range - from room temperature to 1000°C
Maximum sample weight - 1g
Weight precision - +/- 0.01%
Experiments are conducted in an air or nitrogen atmosphere.

The conditions under which the current TGA test was carried out are: heating the sample from 20 to 500 °C under nitrogen, with a heating step of 20 ° C / min.

3. Results and Discussion:

3.1 Electromagnetic properies in THz frequency range:

Table 2 show that for ternary nanocomposites containing MWCNT and GNP show the highest electromagnetic shielding efficiency (EMI) of 97-100%. Due to high reflection of 53% and a very high absorption value of 47% the trinary composite 4.5%GNP/1.5%MWCNT achieves the highest EMI of 100%. The pure PLA matrix has the smallest value of EMI shielding due to a high transmission. It is obvious that in ternary composites, the reflection and absorption decrease with decreasing of amount of MWCNT (Fig.4). For the binary composites, the graphene composite (6wt% GNP/PLA) achieve the highest 96% EMI shielding, due to high reflection (52%) and high absorption (44%) and transmission only 4%. The 6% MWCNT/GNP has the lowest value EMI of 62% in THz range.

Table 2: *The results for THz frequency, solution blending for reflection-transmission-absorption (R-T-A) in range 0.2 – 0.6 THz*

No.	Content of filler [wt%]	Thickness [mm]	R-mid	T-mid	A-mid 1-R-T	EMI [%]
1	PLA	1.07	0.30	0.79	0	30
2	6% GNP/PLA	0.84	0.52	0.04	0.44	96
3	6%MWCNT/PLA	0.89	0.32	0.38	0.30	62
4	1.5%GNP/4.5% WCNT/PLA	0.97	0.48	0.03	0.49	97
5	3%GNP/3% MWCNT/PLA	0.76	0.55	0.02	0.43	98
6	4.5%GNP/1.5% MWCNT/PLA	0.97	0.53	0	0.47	100

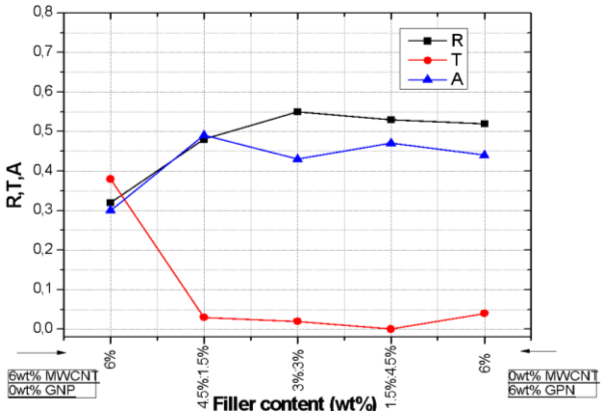

Fig. 4 *The comparison of electromagnetic response (reflection/transmission/absorption coefficients) at 0.3 THz of 1-mm thick samples with different MWCNT- and GNP-content*

3.2. Electromagnetic properies in GHz frequency range:

Table 3 and Figure 5 present the electromagnetic properties of the 6wt% binary and ternary nanocomposites in the GHz wave range.

Table 3: The results for 32.5 GHz frequency, solution blending for reflection-transmission-absorption (R-T-A)

No	Content of filler, [wt%]	Thickness [mm]	R	T	A-mid	EMI [%]
1	PLA	1	0.25	0.75	0.003	25
2	6% GNP/PLA	1	0.47	0.15	0.38	85
3	6% MWCNT/PLA	0.93	0.44	0.40	0.16	60
4	1.5%GNP/4.5%MWCNT/ PLA	0.96	0.67	0.19	0.14	81
5	3%GNP/3% MWCNT/ PLA	0.99	0.41	0.28	0.31	72
6	4.5%GNP/1.5%MWCNT/ PLA	0.94	0.50	0.09	0.41	91

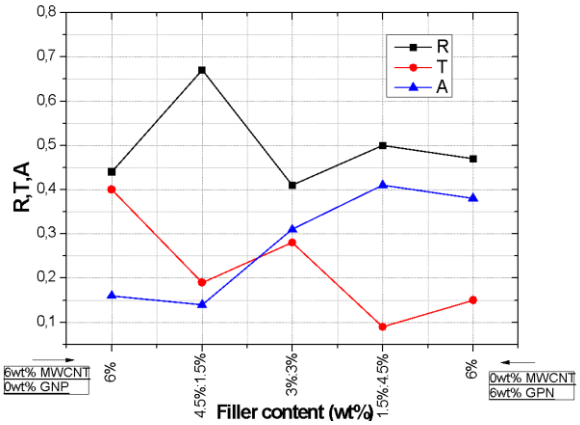

Figure 5 *Comparison of reflection/transmission/absorption coefficients of 1-mm thick composite at 32.5 GHz with different mixtures of MWCNT and GNP.*

In the GHz frequency range, the graphene composites (6wt% GNP/PLA) achieve higher EMI shielding (85%), compared to that of the binary composite 6wt% MWCNT/PLA (60%). In the ternary nanocomposites, both absorption and reflection are higher than those of binary composites, which speaks for synergy in the properties generated by the combination of the two carbon nanoparticles. The highest EMI shielding (91%) in the GHz zone is observed for bi-filler composites with a combined content of filler of 4.5wt% GNP / 1.5wt% MWCNT / PLA, where high absorption (41%) and high reflection (50%) are achieved (Table 3).

3.3. DSC Analysis:

This study was helpful to understand a shelf-life of the samples during storage in room conditions, related with the PLA degradation due to the exposure to humidity and UV light. First step was to measure fresh samples and after that we measured the same samples after 18 months storage in room conditions. The Table 4 summarize the DSC determined specific temperatures for glass transition (Tg), cold crystallization (Tcc) and melting (Tm), as well as the enthalpies of crystallization and melting (ΔHcc and ΔHm). Figure 6 compares the DSC thermodiagrames from the first run of fresh samples and samples after 18 months storage in room conditions.

Table 4 *Results from DSC analysis for two type samples – fresh samples and after 18 months storage samples.*

Name of the fresh samples	**DSC result of the fresh samples**					
	Tg, °C	**Tcc, °C**	**Tm, °C**	**ΔHcc, J/g**	**ΔHm, J/g**	**χc, %**
PLA	50.0	104.3	144.4	13.5	17.3	4.1
6% GNP/PLA	54.1	119.3	147.0	12.6	13.2	0.7
6% MWCNT/PLA	49.8	105.3	144.8	10.2	15.3	5.8
3%GNP/3% MWCNT/PLA	52.4	117.3	145.8	6.2	12.1	6.7
1.5%GNP/4.5% MWCNT/PLA	53.1	110.2	146.2	7.6	14.0	7.3
4.5%GNP/1.5% MWCNT/PLA	52.0	113.2	145.7	8.6	13.5	5.6
Name of the storage samples	**DSC results of the 18m storage**					
	Tg, °C	**Tcc, °C**	**Tm, °C**	**ΔHcc, J/g**	**ΔHm, J/g**	**χc, %**
PLA	62.6	119.4	148.5	5.8	9.1	3.5
6% GNP/PLA	62.3	-	148.1	-	2.8	3.3
6% MWCNT/PLA	61.3	127.3	146.5	0.6	2.6	2.4
3%GNP/3% MWCNT/PLA	63.7	123.5	148.7	1.8	5.0	3.7
1.5%GNP/4.5% MWCNT/PLA	61.7	125.3	146.8	0.8	3.5	3.1
4.5%GNP/1.5% MWCNT/PLA	63.9	119.8	150.2	4.5	11.0	7.4

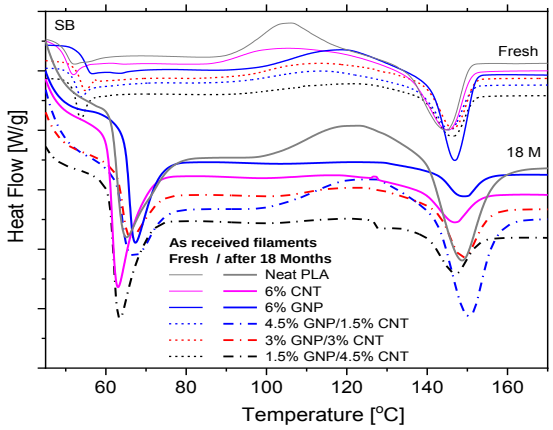

Fig. 6 *Comparison of DSC curves between binary (GNP/PLA, MWCNT/PLA) and ternary (GNP/MWCNT/PLA) composites investigated as fresh samples and after 18 months storage*

From DSC analysis (Table 4) for the both type of samples (fresh and after 18 months) the binary composites of 6% GNP show higher temperatures of crystallization and melting compared with the same amount of MWCNT. Cold crystallization peak increase with (15°C) for fresh samples and (8°C) for samples after 18 months, if compare with pure PLA (104°C) and (119.4), respectively. For ternary composites 1.5% GNP/4.5% MWCNT from fresh samples has the biggest % of crystallinity which is comparable with 4.5%GNP/1.5%MWCNT from samples after 18 months storage. The peaks of cold crystallization and melting are shifted on the right side due to the higher temperature for samples after 18 months storage. Generally, glass transition temperature has increased with ~ 9 °C for samples after 18 months storage. The binary composite with 6wt% GNP has the higher temperature of glass transition for both type of samples (fresh and after 18 months storage) which is indicated that this temperature doesn't change with the time and storage of the samples. For ternary composites it is obvious that with decreasing filler content of MWCNT Tg is increased (for fresh samples) and decreased for samples investigate after 18 months (table 4). The crystallinity also decreases – for fresh samples it is around 4% for near PLA matrix and 6-7% for the nanocomposites after 18 months storage due to some nucleation effect of nanofillers on PLA, resulting in α′–α phase transition. Almost twice decrease of the % crystallinity (to 2-3%) is observed in the aged filaments if compared with the fresh prepared one.

From those result it can be concluded that thermal characteristics, like of glass transition, crystallization and melting were enhanced for these samples after 18 months storage (Fig. 6). The % crystallinity is slightly decreased for some compositions confirming very slight effect of PLA degradation at room storage conditions.

3.4 TGA Analysis:

The TGA analysis was used to determine the thermal stability and degradation of the PLA-based binary and ternary composites with GNP and MWCNTs. Results are presented in Fig. 7 and Table 5.

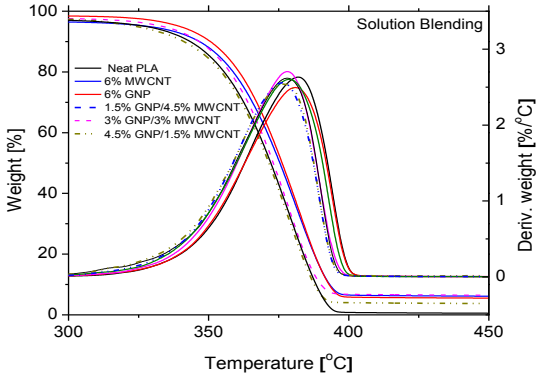

Fig.7 *TGA curve weight vs temperature for nanocomposites with maximum of 6wt% nanofiller (GNP, MWCNT and mixed)*

Table 5 *The values of T_{onset} , $T_{10\%}$, peak of degradation, mass loss at 105°C, and residue ash at 490°C for binary (GNP/PLA, MWCNT/PLA) and ternary (GNP/MWCNT/PLA) composite prepared by solution blending method.*

Name	T_{onset} [°C]	$T_{10\%}$ [°C]	Peak of degr. T_p °C]	Mass of loss at 105°C [%]	Residue ash at 490 °C, [%]
PLA	304.5	343.0	378.6	0.3	0.5
6%GNP/ PLA	314.3	350.3	382.3	0.2	5.4
6%MWCNT/ PLA	311.4	346.5	380.6	0.3	6.0
1.5 %GNP/ 4.5%MWCNT	313.0	344.3	378.9	0.4	4.7
1.5%GNP/ 4.5% MWCNT/ PLA dried	310.5	342.4	376.2	0.3	6.1
3%GNP/ 3%MWCNT/PLA	308.3	346.5	378.3	0.3	6.3
4.5%GNP/ 1.5%MWCNT/PLA	289.5	340.8	361.1	0.3	2.6
4.5%GNP/ 1.5%MWCNT/ PLA dried	289.5	340.2	376.9	0.3	3.0

TGA analysis (fig. 2b) show that the binary nanocomposite with graphene, 6% GNP/PLA has the highest values for the three measured temperatures: Tonset (314°C), T10% (350° C) and Tp (382°C). Mass loss at 105°C is lowest for this composite (0.2wt%), which indicates that graphene nanoplates are as barriers for heating. Binary composite with 6% MWCNT/PLA has only 3-4°C lower thermal stability than the composite with 6% GNP. The thermal stability of ternary nanocomposites is slightly lower than that of binary systems. The T_{onset} (initial degradation) also increases with 4°C from pure PLA to 4.5%GNP/1.5wt%MWCNT. Residue ash increases with 7% from pure PLA to 3wt%GNP/3wt%MWCNT. Two nanocomposites were additional dried. For ternary nanocomposites with 4.5% GNP/1.5% MWCNT shows that thermal stability is improved with 16°C and shifted on the right side due to higher temperature compared to the same sample that is not dried (table 5). The other nanocomposite 1.5% GNP/4.5% MWCNT shows that the additional dried sample has lower values (2-3°C) for all characteristics compared with not dried sample.

4. Conclusion:

The binary and ternary composites based on PLA filled with 6 wt% GNP and MWCNTs prepared by solution blending are studied here with. Good electromagnetic and thermal properties are obtained as varying the filler ratios.

The graphene nanoplatelets (GNP) in PLA composites are a more efficient EMI absorbing filler than MWCNT in both GHz and THz frequency ranges for the 6wt% filled binary nanocomposites produced by solution blending technique.

For binary composites with 6 wt.% GNP, about 85% EMI shielding is achieved due to a high reflection of 47% but also a relatively high absorption of 38%. These composites show different behavior at reflection / transmission/ absorption rates compared to carbon nanotubes. As the content of the filler increases, the transmission gradually decreases, reaching the lowest value of 15% at 6%GNP when filling the system up to the maximum.

In ternary nanocomposites - absorption and reflection are higher than those of binary, which speaks for synergy in the properties produced by the combination of the two carbon nanoparticles. The highest level of EMI shielding (91%) in GHz is observed in combined ternary compositions with 4.5%GNP/1.5% MWCNT, where high absorption (41%) and high reflection (50%) are achieved.

The fresh produced filaments were compared with the aged filaments after 18 months storage in room conditions. A nucleation effect of graphene and carbon nanotubes on the crystal structure of PLA was observed. Our findings confirm that the % crystallinity of the fresh extruded filaments is about 4% for the neat PLA and 6-7% for the nanocomposites due to some nucleation effect of nanofillers on PLA, resulting in recrystallization, producing α′–α phase transition. Almost twice decrease of the % crystallinity (to 2-3%) is observed in the aged filaments if compared with the fresh prepared one. The effects was associated with structural changes in the PLA biopolymer due to the long-term exposure to humidity, UV light and temperature, typical for room storage environment. Different nucleation effects are observed for both GNP and MWCNT fillers.

The nanocomposite content 6% GNP has the lowest (0.2%) mass of loss at 105°C. This show that graphene nanoplatelets are well dispersed and they are a barrier for heat distribution and exposure to humidity into the nanocomposite. The binary nanocomposite with 6% MWCNT has a lower thermal stability (3-4°C) compare with 6% GNP. The lowest thermal stability has a ternary nanocomposite 4.5% GNP/1.5% MWCNT (17°C compare with pure PLA). In general thermal stability decreases with the decreasing the MWCNT content for the ternary nanocomposites, possibly as a results of a bad dispersion of the fillers.

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INVESTIGATION OF RHEOLOGICAL AND SURFACE PROPERTIES OF POLY(LACTIC)ACID POLYMER / CARBON NANOFILLER NANOCOMPOSITES AND THEIR FUTURE APPLICATIONS

PhD student Ivanova R.[1*], Prof. D.Sc. Kotsilkova R.[1]

[1] Institute of Mechanics (OLEM), Bulgarian Academy of Sciences, Bulgaria
shtastie.ivanova@gmail.com

Abstract. *The recent subject of great research challenge and one of the most active area of research for well in materials science include the development of nanofiller reinforced polymer materials for additive manufacturing application. The dispersion of nanofiller in polymer matrix is a critical issue not only for control of processing but also for pre-defined properties. Quantitative analysis of extent of dispersion of nanofiller by measuring the rheological and surface characteristics of polymer nanocomposites has great technical importance for improving processing conditions, as well as for understanding the fundamental characteristics of materials at the nanoscale. The incorporation of nanofiller graphene into polymers is a promising approach to impart certain electrical and magnetic properties, mechanical reinforcement and high thermal conductivity to the resulting material. Rheological and surface properties of the poly(lactic) acid (PLA) based nanocomposites incorporating 0-9 wt.%. graphene nanoplates (GNPs) were investigated in the present work and a new strategy to tune such properties of PLA matrix by varying filler content is proposed.*

KEYWORDS*: RHEOLOGY, SURFACE PROPERTIESE, DISPERSION, NANOFILLERS, CARBON NANOTUBES, GRAPHENE, POLY(LACTIC)ACID POLYMER.*

1. Introduction

Due to significant features, carbon nanofillers have gained particular attention as polymer reinforcement [1]. Incorporation of carbon nanomaterial in polymer matrix has led to the production of versatile composites with improved mechanical and electrical properties. Polymer/carbon nanofiller nanocomposites have been used in range of technical applications such as sensors, solar cell, electromagnetic interference (EMI) shielding materials, etc. Since the discovery two decades ago, graphene family has drawn remarkable attention because of their unique electrical, thermal, optical, mechanical and flammable properties. They have been widely used to improve polymer properties. These nanofillers produce huge interfacial areas between the polymer and the fillers. Despite the intensive research on graphene nanocomposites, understanding ~~of~~ the importance of the filler-polymer interface is still limited and further investigation of the structure-property relationships is needed. Graphene, a monolayer of sp2-hybridized carbon atoms arranged in a two-dimensional lattice, has attracted tremendous attention in recent years owing to its exceptional thermal, mechanical, and electrical properties [1-3]. It is known to all that the properties of composites depend not only on the strength of the interfaces between nanofillers and matrix but also the dispersion status of nanofillers. High specific surface area and wrinkled surface morphology of nanofillers would lead to a reinforced interface. However, the relationship between dispersion status and enhancement effect of nanofillers was seldom discussed systematically due to the difficulties in its quantitative characterization.

In the present work, we report on rheological and surface properties characterization of *Poly* (*lactic acid*) (PLA)-based nanocomposites incorporating graphene nanoplatelets (GNP) with varying filler ratios. The GNP/PLA composite films were investigated by Rheology, Zeta potential and Contact angle measurements. The effect of filler types and filler loading on rheological and surface properties of composite films were studied by investigate the rheological behavior in oscillatory and steady shear flow, and measuring isoelectric point, contact angle and calculate surface free energy of composites films. The aim of the study is to clarify the degree of dispersion of monofiller, GNP at various fillers ratio in PLA matrix, as well as to understand better the interfacial filler-polymer interactions. In this study we present a new strategy to tune the rheological and surface properties of PLA matrix by varying the GNP filler contents.

2. Materials and methods

2.1. Materials

The poly(lactic) acid (PLA) polymer used in this study was Ingeo™ Biopolymer PLA-3D850 (Nature Works) with MFR 7-9 g/10 min (210°C, 2.16kg), peak melt temperature ~180 ºC, glass transition temperature ~ 60 °C, tensile elongation 3.1%. Ingeo™ 3D850 is a grade developed for manufacturing 3D printer filament having some remarkable 3D printing characteristics such as precise detail, good adhesion to build plates, less warping or ruling, and low odor.
The Graphene Nanoplates (GNPs) adopted as nanofillers were supplied from Times Nano, China, having commercial code (TNGNP) [4]. The specific features of the used carbon nanofiller IS collected in Table 1.

Table 1. *Characteristics of GNPs used in PLA nanocomposites*

Property	**GNPs (TNGNP)**
Purity, wt.%	>99,5
Number of layers / Thickness, nm	<20 / 4-20
Diameter/medium size, μm	5-10
Length, μm	-
Outer diameter, nm	-
Aspect ratio	~250
Transition Metal oxide, %	-
Surface area, m^2/g	-

2.2. Methods of preparation of melt extrusion

Nanocomposites were prepared by melt extrusion at 170 – 180 ^oC, using a tween screw extruder (COLLIN Teach-Line ZK25T) at screw speed 40 rpm. Monofiller (GNP/ PLA) composites, as varying the filler content from 1.5 to 9 wt.% were produced.

2.3. Methods for characterization

2.3.1. Rheological measurements

The rheological measurements were carried out with AR-G2 Rheometer (TA Instruments) using electrical-heated parallel plate geometry (25 mm diameter) and gap size of 500 μm between plates. The test samples for rheological analysis were prepared by pressing of the nanocomposite filaments produced by melt extrusion, at 1 ton and temperature of 200°C to discs with diameter of 25 mm and thickness of 1.5 mm.

Fig.1. *Rheometer AR-G2*

The viscoelastic flow properties were measured using low amplitude oscillatory flow mode, at a temperature of 200°C. The complex dynamic viscosity η*, storage modulus G', and loss modulus G"were measured versus the angular frequency ω of 1 – 100 rad/s at low strain amplitude of 0.1 %. The linear viscoelastic strain amplitude of 0.1 % was preliminary determined by strain sweep test at angular frequency of 1 Hz. Before starting the rheological experiment, the tested material was heated at 200°C for 15 min. in the gap between the parallel plates, and pre-shear was applied to avoid unwanted errors during the measurement. The TA Advantage Software was used for data analysis and calculation.

2.3.2. Zeta potential

Composites surface zeta potentials are determined by streaming potential measurements that are believed to be surface sensitive [5]. Zeta potential (ξ) analysis was performed as a function of pH to determine the isoelectric point (IEP) of all polymer-filler composites. The isoelectric point of the flat surface of neat PLA and nanocomposites with and without incorporating varying amounts of 1.5 – 9 wt% GNP in PLA matrix have been measured at room temperature by SurPASS electrokinetic analyzer (Anton Paar GmbH, Austria).

Fig.2. The SurPASS 3 surface charge analysis system, Anton Paar

The film sample was cut from prepared in advance pressed films and adjusted to the dimensions of the sample holders and fixed using double-sided adhesive tape. The required pH value in the samples was adjusted by adding an appropriate amount of 0.05 M HCl or 0.05 M NaOH. The zeta potential measurements were carried out in the pH value range of 2 – 6. By equipment we determine the zeta potential at the surface of a macroscopic solid in contact with an aqueous solution. Zeta potential was used to further characterize the nature of the interaction between PLA with GNP, and compare with pure PLA For each pH, the zeta potential measurement was repeated 4 times and average was taken.

2.3.3. Contact angle

The equipment used for measuring of samples for the Contact angle analysis was A DSA100 – KR*Ü*SS goniometer (Kruss, Hamburg, Germany). The contact angles (CA) of the liquid droplet on the flat surface with and without incorporating varying amounts of GNP in PLA matrix have been measured with two different liquids with varying surface tension at 20 °C to determinate the Surface Free Energy (SFE). The used liquids were deposited onto the film by a sessile drop method [6].

Fig.3. *KRÜSS goniometer - DSA100*

The fitting used for each drop was determined using the best fit observed, and at least twenty measurements were performed for each sample. Data were collected with Advance-Drop shape software, from *KRÜSS.* Films were characterized using two liquids - Mili Q water and ethylene glycol, to be able to perform the two-component surface energy characterization. The films were attached to a microscope glass slider with double sided tape for the duration of the analysis. All measurements were made in static contact angle mode.

The SFE values were calculated using Fowkes methodology [7-9]. The values of the contact angles (water and ethylene glycol) were used to calculate the surface energy (γ) using an harmonic mean equation [10]. The solution of the equation also gives the values of dispersion (γ^d) and polar (γ^p) components of surface energy, where γ^p is a polar component due to dipole-dipole interactions and γ^d is dispersed component. The polar component is the sum of polar, hydrogen, inductive, and acid-base interactions, while the dispersive component accounts for van der Waals and other non-site specific interactions [11-14].

3. Results and Discussion:

3.1. Rheological measurements

The effect of graphene on the linear viscoelastic response of the PLA polymer and the composites at 200°C is shown in Figure 4. The frequency dependence of the dynamic complex viscosity η* is shown in Figure 4 and the storage and loss moduli (G' & G") versus angular frequency ω is seen on Figure 5 as varying the filler contents from 1.5 to 9 wt% for GNP/PLA nanocomposites.

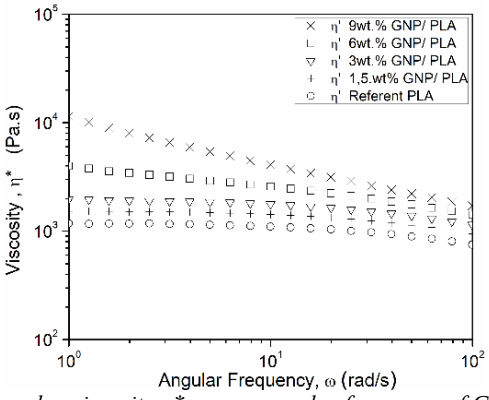

Fig.4. *Complex viscosity η* versus angular frequency of GNP/PLA nanocomposites at 200°C with varying the filler contents from 0 to 9 wt%.*

Figure 4 shows, that 1.5 and 3 wt% GNP/PLA composites have a Newtonian plateau in the low frequency range (ω < 10 s-1), similar to the neat PLA, while 6 and 9 wt% GNP/PLA demonstrate pseudo-plastic flow behavior, associated with percolation.

In Figure 5, the viscoelastic moduli G' and G" versus angular frequency ω are shown. In the terminal region, ω→0, the storage G' and loss G" modulus of the neat PLA fit with scaling law, G' ~ ω^2 and G" ~ ω^1 . For GNP/PLA composites in Figure 5, the slope of both moduli slightly decreases by increasing the filler contents from 1.5 to 3 wt%, while at 6 and 9 wt% GNPs, the slope of both

dynamic moduli decreases significantly, but the flow behavior is liquid-like, with G' < G".

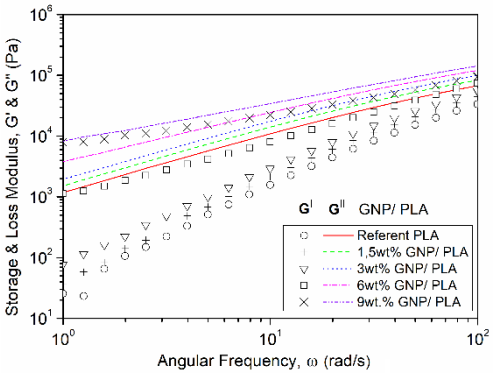

Fig.5. *Storage and loss moduli G' and G" versus angular frequency of GNP/PLA nanocomposites at 200°C with varying the filler contents from 0 to 9 wt%.*

It is important to determine the rheological percolation threshold as the viscosity and the properties of nanocomposites are generally enhanced above this critical filler concentration [15]. The rheological percolation threshold is usually associated with the structural liquid-to-solid transition indicating the formation of a percolation network of interconnected nanoparticles, immobilized with matrix polymer [15, 16, 17 – 19]. Different approaches are used in the literature to determine the percolation threshold [15, 18, 20]. In this study we apply the rheological criteria: Cole-Cole plot, in order to verify applicability for the studied GNP/PLA nanocomposites for precise estimation of the rheological percolation threshold.

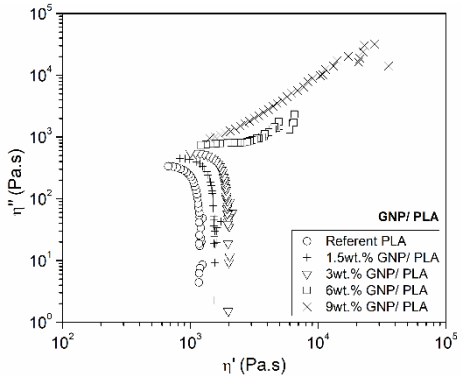

Fig.6. *Cole-Cole plot of dynamic viscosity η' versus imaginary viscosity η" for: GNP/PLA nanocomposite at 200°C with varying the filler contents of 0 – 9 wt%.*

The Cole-Cole plot, which presents the frequency dependence of imaginary viscosity η″ versus real viscosity η' is shown on fig.6. The Cole-Cole plot is used to identify the structural changes in the PLA polymer matrix due to the incorporation of GNP filler. The real part and imaginary part of complex viscosity are calculated from the dynamic modulus as follows: η' = G''/ω and η'' = G'/ω. As seen, for the GNP/PLA composites at low nanofiller contents 0–3 wt%, the Cole–Cole plot exhibits a semi-circular shape with one arc corresponding to the relaxation of the PLA matrix [21]. While at 6 – 9 wt% GNP/PLA the plots exhibit deviation from the semi-circular shape and shows a linear variation of the storage viscosity versus the loss viscosity. This is a characteristic for a gel-like structure which indicates that maximum particle-particle interaction has occurred, associated with percolation. Therefore, the rheological percolation threshold that may be determined using the Cole-Cole plots is around ϕ_p < 6 wt% for the GNP/PLA nanocomposites.

3.2. Zeta potential measurements

The quality and stability of nanofiller dispersion in the PLA matrix composites were evaluated by zeta potential measurements; when the material is immersed in a solvent a charge may develop at the interface creating a potential. Figure 7 presents zeta potential curves of the nanocomposite films as a function of pH for monofiller nanocomposites, compared to the neat PLA. The isoelectric point (IEP) of the films, which is a measure of the surface properties, was observed at pH=2.6 for pure PLA, and it increases gradually to pH=3.6 by increasing the GNP content from 1.5 to 9 wt.%, due to improved conductivity on the surface by the graphene nanofiller. The values of measured IEP and zeta potential |ζ| for GNP/PLA composites are summarized in Table 2.

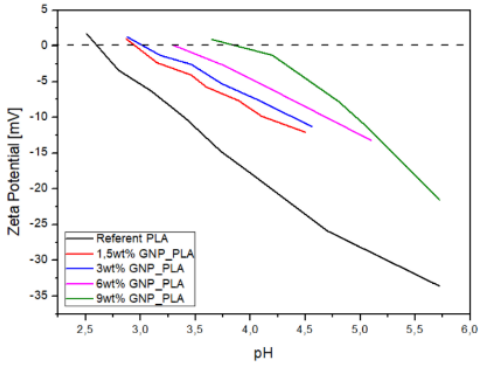

Fig.7. *Zeta potential versus pH factor of monofiller, GNP/PLA composites, as varying the graphene content*

Table 2. *Summarized results for isoelectric point (IEP) and zeta potential |ζ|) of GNP/PLA composites*

Sample	Isoelectric point [pH]	Zeta potential |ζ|, mV
Pure PLA	2.6	-33.59
1.5wt%GNP/ PLA	2.9	-12.06
3wt%GNP/ PLA	3	-11.28
6wt%GNP/ PLA	3,3	-13.22
9wt%GNP/ PLA	3.6	-21.53

Results indicate that alterations in the pH have a large effect on zeta potential, this referring for agglomerate size. The change in zeta potential was found to alter the stability of the nanoparticle suspension. The suspension stability is dependent upon physical characteristics of both the suspended nanoparticles and their suspension medium. The zeta (ζ)-potential often correlates strongly to dispersion stability with higher magnitude zeta potentials (|ζ|) being more stable due to electrostatic repulsion between particles. Schramm [22] proposed, as a general guide, that at |ζ| of 0–10 mV the dispersion will be unstable, at 10–30 mV will be slightly to moderately stable; at 30–60 mV will have good stability, and at 60 mV will have excellent stability for electrostatically repelling particles. In our case, with increasing the GNP content the GNP/PLA dispersion system gets more stable. As seen from Table 2, the PLA matrix polymer has the highest value of |ζ| ~ 34 mV. At 9 wt% GNP content, the |ζ| value sharply grow to ~ 22 mV, so according to [22] we may conclude that such dispersions will be moderately stable. The steadily rising of the absolute value of Zeta potential to 22 mV, as well as the value of the IEP from pH 2.6 for PLA to 3.6 for 9wt% GNP/PLA may be associated with percolation. Our previous studies on rheological behavior [23,24] and electrical properties [24] confirm that the percolation of the GNP/PLA composites is around and above 6 wt% graphene content. From above discussions, we may conclude that the most stable dispersion of GNPs in PLA polymer was achieved above 6wt% GNP content, this related with the formation of a percolated network of well dispersed graphene platelets in the hydrophilic PLA polymer. Therefore, the 9wt.% GNP/PLA composites with Zeta potential of |ζ| = 22 mV have more stable dispersion, due to the percolated network of nanolpatelets, than the 1.5 - 6wt% GNP/PLA composites with values of |ζ| =11-13 mV, which demonstrate a flocculated, fractal-like structure [23].

3.3. Contact angle measurements

The contact angles (CA) of the liquid droplet on surface of films with and without incorporating varying amounts of GNP in PLA matrix have been measured with two different liquids with varying surface tension. Contact angle measurements investigate surface tension, and they are used to calculate surface free energy (SFE).

Contact angle data for the two test liquids (water and ethylene glycol) apply for monofiller system on base on GNP/PLA are plotted in Figure 8 (a,b). Calculated Surface free energy and its polar and dispersive components are presented on Fig.9. The average values of all surface characteristics for the monofiller GNP/PLA composites are summarized in Table 3.

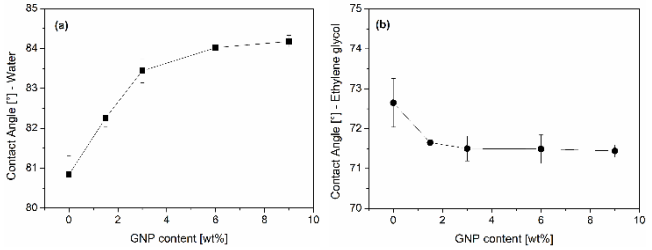

Fig.8. *Contact angle vs. GNP content for monofiller GNP/PLA composite, as varying the filler combinations for the two test liquids: (a) water ; (b) ethylene glycol*

It can be observed that with increasing the GNP loading slightly higher contact angle values are obtained compared to the neat PLA in the case of water as a liquid. The water contact angle of 9 wt.% PLA/GNP film increased with 3◦, if compared to that of pristine PLA films. This may be associated with a small hydrophobic effect of GNP filler. This phenomenon is probably attributed to the hybrid structure of the monofiller nanocomposite, which is related with the interaction between the GNP surfaces and the hydroxyl group of PLA, this leading to a decrease of hydrophilicity of the GNP/PLA composite surfaces. In agreement with Ref. [25], the obtained composites in our study refer to the contact angle values of $0° < \theta < 90°$, where the surface is considered hydrophilic, which corresponds to high wettability. The PLA surface has a lower contact angle of water, therefore exhibit better wettability with water compared to the GNP/PLA surfaces with higher contact angle.

In the case of ethylene glycol liquid, the contact angle is of ~10^o lower than that of water; it slightly decreases from 73^o to 71^o, by addition of only 1.5% GNP, but it goes to plateau with increasing the GNP content to 9 wt.%. Results show that the wettability of GNP/PLA composite surfaces and their lubricant properties to organic liquids will be very good.

The two different liquids (water and ethylene glycol) of known polar and disperse components was used to calculate the surface free energy of GNP/PLA composite films. Table 3 shows the surface free energy for the two liquids used in this study.

Contact angles collected yielded information regarded changes to the energy of the film surfaces before and after reinforced with fillers. The variation of surface free energy against filler's content is given in the Figure 9, showing γ (surface energy) and its polar (γ^p) and dispersive (γ^d) component of the monofiller GNP/PLA composite, compared to the neat PLA.

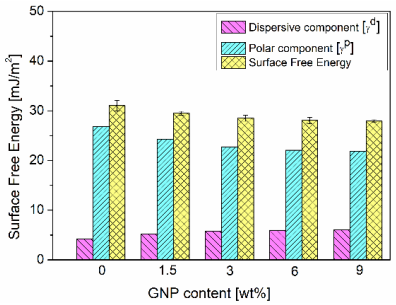

Fig.9. *Calculated surface free energy from contact angle test for the mono-filler GNP/PLA composite, as varying the filler content.*

Looking at the data (Fig.9 and table 3), we can note that there is a small decrease of surface energy, γ, by increasing the GNP content, which is more pronounced at 1.5wt% GNP. The decrease in γ is mainly caused by a slight reduction in the polar component which involves a strongly polarized interaction of hydrogen bonds, indicating for less polar groups at the surface of the film. This may be associated with a slight increase of the interfacial polymer-filler interactions, by increasing the GNP content. Dispersive component is slightly increasing, which indicate for a small increase in particle-particle interactions with an increase in the GNP content to 9wt%.

Table.3. *The contact angle (at 20°C) and surface energies sample components of mono-filler composites GNP/ PLA*

Sample	Contact Angle, [°]		Surface energy, [mJ/m^2]		
	Mili Q water	Ethylene glycol	γ	γ^d	γ^p
Neat PLA	80.8±0.5	72.7±0.6	31.1±1.1	4.2	26.9
1.5wt%GNP/PLA	82.3±0.2	71.7±0.1	29.5±0.4	5.2	24.3
3wt%GNP/ PLA	83.4±0.3	71.5±0.3	28.5±0.6	5.7	22.8
6wt%GNP/ PLA	84.0±0.2	71.5±0.6	28.1±0.7	6.0	22.1
9wt%GNP/ PLA	84.1±0.2	71.4±0.2	27.9±0.3	6.1	21.9

It may be concluded that, due to non-polar behavior of filler and polar behavior of polymer the wettability with water of the GNP/PLA composite surfaces slightly decreases by increasing the GNP content from 1.5 to 9wt%. This may be associated with the decrease of polar component of the surface energy, which is connected with dipole-dipole forces leading to an increase of interfacial polymer-filler interactions. On another hand, the dispersive components correspond to the Van der Waals forces. The results show that the dispersive component is slightly increasing, therefore stronger Van der Waals interactions between nanoplatelets are expected by increasing the GNP content.

4. Future application of resulted nanocomposites

The field of nanoscience has blossomed over the last two decades and the importance of nanotechnology increase in areas such as computing, sensors, biomedical and many other applications. In this regard the discovery of graphene [26] and graphene-based polymer nanocomposites is an important addition in area of nanoscience. The superior properties of graphene compared to polymers are reflected in graphene-based polymer composites. Graphene-based polymer composites show superior mechanical, thermal, gas barrier, electrical and flame retardant properties, compared to the neat polymer [27–31]. Our study adds new knowledge about tunable physicochemical properties of the nanocomposites by varying the GNP content and distribution of graphene layers in the polymer matrix, as well as interfacial bonding between the graphene layers and polymer matrix. These properties open new opportunities to revolutionize a variety of practical applications, e.g. multifunctional composites, detectors, smart wearables, paints and printing. Carbon nanofillers have great advantages as additives in polymers for application in Additive Manufacturing (3D printing). It should be highlighted that 3D printing is not only an innovative processing technology, but it is the future of the manufacturing industries. Therefore, unlimited needs exist for novel materials suitable for 3D printing for variety of applications that require improved mechanical performances, conductivity and other functional properties of the final products.

5. Conclusion

Graphene-based polymer nanocomposites are one of the most auspicious developments in the field of material science. The composites based on PLA filled with 0 to 9 wt% GNP filler content prepared by melt extrusion are studied herewith. Rheological and surface properties are obtained as varying the filler content. Rheological percolation threshold for GNP/PLA was estimated around 6 wt% GNP. The wettability with water and the surface

energy of the GNP/PLA surfaces decreases by increasing the GNP content from 1.5 to 9wt%. The obtained effects are associated with a decrease of hydrophobicity and an increase of interfacial polymer-filler interactions. This is proposed as a new strategy to tune the rheological and surface properties of PLA matrix by varying GNP filler contents.

Acknowledgments

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AERIATION OF CULTURE MEDIA WITH POWDER DISPERSERS WHEN CULTIVATING YEAST CULTURES DURING MILK WHEY PROCESSING

АЭРИРОВАНИЕ ПИТАТЕЛЬНЫХ СРЕД ПОРОШКОВЫМИ ДИСПЕРГАТОРАМИ ПРИ КУЛЬТИВИРОВАНИИ ДРОЖЖЕВЫХ КУЛЬТУР В ПРОЦЕССЕ ПЕРЕРАБОТКИ МОЛОЧНОЙ СЫВОРОТКИ

Prof., Dr. Eng., Cor. Member of NAS of Belarus Ilyushchanka A.F.[1, 2],
Head of the Lab. Charniak I.N.[2], PhD of Eng., Doc. Kusin R.A.[3], PhD of Eng., Yakimovich N.N.[4], Res. Shunkevich A. [4]
State Research and Production Powder Metallurgy Association [1] – Minsk, Republic of Belarus
State Scientific Institution "O.V. Roman Powder Metallurgy Institute" [2] – Minsk, Republic of Belarus
Belarusian State Agriculture Technical University [3] – Minsk, Republic of Belarus
State Scientific Institution "Institute of Physical-Organical Chemistry of NAS of Belarus" [4] – Minsk, Republic of Belarus

E-mail: alexil@mail.belpak.by, 19081877@mail.ru, irinacharniak@tut.by, gms_124@mail.ru

Abstract: *The characteristics and structure of aerators based on titanium powders have been given, as well as the information about the effectiveness of their application when cultivating yeast cultures during milk whey processing.*

KEYWORDS: POWDER AERATORS, BIOSYNTHESIS OF YEAST CULTURE MEDIUM WITH AIR OXYGEN, MILK.

1. Introduction

One of the effective ways to use milk whey is its processing by means of aerobic microorganisms *Debaryomyces hansenii var hansenii* BIM Y-4 (D.h.v.) in order to produce feed protein [1]. An essential condition for the cultivation of these microorganisms is the aeration of the fermentation medium, that is, the process of its saturation with oxygen in the air.

The most common method that provides effective dissolution of oxygen in a liquid medium is the method of blowing through a fermentation solution of atmospheric air with simultaneous mixing of the solution with a turbine multilayered mixer.

In other equal conditions, the intensity of the oxygen dissolution is determined by the aerator properties, which directly distributes the air flow in the culture fluid. Compared to others, powder aerators made of titanium powders are the most preferred: they have high corrosion resistance and strength, are well regenerated, and provide a high uniformity of air flow distribution over the area of dispersion and the required size of air bubbles. Moreover, the manufacturing technology of powder aerators makes it possible to regulate the size and density of the bubbles [2].

The purpose of the work is to provide the efficiency of powder aerators for saturating the culture fluid with oxygen in the air at biosynthesis of yeast cultures during milk whey processing.

1. Research data.

Laboratory studies were performed in the State Scientific Institution "Institute of Physical-Organical Chemistry of NAS of Belarus on a laboratory bioreactor EDF-5.2 (Biotehniskais Centrs, Latvia) equipped with a sensor for measuring dissolved oxygen and a flowmeter with a valve for controlling and regulating air flow (Figure 1). Distilled water was used as a model fluid for testing powder dispersers. Studies in production conditions were carried out using a pure culture device with a volume of 6.0 m^3 at Bobruisk Biotechnology Plant. Concentrated milk whey diluted to four percent lactose, manufactured by Gormolzavod No. 1 in Minsk, was used as the base of the culture medium. Titanium powders of grades TPP-5 and TPP-8 manufactured by AVISMA, a branch of Public Joint-Stock Company CORPORATION VSMPO-AVISMA (Bereznyaki, Russia) were used to manufacture the aerators. When the adjustment of the particle size distribution of the powders was required, the specified fractions were obtained by sieving the indicated grades. The permeability coefficient of the samples was determined according to GOST 25283-93.

Fig. 1. *The process of dispersing air through a powder disperser*

The concentration of bacterial biomass in the culture fluid and fermentation media was determined by the value of optical density with a length of 400 nm on SF-46 spectrophotometer. The end of the cultivation process in production conditions was considered the time when the lactose content was less than 0.5%. The determination of the lactose content was carried out using Bertrand's method modified by Shorl.

2. Results and discussion

Porous powder materials (PPMs), from which aerators were made, surpass other types of materials in terms of corrosion resistance, strength, regenerability and efficiency [3]. Regulating the structure of PPM by changing the size of the particles of the initial powder and modes of manufacture, it is possible to change the characteristics of the resulting products in a wide range, ensuring the effectiveness of their application. In this case, it is the diameter of the gas bubbles and the throughput capacity.

Figure 2 shows the calculated dependences of the bubble size on the powder particle size for various PPMs given in ref. [4] and performed according to the methods ref. [2] and [4].

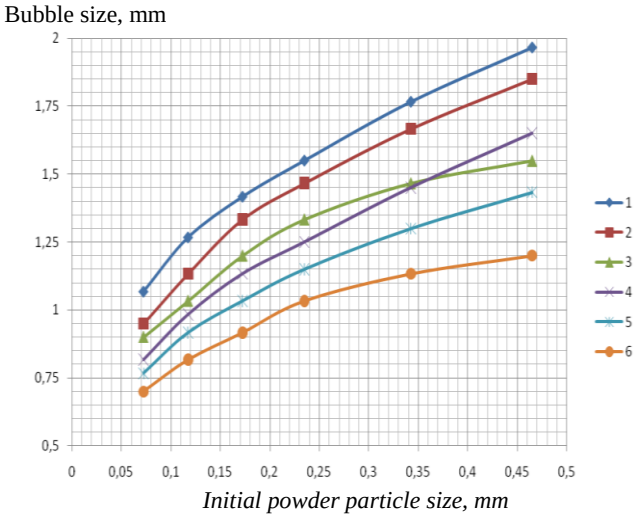


Fig. 2. *Calculated dependences of the bubble size on the powder particle sizes:*
1 – titanium [2]; 2 – steel [2]; 3 – bronze [2];
4 – titanium [4]; 5 – steel [4]; 6 – bronze [4]

Figure 2 shows the dependencies of the permeability coefficient on the technological modes of production (compression pressure) for three titanium powder fractions (the graph shows the average particle sizes calculated by Anderson's formula of the following particle size distribution: (minus 400 + 315), (minus 630 + 400) and (minus 1000 + 630) μm). The analysis of these dependencies indicates the possibility of regulating the throughput capacity in a wide range.

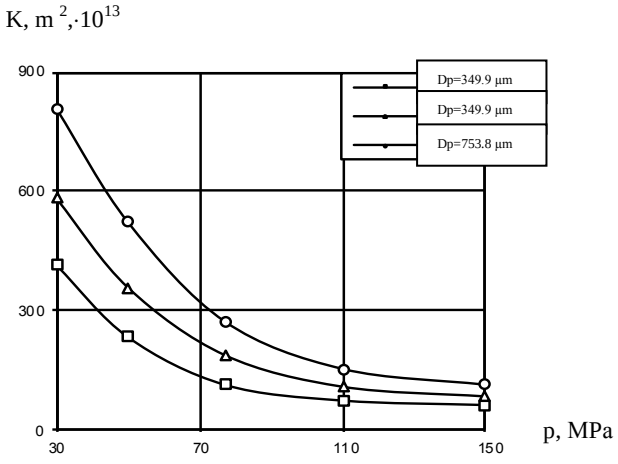
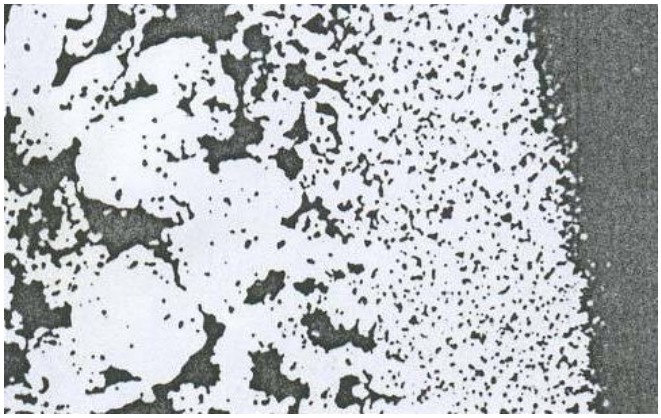


Fig. 3. *The dependence of PPM permeability on the compression pressure*

The efficiency of using PPM-based aerators can be improved due to the use of modern methods for creating two-layer porous structures [5, 6] shown in Figure 3. The pore sizes of such materials (determine the refining fineness during filtration or the size of bubbles during dispersion) are similar or close to the pore size of a monolayer material made of powder of a fine fraction, and the permeability coefficient (determines the throughput capacity) is an integral value and causes an increase in the efficiency of application of entire material. At the same time, a decrease in the thickness of the fine disperse layer (Figure 4 b) leads to an increase in efficiency, with some complication of the manufacturing technology and a slight deterioration in the uniformity of distribution of properties over the working surface.



a)

b)

Fig. 4. *Two-layer PPMs, obtained by joint pressing of powders of different fractions:*
a) by layering filling; b) by applying a layer of fine disperse powder to one of the forming elements

Studies have shown that a porous powder aerator based on titanium powder has a saturation rate 1.6 times higher than the standard (perforated) one. Comparison in the process of cultivation of yeast microorganisms *D.f.v.*, when dispersing air through standard and powder dispersers on a laboratory fermentor, has also showed an advantage of the latter: an increase in biomass was about 25% with the same air flow (1 l/min per 1 liter of culture fluid).
Studies in production conditions were carried out at the Bobruisk Biotechnology Plant in the pure culture device (a production fermentor for the preparation of *D.f.v.* seed material intended for processing milk whey in a operating device with the aim of producing a protein feed additive). A device was developed for saturating the culture medium with oxygen in the air. Its drawing is shown in Figure 5.

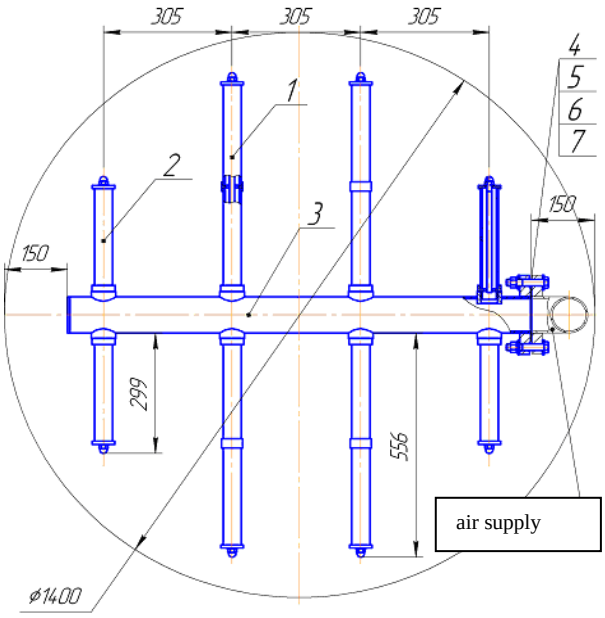


Fig. 5. *A device for saturating the culture medium with oxygen in the air:*
1, 2 – aerator; 3 – collector, 4 – bolt; 5 – nut; 6, 7 – washer

Tests have shown that the device for saturation of the culture medium provided the completion of the cultivation process in 12 hours, in comparison with 14 hours using the standard (perforated) disperser.

3. Conclusion

As a result of research, it has been established that the developed device for saturation of the culture medium with oxygen in the air based on powder material in comparison with the traditional perforated disperser provides a higher saturation rate (1.6 times) of biomass of the yeast microorganisms, significantly reduces the fermentation time (by 15%) and contributes higher biomass accumulation (up to 25%).

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GAS TURBINE UPGRADE WITH HEAT REGENERATOR - NUMERICAL ANALYSIS OF ADVANTAGES AND DISADVANTAGES

PhD. Mrzljak Vedran[1], Student Perčić Gregor[1], Prof. PhD. Prpić-Oršić Jasna[1]
[1]Faculty of Engineering, University of Rijeka, Vukovarska 58, 51000 Rijeka, Croatia
E-mail: vedran.mrzljak@riteh.hr, gpercic@riteh.hr, jasna.prpic-orsic@riteh.hr

Abstract: *The paper presents analysis of industrial gas turbine and its upgrade with heat regenerator. Based on a gas turbine operational data from a thermal power plant (base process) it was investigated advantages and disadvantages of heat regenerator implementation in the gas turbine process. Regenerator efficiencies were varied between 75% and 95%. Heat regenerator causes decrease of gas turbine fuel consumption up to 0.621 kg/s with a simultaneous increase in gas turbine process efficiency up to 10.52%. The main disadvantages of heat regenerator implementation are decrease in turbine cumulative and useful power along with decrease in the cumulative amount of heat released from the process.*

KEYWORDS: GAS TURBINE, HEAT REGENERATOR, POWER, FUEL CONSUMPTION, EFFICIENCY

1. Introduction

Gas turbines are today widely used for power (and heat) production as stand-alone devices [1] and [2], or in combined [3] and cogeneration plants [4].

Scientists are intensively investigating improvements of such systems in which the gas turbine is essential operation element. The most used improvement of such power plants is integration of solar systems. As an example, Ameri and Mohammadzadeh [5] investigated a novel solar integrated combined cycle power plant, while Dabwan and Mokheimer [6] analyzed optimal integration of linear Fresnel reflector with gas turbine cogeneration power plant.

An interesting investigation of combined cycle power plants presents Kang et al. [7] which provide energy analysis of a particle suspension solar combined cycle power plant. Energy, exergy and economic (3E) analysis of integrated solar direct steam generation combined cycle power plant presented Adibhatla and Kaushik [8].

In this paper is investigated operation of gas turbine when the heat regenerator is implemented in its process. Heat regeneration process brings several advantages and disadvantages in the gas turbine process. The most important advantages are reduction of fuel consumption and significant increase in gas turbine process efficiency. This analysis and its results can be applied on any stand-alone gas turbine in power plants or in marine systems.

2. Base gas turbine process

Gas turbine base process operates according to the schema from Fig. 1. Turbo-compressor compresses air from the atmosphere and delivers it to combustion chambers. In the combustion chambers are produced combustion gases (heat addition by fuel combustion) and at the combustion chamber outlet maximum process temperature occurs. Combustion gases prepared at the combustion chamber outlet enters to the gas turbine and expanded. After expansion, combustion gases are released from the gas turbine process to the atmosphere (or can be used for any heating purposes due to a high enough temperature). Temperature-specific entropy diagram of the base gas turbine process is presented in Fig. 2.

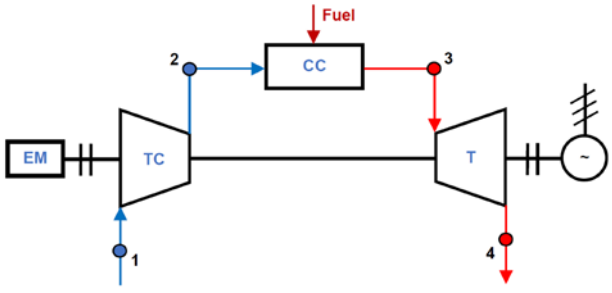

Fig. 1. *Base gas turbine process (EM = electric motor; TC = turbo-compressor; CC = combustion chamber; T = gas turbine)*

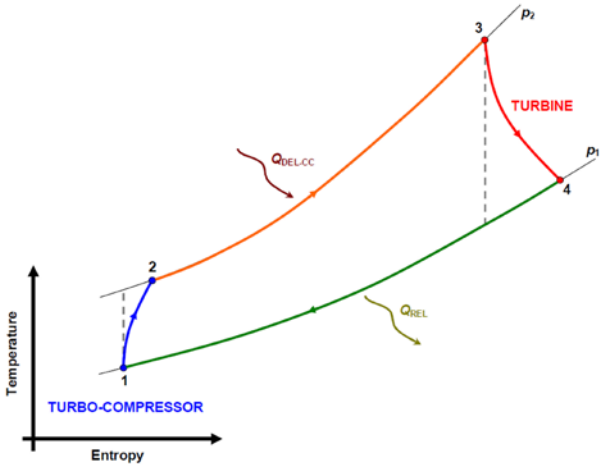

Fig. 2. *T-s diagram of the base gas turbine process*

3. Equations for the gas turbine base process analysis

All the equations for base gas turbine process analysis can be found in [9] and [10]. For each operating point of any gas turbine process (consequentially for the base gas turbine process) specific enthalpy of operating medium is calculated as:

$$h = c_p \cdot T \tag{1}$$

where c_p is the specific heat capacity of operating medium at constant pressure and T is current operating medium temperature. Specific heat capacity at constant pressure (c_p) is a function of current temperature and is calculated by using polynomials presented in [11] for air, according to Eq. 2 and for combustion gases (cg), according to Eq. 3:

$$c_{p,air}(T) = 1.0484 - 0.0003837 \cdot T + \\ + \frac{9.45378}{10^7} \cdot T^2 - \frac{5.49031}{10^{10}} \cdot T^3 + \frac{7.92981}{10^{14}} \cdot T^4 \tag{2}$$

$$c_{p,cg}(T) = 0.936087 + \frac{0.010749}{10^2} \cdot T + \\ + \frac{0.0172103}{10^5} \cdot T^2 - \frac{0.07247}{10^9} \cdot T^3 \tag{3}$$

In both polynomials (Eq. 2 and Eq. 3) temperature T must be inserted in (K) to obtain c_p in (kJ/kg·K).

According to Fig. 1 and Fig. 2, the operating parameters of the gas turbine base process are:

- Turbo-compressor power:

$$P_{TC} = \dot{m}_{air} \cdot (h_2 - h_1) = \dot{m}_{air} \cdot (T_2 \cdot c_{p,2} - T_1 \cdot c_{p,1}) \tag{4}$$

- Turbine developed power:

$$P_{\mathrm{T}} = \dot{m}_{\mathrm{cg}} \cdot (h_3 - h_4) = \dot{m}_{\mathrm{cg}} \cdot (T_3 \cdot c_{\mathrm{p},3} - T_4 \cdot c_{\mathrm{p},4}) \quad (5)$$

- Useful power:

$$P_{\mathrm{US}} = P_{\mathrm{T}} - P_{\mathrm{TC}} \quad (6)$$

- The amount of heat delivered in combustion chambers by fuel:

$$Q_{\mathrm{DEL\text{-}CC}} = \dot{m}_{\mathrm{cg}} \cdot (h_3 - h_2) = \dot{m}_{\mathrm{cg}} \cdot (T_3 \cdot c_{\mathrm{p},3} - T_2 \cdot c_{\mathrm{p},2}) \quad (7)$$

- The cumulative amount of heat released from the gas turbine process:

$$Q_{\mathrm{REL}} = \dot{m}_{\mathrm{cg}} \cdot (h_4 - h_1) = \dot{m}_{\mathrm{cg}} \cdot (T_4 \cdot c_{\mathrm{p},4} - T_1 \cdot c_{\mathrm{p},1}) \quad (8)$$

- Useful heat released from the process:

$$Q_{\mathrm{REL,US}} = \dot{m}_{\mathrm{cg}} \cdot (h_4 - h_{433.15}) = \dot{m}_{\mathrm{cg}} \cdot (T_4 \cdot c_{\mathrm{p},4} - 433.15\ \mathrm{K} \cdot c_{\mathrm{p},433.15}) \quad (9)$$

Useful heat released from the process is the heat amount which can be used for any additional heating. Combustion gases with temperature lower than 433.15 K cannot be used for additional heating because it will cause significant low-temperature corrosion.

- Gas turbine process efficiency:

$$\eta_{\mathrm{GT}} = \frac{P_{\mathrm{US}}}{Q_{\mathrm{DEL\text{-}CC}}} = \frac{P_{\mathrm{T}} - P_{\mathrm{TC}}}{Q_{\mathrm{DEL\text{-}CC}}} \quad (10)$$

- Combustion chamber efficiency:

$$\eta_{\mathrm{CC}} = \frac{Q_{\mathrm{DEL\text{-}CC}}}{LHV \cdot \dot{m}_{\mathrm{F}}} = \frac{\dot{m}_{\mathrm{cg}} \cdot (h_3 - h_2)}{LHV \cdot \dot{m}_{\mathrm{F}}} = \frac{\dot{m}_{\mathrm{cg}} \cdot (T_3 \cdot c_{\mathrm{p},3} - T_2 \cdot c_{\mathrm{p},2})}{LHV \cdot \dot{m}_{\mathrm{F}}} \quad (11)$$

where LHV is the lower heating value of used fuel in (kJ/kg) and $\dot{m}_{\mathrm{F}}$ is combustion chambers fuel mass flow in (kg/s).

- Specific fuel consumption:

$$SFC = \frac{\dot{m}_{\mathrm{F}}}{P_{\mathrm{US}}} = \frac{\dot{m}_{\mathrm{F}}}{P_{\mathrm{T}} - P_{\mathrm{TC}}} \quad (12)$$

4. Operating parameters of the gas turbine base process

Base gas turbine operating process, without additional heat regenerator implementation, is similar to process from [11]. Pressure drops in combustion chambers and at the turbine outlet are neglected. In accordance to Fig. 1 and Fig. 2, the operating parameters of the base gas turbine process are presented in Table 1.

Table 1. *Operating parameters of the base gas turbine process*

Operating point*	Temperature (K)	Pressure (bar)
1	293.15	1.00
2	608.15	11.68
3	1263.15	11.68
4	773.15	1.00
Air mass flow	119.97 kg/s	
Used fuel	Natural gas	
Fuel lower heating value (*LHV*)	50000 kJ/kg	
Fuel mass flow	2.79 kg/s	
Combustion gases mass flow**	122.76 kg/s	

* According to Fig. 1 and Fig. 2

** Combustion gases mass flow is the sum of air mass flow and fuel mass flow

5. Upgrade of the base turbine base process with a heat regenerator

Heat regenerator implemented in the base gas turbine process can be recuperative or regenerative heat exchanger. In the gas turbine processes, heat regenerators are mounted before combustion chambers, Fig. 3. Combustion gases from the gas turbine outlet are used in the heat regenerator with an aim to heat the air before its entrance into combustion chambers. In such way, air is additionally heated before combustion chambers, therefore, to obtain the same peak temperature of combustion gases in the combustion chambers will be used less fuel. On the other side, one part of heat from combustion gases at the turbine outlet will be utilized for additional heating. Based on a several analysis, implementation of heat regenerator decreases gas turbine fuel consumption and significantly increases gas turbine process efficiency. This investigation will present the range of fuel savings and process efficiency increase, along with analysis of other gas turbine operation parameters when heat regenerator of various efficiencies is implemented in the base gas turbine process.

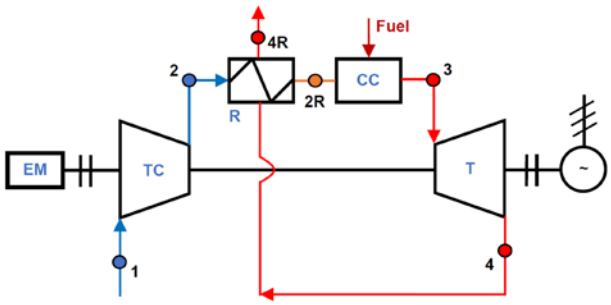

Fig. 3. *Base gas turbine process upgraded with heat regenerator (EM = electric motor; TC = turbo-compressor; R = regenerator; CC = combustion chamber; T = gas turbine)*

Temperature-specific entropy diagram of the gas turbine process with implemented heat regenerator is presented in Fig. 4. One part of heat contained in combustion gases (4 - 4R) is used for air heating after compression (2 - 2R). Air with temperature $T_{2\mathrm{R}}$ enters in combustion chambers.

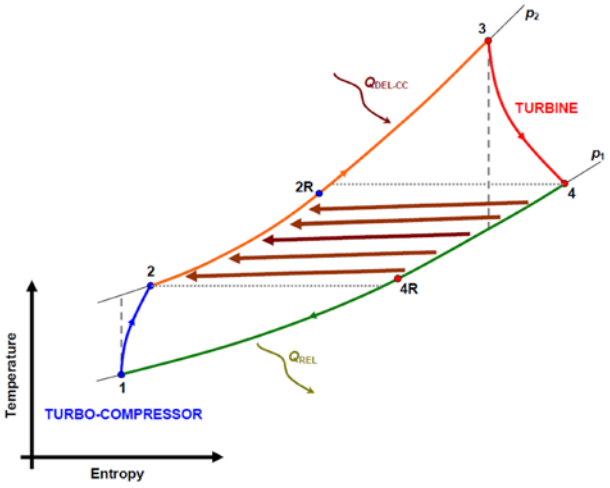

Fig. 4. *T-s diagram of the base gas turbine process with heat regenerator upgrade*

In the literature [12] is found that heat regenerator's efficiency (η_{reg}) frequently used in gas turbine power plants, varies between 75% and 95% what is adopted in this analysis. Heat regenerator efficiency is used to calculate the temperature of air after regenerator ($T_{2\mathrm{R}}$, Fig. 4). Temperature $T_{2\mathrm{R}}$ is calculated according to Fig. 4 by an equation:

$$T_{2\mathrm{R}} = T_2 \cdot \frac{c_{\mathrm{p},2}}{c_{\mathrm{p},2\mathrm{R}}} + \frac{\eta_{\mathrm{reg}}}{c_{\mathrm{p},2\mathrm{R}}} \cdot (T_4 \cdot c_{\mathrm{p},4} - T_2 \cdot c_{\mathrm{p},2}) \quad (13)$$

where $c_{\mathrm{p},2\mathrm{R}}$ is calculated as an average value of specific heat capacities at constant pressure between operating points 2 and 3, Fig. 4.

The air mass flow and combustion chamber efficiency remain the same in the process with heat regenerator as in the base gas turbine process. Heat regenerator decreases fuel mass flow used in the combustion chambers, so the fuel mass flow of the gas turbine process with heat regenerator is now calculated as:

$$\dot{m}_{\mathrm{F,reg}} = \frac{\dot{m}_{\mathrm{air}} \cdot \left(h_3 - h_{2\mathrm{R}}\right)}{LHV \cdot \eta_{\mathrm{CC}} - \left(h_3 - h_{2\mathrm{R}}\right)} = \\ = \frac{\dot{m}_{\mathrm{air}} \cdot \left(T_3 \cdot c_{\mathrm{p},3} - T_{2\mathrm{R}} \cdot c_{\mathrm{p},2\mathrm{R}}\right)}{LHV \cdot \eta_{\mathrm{CC}} - T_3 \cdot c_{\mathrm{p},3} + T_{2\mathrm{R}} \cdot c_{\mathrm{p},2\mathrm{R}}} \tag{14}$$

In the gas turbine process with heat regenerator, turbo-compressor power, turbine developed power and useful power are calculated with the same equations as in the base process. As the heat regenerator causes a change in fuel mass flow, the combustion gases mass flow has also changed what influenced turbine developed power and useful power.

The amount of heat delivered in combustion chambers by fuel when the heat regenerator is applied is calculated according to Fig. 4 by an equation:

$$Q_{\mathrm{DEL\text{-}CC,reg}} = \dot{m}_{\mathrm{cg}} \cdot \left(h_3 - h_{2\mathrm{R}}\right) = \dot{m}_{\mathrm{cg}} \cdot \left(T_3 \cdot c_{\mathrm{p},3} - T_{2\mathrm{R}} \cdot c_{\mathrm{p},2\mathrm{R}}\right) \tag{15}$$

The cumulative amount of heat released from the gas turbine process and useful heat released from the process with heat regenerator is calculated by using the same equations as for base gas turbine process (with a note that combustion gases mass flow is changed by implementing heat regenerator). Gas turbine process efficiency and specific fuel consumption also have the same equations in a process with heat regenerator as in the base gas turbine process.

6. Results of heat regenerator implementation in the gas turbine base process

In all of the figures which presented the results of conducted analysis, the change in gas turbine operating parameters during heat regenerator implementation is presented in relation to heat regenerator efficiency. Regenerator efficiencies were varied from 75% up to 95% what is an expected range of efficiency for the most practically applicable heat regenerators. The base gas turbine process does not include heat regenerator, so in the figures from this section operating parameters of the base process is shown with regenerator efficiency equal to 0%.

Fig. 5 presented reduction in gas turbine fuel consumption when the heat regenerator is implemented in the process. It can be seen that implementation of heat regenerator significantly reduces fuel consumption, even in the case of the lowest observed regenerator efficiency of 75%. Increase in regenerator efficiency causes further decrease of gas turbine fuel consumption.

Fuel savings are presented in comparison with the base gas turbine process. For the lowest observed heat regenerator efficiency of 75% fuel savings amount 0.491 kg/s. Increase in heat regenerator efficiency resulted in an increase in fuel savings. The highest fuel savings are obtained for the highest observed regenerator efficiency equal to 95% and amounts 0.621 kg/s.

Reduction of fuel consumption caused by heat regenerator will resulted with the decrease of combustion gases mass flow. As the gas turbine operates between two constant temperatures and two constant pressures, decrease of combustion gases mass flow will result with a decrease in turbine cumulative developed power, Fig. 6.

When compared with the turbine base process, from Fig. 6 it can be seen that the maximum decrease in turbine cumulative developed power caused by heat regenerator implementation will be in the range of 420 kW for the highest observed regenerator efficiencies. The same trend is visible in the change of gas turbine useful power which will be used for any power consumer operation.

Increase in heat regenerator efficiency resulted in a decrease of turbine cumulative and useful power due to combustion chambers fuel consumption decrease, Fig. 6.

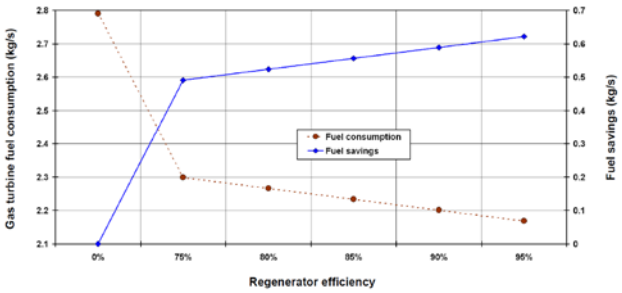

Fig. 5. *Gas turbine fuel consumption and fuel savings after regenerator implementation*

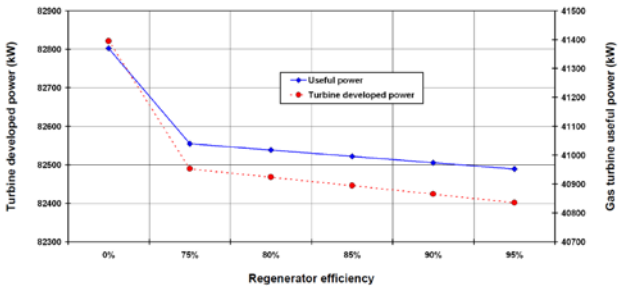

Fig. 6. *Gas turbine cumulative and useful developed power change in relation to regenerator efficiency*

Heat regenerator implementation in the gas turbine process reduces fuel consumption and significantly reduces heat amount delivered by fuel in the combustion chambers in comparison with a base gas turbine process (from 107597.22 kW in the base process to 88658.96 kW in the process with regenerator which efficiency is equal to 75%), Fig. 7. Increase in regenerator efficiency causes further reduction of heat delivered in the combustion chambers by fuel. Regenerator operation also reduces the cumulative amount of heat released by combustion gases from the gas turbine process and simultaneously reduces useful released heat.

In the base gas turbine process, air temperature at the combustion chamber inlet is equal to 608.15 K. Implementation of the heat regenerator increases air temperature at the combustion chamber inlet, which is the primary purpose of heat regeneration process. When heat regenerator has an efficiency of 75%, air temperature at the combustion chamber inlet (air temperature after regenerator) is equal to 702.5 K and increases with an increase in regenerator efficiency, Fig. 8. At the highest regenerator efficiency of 95%, air temperature at the combustion chamber inlet is equal to 738.34 K.

In Fig. 8 is visible that an increase in the air temperature at the combustion chamber inlet is directly proportional to increase in gas turbine process efficiency. Efficiency of the base gas turbine process is equal to 38.45%. Implementation of the heat regenerator increases gas turbine process efficiency to 46.29% when applied the regenerator which efficiency is 75%. The highest gas turbine process efficiency amounts 48.97% and is obtained with a regenerator which efficiency is the highest observed (95%).

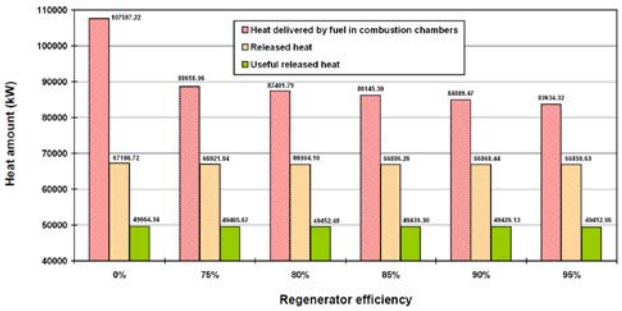

Fig. 7. *Gas turbine delivered and released heat amount change in relation to regenerator efficiency*

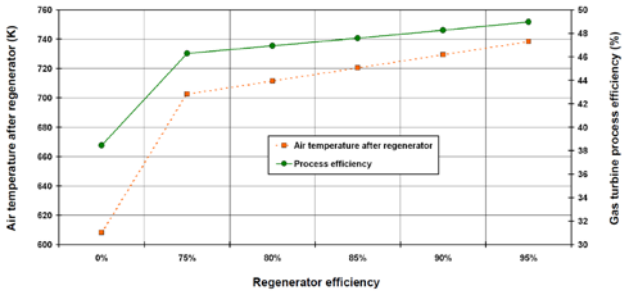

Fig. 8. *Change in gas turbine process efficiency and air temperature after regenerator in relation to regenerator efficiency*

Specific fuel consumption is calculated as a ratio of fuel consumption and useful produced gas turbine power. The base gas turbine process has specific fuel consumption equal to 242.78 g/kWh, Fig. 9. Implementation of heat regenerator in the gas turbine process reduces specific fuel consumption because fuel consumption decreases faster than useful power, regardless of regenerator efficiency. At the lowest observed regenerator efficiency of 75% specific fuel consumption amounts 201.67 g/kWh, while at the highest observed regenerator efficiency of 95% specific fuel consumption has the lowest value of 190.64 g/kWh, Fig. 9.

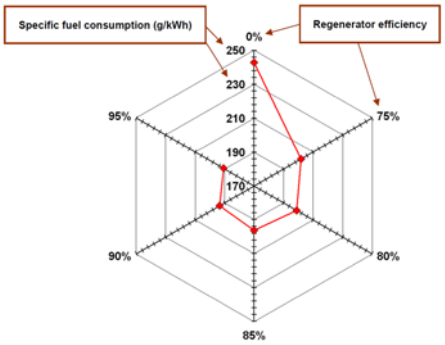

Fig. 9. *Change in gas turbine specific fuel consumption in relation to regenerator efficiency*

7. Conclusions

Implementing a heat regenerator in the base gas turbine process resulted with several advantages and disadvantages. The main advantages are:

- Heat regenerator significantly reduces fuel consumption what is the most important advantage because the fuel costs are dominant elements in complete gas turbine operation costs. Increase in regenerator efficiency causes further reduction of gas turbine fuel consumption.
- Consequentially with fuel consumption reduction, heat regenerator also significantly reduces heat amount delivered by fuel in the combustion chambers.
- Gas turbine with heat regenerator has significantly higher process efficiency when compared to the base gas turbine process. Process efficiency increases with the increase in heat regenerator efficiency.
- Heat regenerator significantly decreases gas turbine specific fuel consumption.

The main disadvantages of heat regenerator implementation in any gas turbine process are:

- Heat regenerator implementation resulted in a decrease in gas turbine developed and useful power due to decrease in combustion gases mass flow. Increase in regenerator efficiency causes further decrease in gas turbine developed and useful power.
- The cumulative amount of heat released from the gas turbine process and useful heat released from the process decreases with heat regenerator implementation. Such disadvantage can be very important if the heat released from the gas turbine is used for additional heating purposes.
- In the gas turbine process heat regenerator is not applicable for a large pressure ratio (p_2/p_1).
- Heat regenerator brings significant additional mass in complete gas turbine process, so it can be applied only in the industrial or marine gas turbines.
- Heat regenerator is a heat exchanger, so it can be expected additional heat transfer and pressure losses (usually with additional maintenance costs).

Finally, for the analyzed base gas turbine process it can be concluded that the implementation of heat regenerator will bring several useful benefits and reduction of operational costs. This conclusion is valid in a situation when the gas turbine operates as a stand-alone power production machine. If such gas turbine operates in combined-cycle power plant, benefits of heat regenerator implementation will be lost due to the additional heat addition (by fuel) in heat recovery steam generator (or more of them).

8. Acknowledgment

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APPLICATION OF MODERN TECHNOLOGIES AND DEVELOPMENTS IN THE RECONSTRUCTION OF "GRAF IGNATIEV" BLVD.

Prof. PhD. Eng. Todorov S., Eng. Mihaylov D.
Faculty of transportation engineering – University of architecture, civil engineering and geodesy, Sofia, Republic of Bulgaria

stoyo_fte@uacg.bg; luckydenko@gmail.com

Abstract: *In view of the projects, which are being implemented in the second programming period 2014-2020 by the metropolitan municipality, a reconstruction of Graf Ignatiev Blvd was planned. An important part of it is the construction of the railway track. In fulfilment of the requirement for the elaboration of a diploma thesis on this topic, a number of options for implementation of the project, which apart from applied have a cognitive value. They meet the requirements for interoperability of technical infrastructure in relation to Commission Regulation (EU) No 1299/2014 of 18 November 2014 concerning the technical specifications for interoperability relating to the infrastructure subsystem of the rail system in the European Union [3].*

Keywords: Interoperability, Regulation No. 1299/2014, Railway track, Tramline

1. Introduction

In view of the projects implemented during the second programming period 2014-2020 by a metropolitan municipality, a reconstruction of the central part of the city was planned, including Graf Ignatiev Blvd., according to the technical requirements and norms of the tramway track [1].

An important part of the reconstruction of the boulevard is the construction of the track. In fulfillment of the requirement for the elaboration of a diploma thesis on the topic, according to [2], a number of project implementation options were considered which besides applied have a cognitive value.

They meet the requirements for interoperability of technical infrastructure in relation to Commission Regulation (EU) No 1299/2014 of 18 November 2014 concerning the technical specifications for interoperability relating to the infrastructure subsystem of the rail system in the European Union in Part [3], which also applies to urban rail transport.

2. Prerequisites and means for solving the problem

2.1. Current situation on "Graf Ignatiev" Blvd.

The current state of the boulevard, which has not been repaired in the first place, is severe: difficult drainage of surface water Fig.1, missing or broken drainage shafts to which the invisible state of the water supply network has to be added; emergency condition of the road surface and the reinforced concrete panels in which the unsightly tram rails are laid Fig. 2; noise and vibrations caused by the tramway movement, the suspension of the wearing ropes of the contact network to the facades of buildings Fig. 3; the construction of a third metroline and the heavy traffic from construction machines at intersections and adjacent streets [4].

2.2. Possible causes and solutions

The reasons for the state of the boulevard are complex but at this stage stand out: long repaired repairs on the water supply, road cover, tramway, contact network, electrical system, etc. In 2017 a change in Regulation No 2 on planning and designing the communication-transport system of urbanized territories [5] entered into force. The radical change that has been made for many years in tram transport [6] is the transition to a normal track gauge of 1435 mm.

A first step to shift to normal gauge is mounted on the third rail for the simultaneous movement of trams in narrow-gauge (1009 mm) and normal gauge [7]. The verification found that the change is not possible within the gauge of the existing boulevard Fig. 4 [5].

Fig.1 Drainage of surface water

Fig.2 Emergency condition of pavement and concrete panels

Fig.3 Status catenary

3. Solution to the examined problem

3.1. Drainage

The drainage of surface water, its removal and discharge to the urban sewage system, which in turn also undergoes changes in the course of the reconstruction but by a separate project, is a complex task. First of all, the longitudinal slope and the water flow along the longitudinal profile of the tram line are to be traced fig.5 [2].

The drainage of the road crossings is decided according to the drainage of the main boulevards, the existing shafts and drainage facilities, fig.6.

3.2. Noise and vibration

Graf Ignatiev Boulevard is emblematic with the surrounding buildings, most of which are cultural monuments. Noise and vibration start with the traffic and the dynamic impact of the tramway. Tram vibrations are transmitted from the track construction to the ground and from there through the foundations of the buildings to the main supporting structure. Another way to transmit noise and vibration are carrier ropes catenary [8, 9], which are anchored in the supporting structure of the building.

The output is the interruption of the chain of transmission of the vibration, improvement of the structure of the track in order to reduce the noise source and placing new load-bearing pillars of the catenary to reduce the anchorage of the supporting ropes in the construction of buildings. The design of the track is improved by applying to a rail fastening Pandrol for tramway and applying ballast less structure [7, 10], which is insulated from an underlying concrete with foam rubber.

The structure for the attachment of catenary is exported mainly of steel pillars, with a cantilever fixed slats Fig. 7 [8]. The attachment of the supporting structures of the buildings remains only exceptionally and lighting.

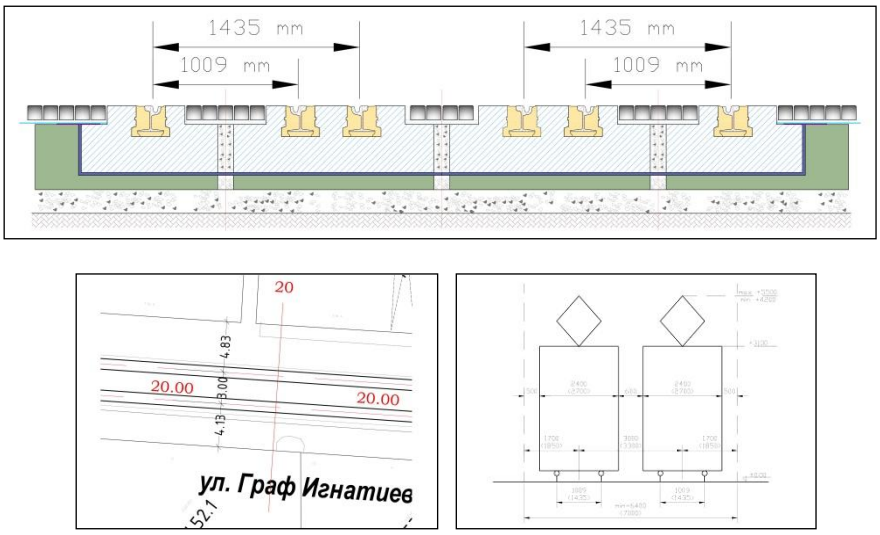

Fig.4 Gauge requirements and options for mounting a third rail

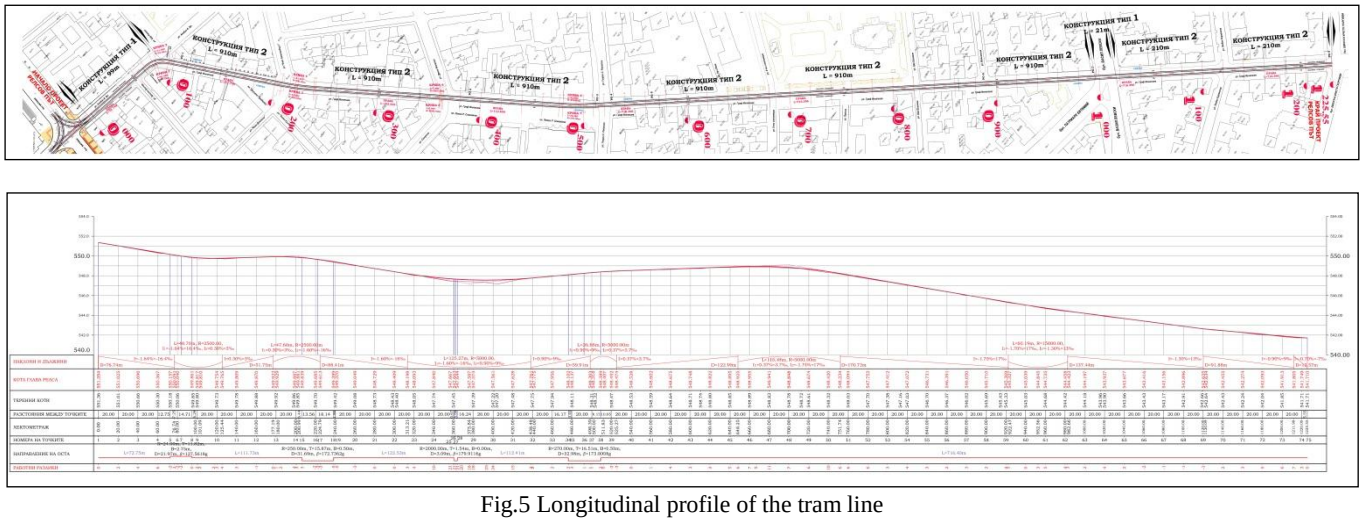

Fig.5 Longitudinal profile of the tram line

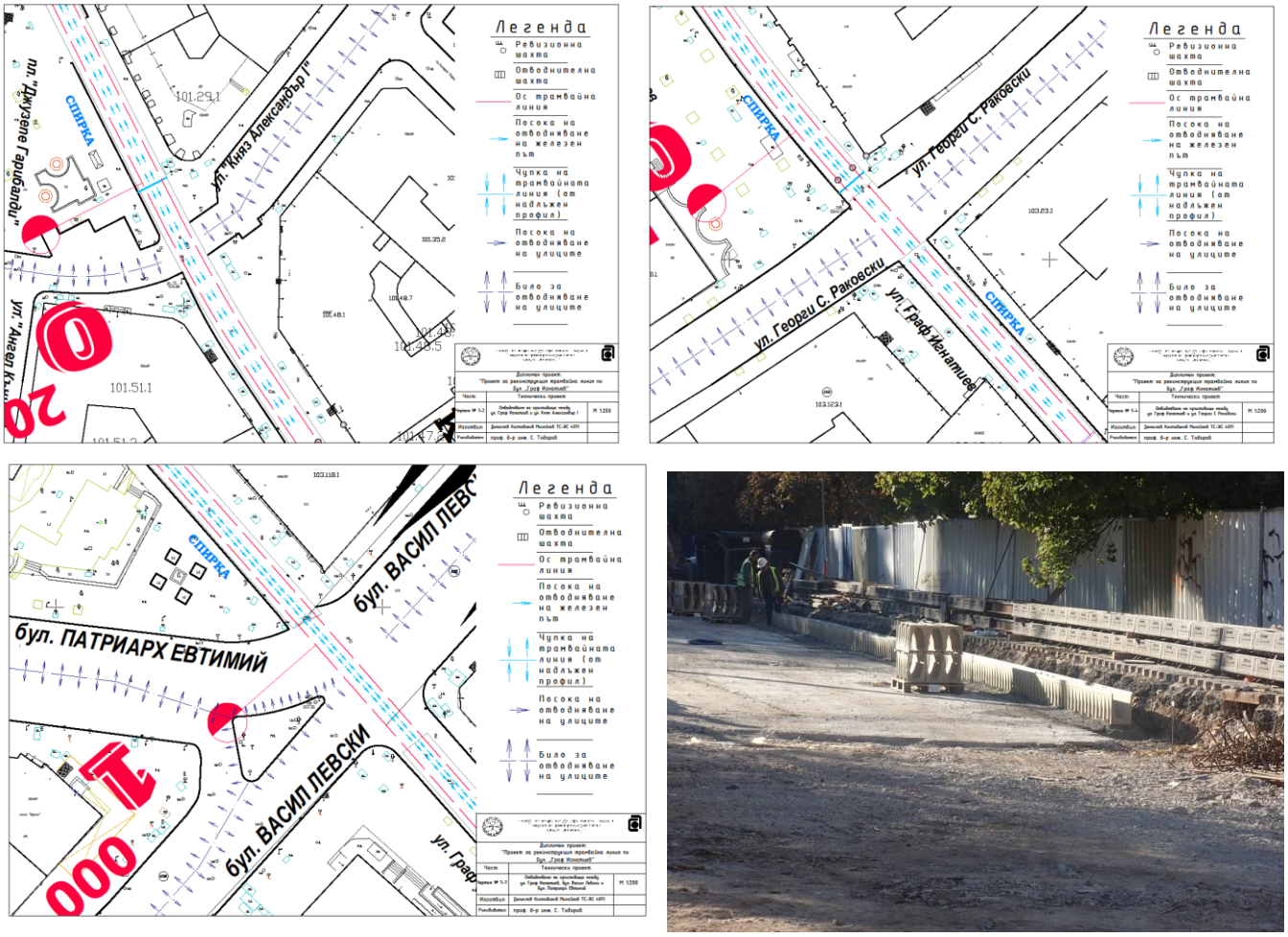

Fig.6 Drainage of main road crossings and drainage ditches

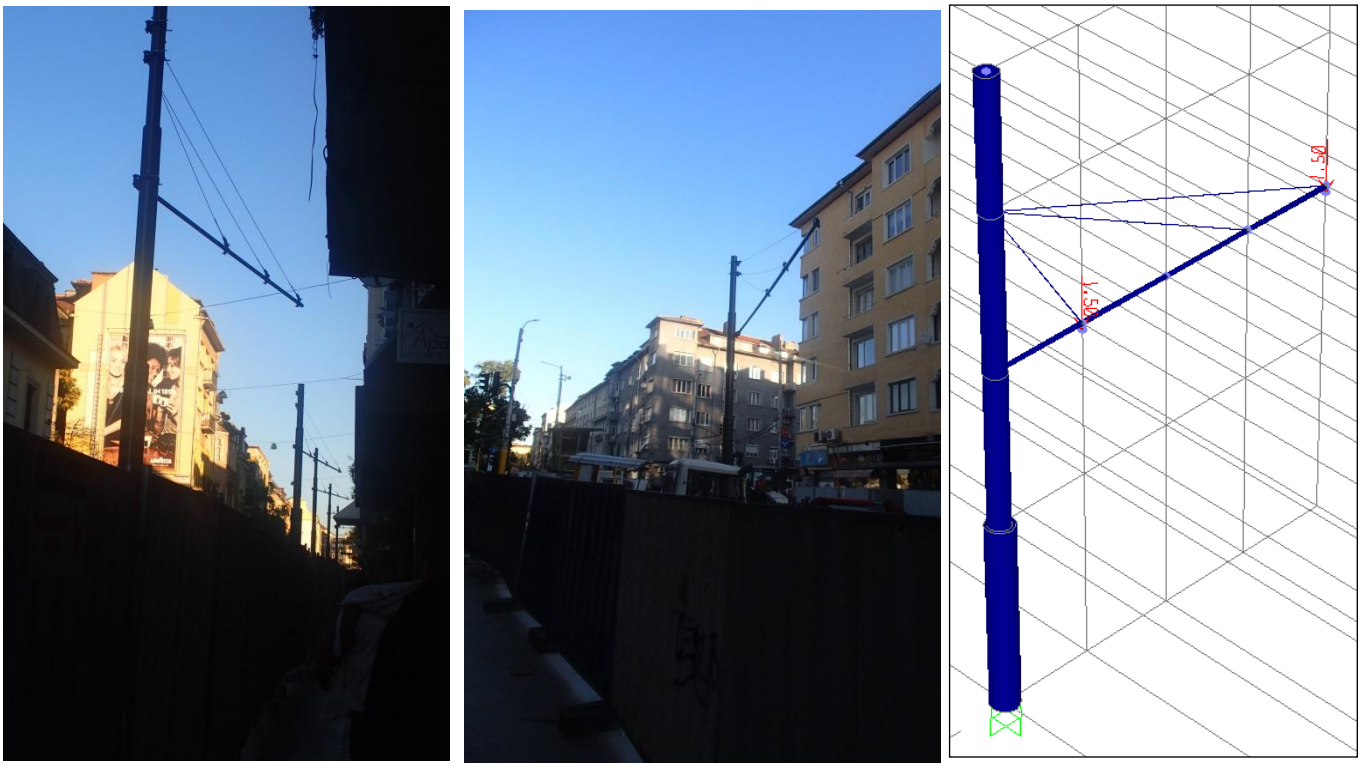

Fig. 7 Support pillars for the catenary

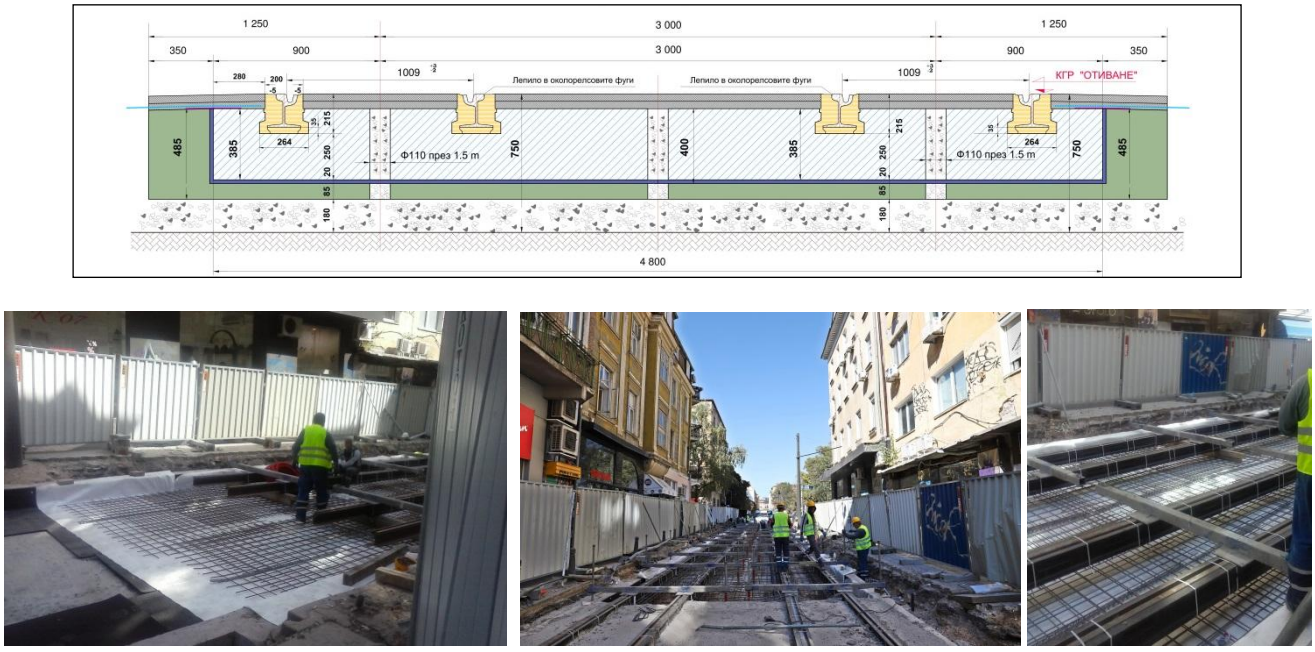

Fig.8 Construction of the tramway track

3.3. Rail Track Solutions

The track construction is improved by adding additional elastic materials (foam rubber):

- a rail tramline Pandrol fastening [10], which covers the rail with a foamed rubber sheath, is applied. This solution reduces vibrations, the rail gets elasticity in the vertical and horizontal plane, adjusts to the wheel load. The noise source is reduced Fig. 8=

- a non-ballast construction of the track is applied which is insulated from the underlayed concrete with a foam rubber, a reinforced concrete "floating" slab, poured in place - the reinforced concrete structure Fig. 8 is interrupted, which is the main conductor of vibrations with insulating and vibration-reducing matter..

4. Results and discussion

The project results are still unclear due to ongoing repairs, performance quality and having started operation. The discussion began in a professional environment, transferred to the public space, including political ground. The actual results will become clear after the start of operations, measurements and comparison of the results with those before and after the repair and with other similar sites in Sofia.

5. Conclusion

The solution to the problems of Sofia's central city district cannot happen suddenly. The way is: finding problems; analysis and study of causes; preparing an assignment and project, providing funding, public discussion and implementation. The investment process is usually 6 or 7 years. There is plenty of time to propose, analyze, and implement a publicly acceptable project.

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INFRARED OPTICAL SENSORS IN BUILDING AUTOMATION

Iureva R. PhD [1], Timko A[1]
Faculty of Computer Technologies and Control – ITMO University [1]
raddayurieva@gmail.com

Abstract: *Speaking about Industry 4.0 we can't help mentioning the role of optical sensors in building automation, especially in smart factories and automation of SCADA system. Building smart factories in concept of Industry 4.0 requires intelligent sensors and seems relevant. The paper considers management system of distributed factory and information security of it if there are used optical sensors.*

Keywords: INDUSTRY 4.0, INFORMATION SECURITY, INFRA-RED SENSORS, CYBER-PHYSICAL SYSTEMS

1. Introduction

Nowadays we are in a technological revolution that will fundamentally change the way we live, work, and interact. In this paper smart factory is considered as building which is going to be automated. Smart factory concept gives tremendous opportunities in comparison with classical factories in case of performance, cost-efficiency and flexibility. However, it is necessary to remember the problems that come with new opportunities.

When introducing new technologies developers often forget about the need to take into account information security up to the implementation stage when the changes required for reduction of the system's vulnerability become too expensive. The problem is relevant despite the fact that the first cyber attack occurred even before the advent of the Internet - in 1982 (Russian sources deny it). Then a group of hackers was able to install a Trojan in the SCADA system which controlled the work of the Siberian oil pipeline. It led to a powerful explosion [2]. The attack was organized by the CIA, although this was not known until 2004. Almost 35 years later, in November 2016, residents of apartment buildings in the Finnish city of Lappeenranta spent a week without heating and hot water. The reason was a powerful DDoS attack on a "smart" system for monitoring water temperature and pressure in radiators [3].

2. Smart Factory Security

Over the next ten years more than 70 billion devices connected worldwide will constantly exchange information with each other. This huge network of devices analyzing, transmitting, outputting data will anticipate our needs and change the perspective of the world (Fig.1, 2) [1].

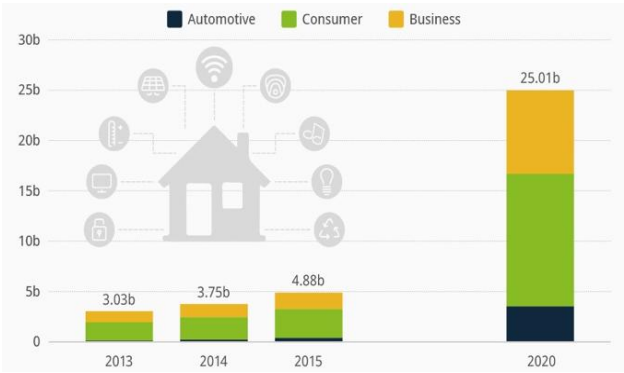

Fig. 1. *Internet of Things to Hit the Mainstream by 2020*

Industry 4.0 refers to the rapid growth of digitization in smart factories [2].

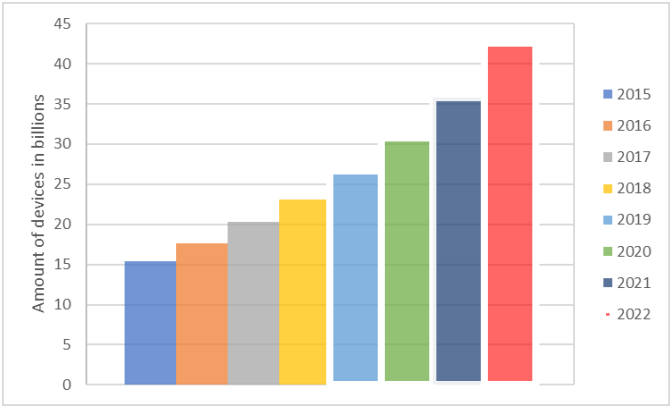

Fig.2. Forecast of the number of devices connected to the "smart factory"

Factories of the future are divided into three categories: digital, smart and virtual. Digital factory involves the use of a wide range of digital tools at all stages of design and manufacturing of products - from the research stage to the prototype. The concept of "Smart Factory" allows you to combine stand-alone machines into a single, controlled and easily analyzed production area, allowing you to evaluate the performance, the need for maintenance, the efficiency of the means of production and much more. It seems relevant to supply factories with a large number of various sensors, collecting information from which it is possible to increase the efficiency of production by reducing equipment downtime and warehouse loading, minimizing staff labor time, and hence optimizing the economic sector of an enterprise. The purpose of this study is to reduce time for recover of a smart factory after cyber-attack equipped with infrared sensors through the implementation of organizational arrangements. (fig.3) [3]. Virtual factory is integration of digital and/or smart factories into a distributed network.

Fig. 3. *Smart Factory Interconnections*

Smart factory devices can be characterized by attributes which are synthetized into the acronym S-E-N-S2-E2 – Sensing, Efficient, Networked, Specialized and Everywhere [4]:

1. "Sensing" means the application of sensors;

2. “Efficient” goes to the possibility to add “intelligence” and “efficiency” to processes by collected data;
3. “Networked” is about wireless connection between devices;
4. “Specialized” considers the specificity of the IoT tools and Computerized and Numerically Controlled (CNC) machines;
5. “Everywhere” means that the invasion of such objects are will exponentially grow in our daily life and in business processes.

The main principles of Smart factories are the following [5]:

1. Interconnection: using sensors and wireless communication CNC machines can provide people remote monitoring of production process for effectiveness and efficiency;
2. Information transparency: a lot of information is collected and analyzed which helps to optimize process, but at the same time creates several vulnerabilities of process;
3. Decentralized decisions: first two principles provide decentralized control of production area and possibility to find inner and outer weak features of the process;
4. Technical assistance: great number of decisions can be made by machines without human interference.

The principle of operation of passive infrared motion detectors is based on the registration of changes in the intensity of infrared radiation during the movement of a thermal object in the detection zone of the sensor (as any thermal object has infrared radiation). The detection zone is formed and configured (its exact geometrical dimensions are determined) using a multi-segment mirror and an optical system on Fresnel lenses, respectively. It consists of a plurality of rays (called detection rays) directed at different angles and in different directions.

Movement detection in the detection zone occurs as follows: the intersection of the rays with thermal object leads to the entry of infrared radiation pulses onto the sensitive element of the device. Modern detectors for signal processing use digital methods with microprocessor. The sensor has a spherical lens that provides a detection zone without distortion, a high collecting ability, the formation of anti-tampering zones in the volumetric and linear detection zones, as well as temperature compensation of the detecting ability when the ambient temperature changes.

Traditional approaches to ensuring information security do not solve the main task for smart factories - ensuring the continuity of the management process in conditions of destabilizing influences. This is primarily due to the lack of thoughtfulness of the security point of view, namely:

- ability to identify machine tools and software in local and global networks;
- use of obsolete general-purpose hardware and software in modern machines;
- weak authorization and authentication tools (default authentication data embedded into the software, unreliable algorithms, etc.);
- weak audit and event logging tools.

3. Cyber-tolerance of smart factory

As at present, the work of production is mainly based on staff, which is both directly working and administrative staff (fig.4). At the same time, even the choice of the optimal schedule and algorithm for the operation of production does not make it possible to promptly redistribute resources and personnel, which impedes production flexibility and introduces errors caused by the human factor. And though concept of smart factory means automation, we have to take people into account.

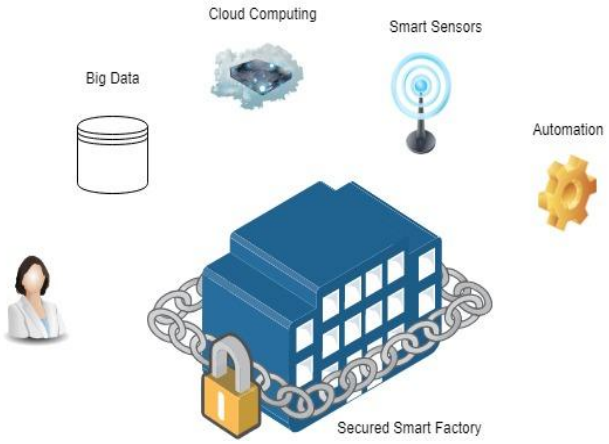

Fig.4. *Staff in Smart Factory*

One of the possible ways to overcome this problem is the use of expensive simulation software and decision support systems that generate recommendations for the organization of the enterprise. However, to work with this software, highly qualified specialists are required, as well as a huge amount of basic data on the actual work of production, which are often unavailable. According to statistics, every second company was subjected to cyber-attacks, and these attacks were mostly ignored by enterprises. At the same time, less than 2% of those attacked report incidents (a blow to reputation and a decrease in the value of shares). To ensure the safe operation of a smart factory infrared motion sensors are used but there are common ways to circumvent them:

1. Screening. The easiest way to "close" sensor is using a piece of glass or other material. The main thing is to know the location of the sensor. When ceiling mounting the sensor should be closed from above, with wall mounting - from the side. You can shield the sensor itself.

2. Movement with interruptions. Most sensors detect a target with a speed range from 0.1 to 5m /s.

3. In the afternoon, when there is a lot of movement and the guard is removed, you can try to short circuit and block the motion sensor. But sometimes a case tamper switch is installed on the detector. In this case, the use of such a method of bypassing the motion sensor is useless.

Cyber-tolerance implies planning actions not only before and during the cyber-attack process, but also after. It is determining who should be informed inside and outside the organization.

As far as infrared optical sensors only help to detect intrusion and are not guarantee information security that is why special measures are required:

1. System-wide measures for the creation of scientific, technical and methodological foundations for the protection of the network to which the CNC machines and other devises are connected;

2. Conducting special tests of used computer equipment and carrying out measures to protect information from leakage through channels of spurious electromagnetic radiation and interference;

3. Development and approval of the functional responsibilities of computer security officials;

4. Determinations of the procedure for the appointment, modification, approval and granting to specific officials of the necessary authority to access system resources;

5. Determination of the procedure for recording, issuing, using and storing removable magnetic storage media containing reference and backup copies of programs and arrays of information, archive data, etc.;

6. Organization of accounting, storage, use and destruction of documents and carriers with non-public information;

7. Distribution of access control details (passwords, encryption keys, etc.);

8. Analysis of system logs, taking action on detected violations of work rules.

4. Conclusions

When developing measures to ensure the information security of smart factories, it is necessary that people and organizations change their thinking and take into account interdependence and sustainability in order to be prepared for such scenarios where cyber risks can arise and affect the operation of systems. In this context, it is advisable to introduce the concept of cyber-tolerance - the ability of the system to resist cyber events.

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PREPARATION AND CHARACTERIZATION OF NANOSTRUCTURED FERRIC HYDROXYPHOSPHATE ADJUVANTS

N. Angelova M.Sc., G. Yordanov Ph.D. D.Sc.

University of Sofia "St. Kliment Ohridski", Faculty of Chemistry and Pharmacy, Sofia, Bulgaria

g.g.yordanov@gmail.com

Abstract: *This article describes part of the results obtained during the development of a new generation of vaccine adjuvants based on nanostructured hydroxyphosphates of tunable composition and physicochemical characteristics. Colloidal gels of ferric hydroxyphosphates of various iron/phosphate ratios were prepared by precipitation techniques, sterilized by autoclaving and analyzed by transmission electron microscopy (TEM) and dark-field optical microscopy. The obtained materials were composed of a network of amorphous nanoparticles (<20 nm in size) that were aggregated into micron-sized structures in physiological saline. Preliminary adsorption experiments indicated the ability of the obtained materials to adsorb protein substances, which is an important prerequisite for their potential application as vaccine adjuvants and further optimization of the production process to achieve reproducibility of the physicochemical characteristics.*

Keywords: ADJUVANT, IRON(III), HYDROXYPHOSPHATE, MORPHOLOGY, ADSORPTION

1. Introduction

Iron is vital for the majority of organisms by participating in the structure of many different enzymes (catalase, lipoxygenases, various oxidoreductases, etc.) and in metabolic reactions, including electron transfer, processes of transport, storage and use of oxygen [1]. Its importance for health had been recognized by the ancient inhabitants of the Balkan region, who used iron-containing red stones (the so-called *Argilla rubra*) prescribed to weak and anemic people [2]. Nowadays, nanosized colloidal dosage forms of ferric hydroxide have found clinical application as formulations for parenteral administration in the treatment of severe iron-deficiency anemia [3-5].

Interestingly, injectable suspensions of the sparingly soluble ferric hydroxide and ferric phosphate have been found to potentiate the immune response against protein antigens and therefore have been proposed for vaccine adjuvant use. The preparation of ferric-based adjuvants and their use in adjuvanted vaccines have been described mostly in patents [6-8] and rarely in scientific articles [9]. It has been found that colloidal iron hydroxide behaved comparably to aluminium hydroxide with respect to supporting induction of an antibody response to tetanus toxoid and also induced long-lasting antibody responses, which protected animals from tick-borne encephalitis virus (TBEV) infection even one year after vaccination [9]. It should be noted that the use of colloidal iron hydroxide as adjuvant had the additional advantage to reproducibly support induction of HIV-1 envelope-specific cytotoxic T lymphocytes (CTL), when used as an adjuvant for a HIV-1 env-carrying recombinant fowlpox virus and being applied via the subcutaneous route, while aluminium hydroxide was much less active in this respect [9]. The ferric phosphate has also been demonstrated to be a good adjuvant; as regards the IgG1, the results obtained have been clearly superior to those obtained when the antigen was administered alone, even though the results were not quite as good as those obtained with aluminium hydroxide; as regards the IgG2, the titers obtained were as high as those obtained with aluminium hydroxide [8]. Also, it has been found that ferric phosphate is a good adjuvant for tetanus toxoid, clearly better than ferric hydroxide under the same conditions [8].

Previous studies on aluminium hydroxyphosphate adjuvants have demonstrated that the metal/phosphate molar ratio has a significant effect on some physicochemical properties [10,11], while similar studies on their ferric-based analogues could not be found in the available literature. Here, we present our research on the preparation of ferric-based hydroxyphosphates of variable iron/phosphate molar ratio as potential candidates for adjuvant use. We studied the effects of the iron/phosphate molar ratio on the ultrastructural morphology and the formation of micron-sized aggregates in physiological saline solution. Preliminary experiments on the electrokinetic properties and protein adsorption were also performed.

2. Materials and Methods

2.1. Reagents

For the preparation of ferric hydroxide and the various ferric hydroxyphosphates, we used iron(III) chloride-6-hydrate (>99%), sodium hydroxide (>98%) and sodium phosphate tribasic dodecahydrate (>98%), purchased from Sigma-Aldrich, Germany.

2.2. Preparation of adjuvant gels

Ferric chloride-6-hydrate (1.45 mmol; 390 mg) was dissolved in distilled water (3.5 ml) and diluted with 20 ml of distilled water. Then, a solution of sodium phosphate tribasic dodecahydrate (1.45 mmol; 550 mg) in distilled water (3.5 ml) was added dropwise with stirring (600 rpm) to prepare the $FePO_4$ dispersion; for preparation of the $Fe(OH)_3$ dispersion, NaOH (4.35 mmol; 175 mg) was used instead of sodium phosphate. Three different hydroxyphosphates were also prepared with initial Fe/P molar ratio 100/75, 100/50 and 101 100/25 by keeping the total amount of iron equal to 1.45 mmol. The hydroxyphosphates were precipitated from the ferric chloride solution by using a mixed solution of sodium hydroxide and sodium phosphate with amounts of regents calculated to obtain the expected composition. For example, in order to obtain the composition $FePO_4.Fe(OH)_3$ (Fe/P = 100/50), 87 mg (2.175 mmol) of NaOH and 275 mg (0.725 mmol) of $Na_3PO_4.12H_2O$, dissolved in 3.5 ml of distilled water, were used. The pH of dispersions should not exceed 7. The precipitates formed were stirrered for 5 minutes at room temperature and were autoclaved for 30 min (121 °C).

2.3. Physicochemical characterization

The particle morphology and ultra-structure were observed by transmission electron microscope JEM-2100 (JEOL) at acceleration voltage of 200 kV, equipped with a micro-analyzer X-Max 80T (Oxford Instruments). Micron-sized aggregates in the gels were visualized directly in 0.9% NaCl by using an optical microscope (Optika B-180, Italy) with a dark-field condenser.

3. Results and discussion

3.1. Physicochemical properties

The ultrastructural morphology of the obtained ferric phosphates prepared by using different initial Fe/P (iron/phosphate) molar ratios showed a network of nanoparticles of average sizes up to about 20 nm that were aggregated into micro-sized structures (up to about 30 μm), as seen from the transmission electron images shown in Fig. 1.

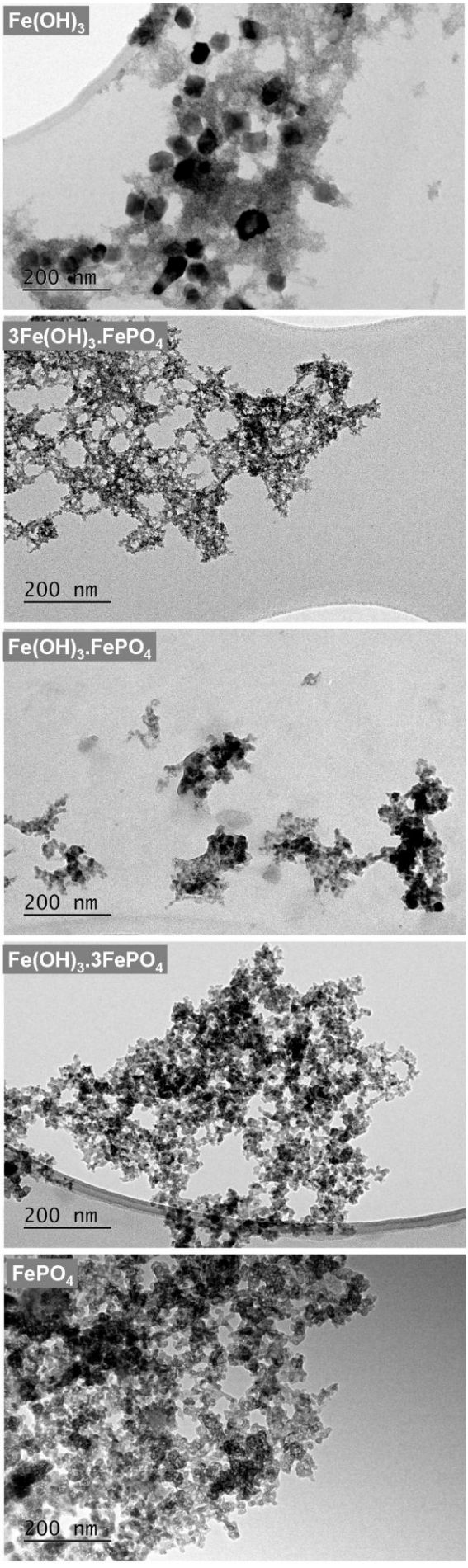

***Fig. 1**. TEM images at magnification of x25k of $Fe(OH)_3$, $FePO_4$ and different ferric hydroxyphosphates (given in the figure legends).*

This morphology was very similar to that of aluminium phosphate currently used in human vaccinations, although the primary nanoparticles of aluminium phosphate are larger, about 20-50 nm in size [12,13]. The increasing hydroxide/phosphate ratio (that corresponds also to increased Fe/P ratio) resulted in the formation of ferric hydroxyphosphates with even smaller primary nanoparticles of sizes <20 nm. These primary nanoparticles were aggregated into clusters via "bridges" of amorphous material.

Analysis by energy dispersive spectrometry (EDS) showed the presence of iron, phosphorous and oxygen. A representative scanning TEM (STEM) image and maps of element (Fe, P and O) distribution in the ferric hydroxyphosphate with an initial molar ratio of Fe/P = 100/50 is shown in Fig. 2. The signals for the elements Fe, P and O are localized in the same areas, indicating the formation of hydroxyphosphate particles (but not separate hydroxide and phosphate particles). Data from quantitative EDS measurements of the Fe/P/O ratio in the obtained materials showed that it was close to that was used in their preparation. However, these values should be interpreted with care, because we found that they may depend on the time for count accumulation probably as a result of changes in the material upon interaction with the electron beam of the microscope. The morphology of the sample can also change upon longer observation times. It should be noted that the interaction with the electron beam can result in heating of the observed sample, dehydration and evaporation of material thus affecting both the morphology and the elemental composition. For that reason, TEM images (Fig. 1) were taken with minimum time of exposure of the material to the electron beam (within less than few minutes).

The electron diffraction analysis showed that the obtained hydroxyphosphates with different hydroxide/phosphate ratio were structurally amorphous. The ultrastructure of the sample formally referred to "ferric hydroxide" or "$Fe(OH)_3$" (prepared by using sodium hydroxide instead of phosphate) was quite different from that of the ferric hydroxyphosphates prepared at similar conditions. TEM observation revealed that it contained nanocrystals of size up to ~50 nm that were dispersed within an amorphous matrix. Under high-resolution mode (HRTEM) the matrix appeared granular, containing vary small particles, about 3 nm in size. The composition of the sample according to EDS analysis corresponded to Fe/O molar ratio of 1.0/2.4, while the nanocrystalline phase was confirmed to be hematite.

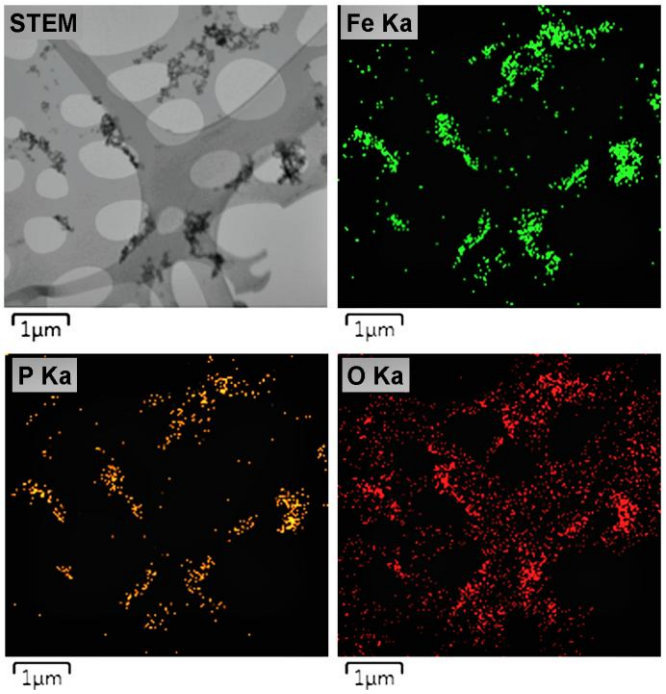

***Fig.2**. STEM image and maps of element (Fe, P and O) distribution of ferric hydroxyphosphate (Fe/P = 100/50), $Fe(OH)_3.FePO_4$.*

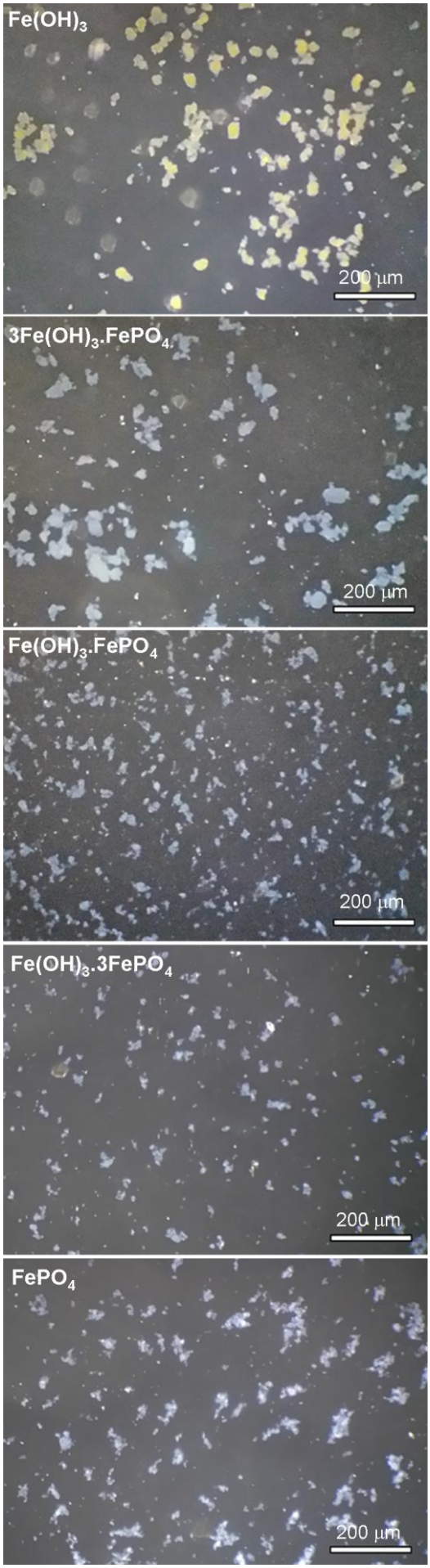

***Fig.3**. Dark-field optical microscopy images of the micron-sized aggregates of ferric hydroxyphosphates in physiological saline.*

Analysis by X-ray powder diffraction (XRD) confirmed the amorphous structure of the obtained materials and the presence of a nanocrystalline hematite phase in the $Fe(OH)_3$ sample (data not shown). It should be noted that the hematite phase was formed during the autoclaving, since the non-autoclaved $Fe(OH)_3$ sample was structurally amorphous.

We used a dark-filed optical microscope to observe the micron-sized aggregates (secondary particles formed by the aggregated primary nanoparticles) in 0.9% NaCl (Fig. 3). There were different structures – raging in size from few microns to about 20-30 μm. The ferric hydroxide sample contained the largest particles, which were colored in yellow. These samples were also prone to relatively faster sedimentation forming a fine precipitate upon standing, while all ferric hydroxyphosphates appeared as gel-like suspensions that formed a gel sediment upon mild centrifugation. The aggregation state of adjuvants in vaccines depends also on its concentration and interactions with proteins and other components of the formulation [14]. The size of secondary adjuvant particles (aggregates) appears to be of importance for both the effective adsorption of antigens and phagocytosis of adjuvant particles by antigen-presenting cells [15,16]. The relatively larger particle size in the case of ferric hydroxide may be a reason to expect a lower rate of phagocytosis compared to the hydroxyphosphates although it can be revealed only by detailed future experiments on the intracellular fate of these adjuvant systems.

3.2. Potentials for adjuvant use

Inorganic adjuvants, such as aluminium oxyhydroxide and hydroxyphosphate, which are currently used in many human and veterinary vaccinations, are known to serve as enhancers of antigen phagocytosis and activation of antigen-presenting cells [17], as well as stimulators of inflammatory reactions that appear to play a key role in mediating adjuvanticity and subsequent development of specific immunity [18]. It is currently known that the immune potentiation requires phagocytosis of the adjuvant/antigen by dendritic cells [19]. Similar mechanisms of adjuvanticity can be assumed also for the ferric-based adjuvants, since it is well-established that particulate ferric hydroxide is rapidly phagocytosed by macrophages upon parenteral administration [20,21]. The ferric-based adjuvants can potentially serve as antigen carriers to the phagocytic antigen-presenting cells. In preliminary experiments, we found that all investigated ferric hydroxyphosphate adjuvant gels had isoelectric points between 3.5 and 4.5, and could adsorb albumin (as a model of protein antigen), about 30 mg/mmol Fe(III) at pH 7, which is an important prerequisite for their potential application as protein antigen carriers (details on zeta-potential measurements and protein adsorption will be reported elsewhere).

Among the most important issues in the development of inorganic adjuvants besides efficacy are their safety [22], immunotoxicity [23] and toxicokinetics [24]. High loading of insoluble adjuvant particles in phagocytic cells without immediate cytotoxicity might predispose to their subsequent transport throughout the body, while on the other hand, heightened solubility of adjuvants and potentially the generation of metal ions in the endosomal environment have been positively correlated with an increase in cell mortality *in vitro* [25]. Although it has been demonstrated that ferric phosphate could be dissolved in citrate solutions, similarly to aluminium phosphate [12], the *in vivo* degradation of the ferric-based adjuvants is still unknown. It might be expected that endosomal degradation of ferric phosphates would result in the release of ferric ions inside phagosomes. Phagocytic cells have the ferroportin transmembrane transporter that facilitates transportation of ferric ions out of the cell [21]. Once exported into the extracellular environment, most of the ferric ions are expected to bind with transferrin (ferric-specific transporter protein in blood plasma) and to be included in the normal iron metabolism. Also, adverse effects from the relatively small amount of iron (few milligrams) applied during vaccination are less likely to occur since iron is present in humans in relatively large amounts (35-50 mg iron/kg body weight). However, detailed toxicokinetic experiments

must be performed in order to evaluate the exact safe doses of the different ferric-based adjuvants.

4. Conclusions

Ferric hydroxyphosphates of various Fe/P molar ratios as potential adjuvants have been prepared and characterized. The hydroxyphosphate gels consisted of networks of primary amorphous nanoparticles of average sizes about <20 nm, smaller in size compared to those of aluminum phosphate adjuvants (20-40 nm). The ferric hydroxide obtained at similar conditions consisted of hematite nanocrystals dispersed into amorphous matrix. These primary nanoparticles formed micron-sized aggregates (secondary particles) in physiological solution. Preliminary experiments indicated the ability of the obtained adjuvant gels to adsorb protein substances, which is an important prerequisite for their potential application as vaccine adjuvants and further optimization of the production process.

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АНАЛИЗ НА ВЪЗМОЖНОСТИТЕ ЗА ИЗПОЛЗВАНЕ НА ТЕРМОПОМПЕНА СИСТЕМА С РАДИАЦИОНЕН ИЗПАРИТЕЛ ЗА ОТОПЛЕНИЕ НА СГРАДИ И ЗАГРЯВАНЕ НА ГОРЕЩА ВОДА ЗА БИТОВИ НУЖДИ (ГВБН)

ANALYSIS OF THE POSSIBILITIES OF USING A HEAT PUMP SYSTEM WITH A RADIATION EVAPORATOR FOR HEATING OF BUILDINGS AND HOT WATER FOR DOMESTIC USE

eng. Traicho Trayanov

***Abstract**: The report presents some results from an experimental study of a solar-water heat pump unit with a radiation evaporator, which was conducted in order to analyze the possibilities for its use for heating of buildings and hot water for domestic use.*

Key words: solar heat pump system, radiation evaporator, renewable energy sources, heating with renewable sources

Technical University Sofia, energydesignbg@gmail.com

Въведение

Оползотворяването на енергията от възобновяемите енергийни източници е една от възможностите за намаляване на експлоатационните разходи на системите за поддържане на параметрите на микроклимата и за битово горещо водоснабдяване в сгради. Климатичните условия на България са предпоставка за значим потенциал, както на слънчевата, така и на енергията на атмосферния въздух. Специфичните особености на топлопобменните процеси между термичните слънчеви колектори и околната среда обаче обуславят по-ниската им ефективност през зимния период и невъзможността за постигане на високи коефициенти на покритие в системите за отопление на сгради.

Друга, широко разпространена в последните десетилетия е технологията за отопление с термопомпени агрегати, оползотворяващи потенциала на атмосферния въздух, чиято ефективност обаче значително намалява при ниски външни температури.

В настоящата публикация е представено изследване на експериментална система за отопление и ГВБН с интегриран термопомпен агрегат с радиационен изпарител.

Основната цел на представените в настоящия доклад резултати е оценка на възможностите за използване и ефективността на термопомпения агрегат в режим на отопление през зимния период. За постигането ѝ са проведени изследвания и са оценени експлоатационните параметри на системата и коефициентът на преобразуване на термопомпения агрегат при различни площ на радиационният изпарител и зададена стойност на вътрешната температура.

Функционална схема на експерименталния стенд

Ефективността на изследвания термопомпен агрегат при различни експлоатационни условия е оценена чрез натурни изпитания на експерименталната система, изградена на площадка за ВЕИ към Технически университет - София. Принципната и функционална схема е показана на фигура 1.

Схемата е разработена по начин, позволяващ оценка на поведението и ефективността на термопомпен агрегат тип „слънце-вода“ с радиационен изпарител при различни експлоатационни условия както при загрявана вода за битови нужди, така и при поддържане на зададена температура в експерименталната къща през отоплителният сезон. При зимни условия от експерименталната система работят два кръга:

- ***Кръг термопомпен агрегат***

За преобразуване на слънчевата енергия в топлина се използва термопомпен агрегат тип „слънце-вода“ с отоплителна мощност 3 000 W. Изпарителят е радиационен тип и е оформен като абсорбер-колектор, в който хладилният агент се изпарява под въздействието на пряката и дифузна слънчева радиация, както и на обмяната на енергия с околната среда. Площта му може да бъде променяна в границите от 0,0 m^2 до 3,2m^2. Кондензаторът е пластинчат топлообменен апарат с водно охлаждане, окомплектован с циркулационна помпа, предпазна и регулираща арматура.

- ***Кръг отопление***

За отнемане на топлината от кондензатора и поддържане на зададена температура в помещението през отоплителният сезон се използва вентилаторен конвектор за подов монтаж тип „въздух – вода“ с максимална отоплителна мощност 3 000 W. По пътя на загряваният топлоносител (вода) са монтирани дебитомер, температурни датчици на подаващият и на връщащият тръбопровод, автоматични обезвъздушители, спирателни кранове, допълваща и филтрираща група, както и предпазна и регулираща арматура.

- ***Кръг ГВБН***

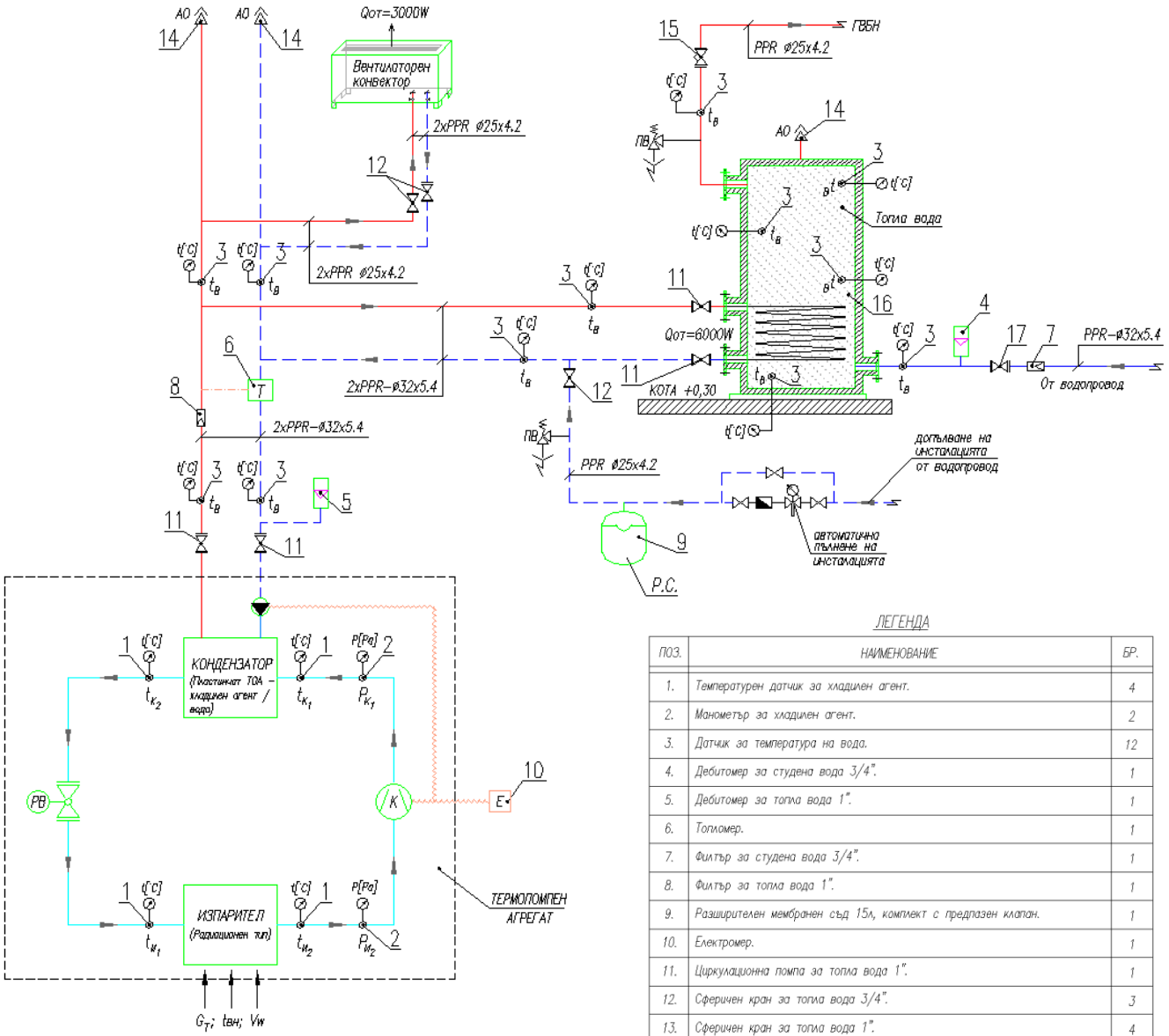
За съхранение на оползотворената от слънцето радиация и енергията на външният въздух е предвиден бивалентен обемен акумулатор с вградена серпентина, окомплектован с електрически нагревател с мощност 3 000 W, термостат, обезвъздушителен и предпазен клапан. Чрез регулиращ вентил по пътя на загряваната водопроводна вода е осигурена възможност за симулиране на различни режими на потребление на топлоносител за битово горещо водоснабдяване.

- ***Система за измерване***

Осигурена е възможност за измерване на дебита на топлоносителя (вода), преминал през вентилаторния конвектор, на налягането на хладилния агент преди и след компресора на термопомпения агрегат, както и на следните температури в седем специфични точки в системата:

Експерименталната система е оборудване с автоматизиране система за измерване и регистриране на следните режимни параметри:

- Температура на хладилния агент на входа и изхода от изпарителя $\vartheta_{0,in}$, $\vartheta_{0,out}$, ^oC;
- Температура на хладилния агент на входа и изхода от компресора $\vartheta_{K,in}$, $\vartheta_{K,out}$, ^oC;
- Температура на хладилния агент на пред и след ТРВ $\vartheta_{V,in}$, $\vartheta_{V,out}$, ^oC;
- Налягане на изпарение и кондензация p_o , p_C , bar;
- Температура на загряваната от термопомпения агрегат вода на входа и изхода от топлинния акумулатор $\vartheta_{HW,in}$, $\vartheta_{HW,out}$, ^oC;
- Температура в долната и горна част на топлинния акумулатор $\vartheta_{ST,in}$, $\vartheta_{ST,out}$, ^oC;
- Дебит на топлоносителя през серпентината на топлинния акумулатор $\dot{m}_{ST}$, m^3/h;
- Дебит на водопроводната вода през топлинния акумулатор $\dot{m}_W$, m^3/h;
- Консумирано електричество P, kWh;
- Интензитет на пълната и дифузна слънчева радиация върху хоризонтална повърхнина, G , G_d , W/m^2.

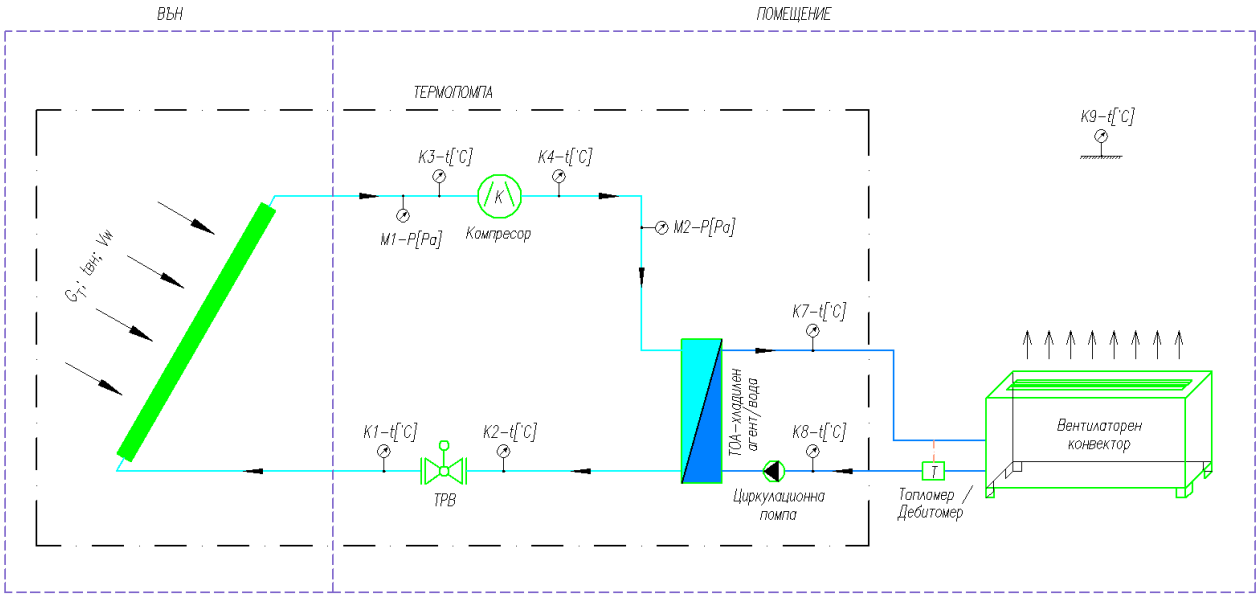


ЛЕГЕНДА

ПОЗ.	НАИМЕНОВАНИЕ	БР.
1.	Температурен датчик за хладилен агент.	4
2.	Манометър за хладилен агент.	2
3.	Датчик за температура на вода.	12
4.	Дебитомер за студена вода 3/4".	1
5.	Дебитомер за топла вода 1".	1
6.	Топломер.	1
7.	Филтър за студена вода 3/4".	1
8.	Филтър за топла вода 1".	1
9.	Разширителен мембранен съд 15л, комплект с предпазен клапан.	1
10.	Електромер.	1
11.	Циркулационна помпа за топла вода 1".	1
12.	Сферичен кран за топла вода 3/4".	3
13.	Сферичен кран за топла вода 1".	4
14.	Автоматичен обезвъздушител 1/2".	3
15.	Кран за топла вода с прецизно контолиране на дебита.	1
16.	Бивалентен акумулатор за топла вода, комплект с предп. и рег. арматура.	1
17.	Сферичен кран за студена вода 3/4".	1

Фигура 1. *Схема на експериментален стенд.*

На фиг. 2 е показана принципна схема на експерименталният стенд в режим на отопление.



Фигура 2. *Принципна схема на експериментален стенд – кръг отопление*

K1 – Температура на хладилния агент след ТРВ;
K2 – Температура на хладилния агент след кондензатора;
K3 – Температура на хладилния агент след изпарителя;
K4 – Температура на хладилния агент след компресора;
K7 – Температура на топлоносителя след кондензатора;
K8 – Температура на топлоносителя след вентилаторния конвектор;
K9 – Температура работната зона на помещението.

По-долу в публикацията са показани резултати на част от експерименталните измервания направени в периода 10.01.2018 – 11.02.2018г.

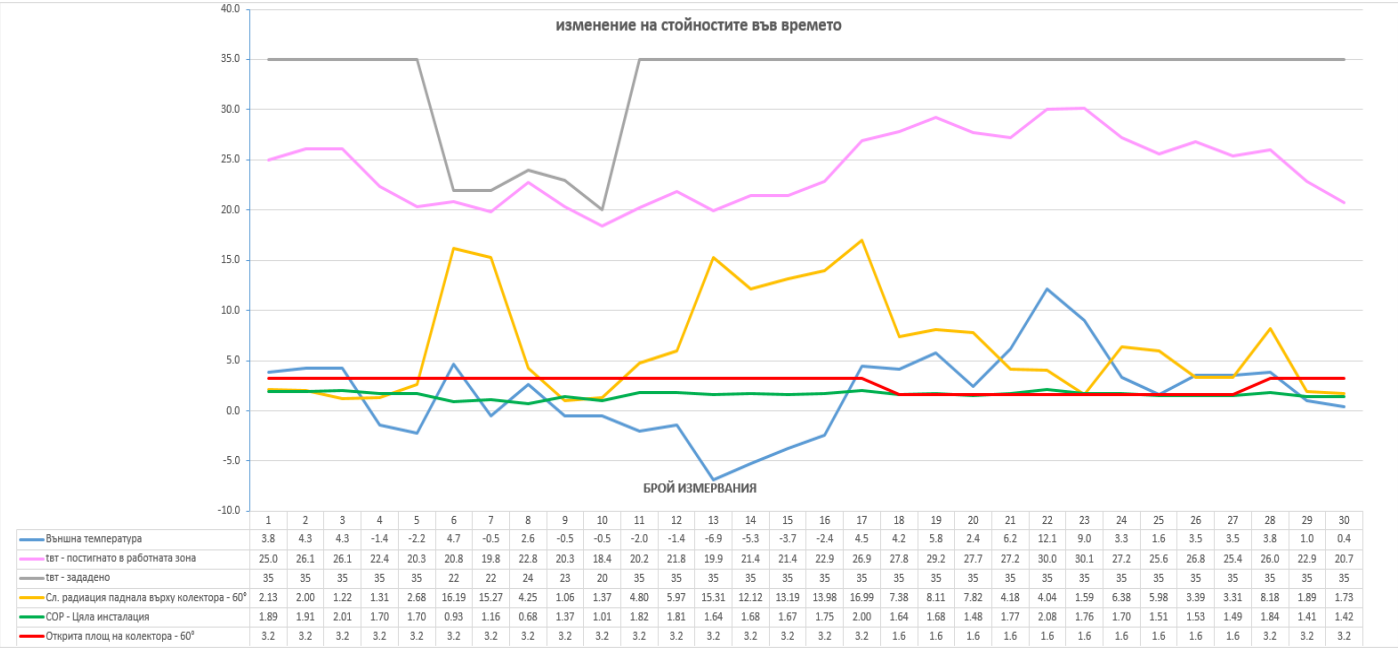
На фиг. 3 са показани в обобщен табличен вид, изменението някой от основните параметри на натурните изследвания направени в периода 10.01.2018 – 11.02.2018г.
В таблицата отчетливо се забелезва обособяването на два периода. Периода от 23.01.2018г. до 28.01.2018г. и периода от 29.01.2018г. до 07.02.2018г.
Общото между тези периоди е, че е зададено поддържането на максимална температура в работното помещение. Разликата в двата перода е, че при първият площта на абсорбер-колетора е максимална (3,2m^2) а при вторият площа е редуцирана с 50% (1,6 m^2).
От таблицата отчетливо се забелезват взаимовръзките между интензитета на слънчевата радиация достигнал до повърхността на радиационният изпарител, външната температура, скоростта на вятъра, количеството валежи и COP на инсталацията, и постигнатата вътрешна температура в работното помещение.

Анализът на показаните по-горе резултати сочи, че при външна температура - 0,5°C и - 6,9°C съответните стойности на вътрешната температура са 18,4°C (21.01.2018 г.) и 19,9°C (21.01.2018 г.). Очевидно е, че повишението на температурата в помещението на 21.01.2018 г. се дължи на значително по-високата стойност на интензитета на попадналата върху радиационния изпарител слънчева радиация.

От таблоцата по-горе се вижда, че при сравнително близки стойности на интензитета на слънчевата радиация (1,37 KWh на 21.01.2018 г. и 1,76 KWh на 03.02.2018 г.), но при съществена разлика във външните температури (- 0,5°C и +9,0°C), са наблюдава и значителна разликата в достигнатите температури в отопляваното помещение (+18,4°C и +30,1°C). Това се дължи основно на конвективния характер на топлообменния процес между радиационния изпарител и околната среда при ниски стойности на интензитета на слънчевата радиация. При подобни експлоатационни условия ефективността на системата в много по-голяма степен зависи от външната температура, отколкото от интензитета на слънчевата радиация.

ОБОБЩЕНИ РЕЗУЛТАТИ ОТ ИЗМЕРВАНИЯТА НАПРАВЕНИ В ПЕРИОДА 10.01.2018г. - 11.02.2018г.																															
Измерване	№/дим.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Дата на измерването - 2018г	дата	10.01	11.01	12.01	13.01	14.01	16.01	18.01	19.01	20.01	21.01	22.01	23.01	24.01	25.01	26.01	27.01	28.01	29.01	30.01	31.01	1.02	2.02	3.02	4.02	5.02	6.02	7.02	8.02	9.02	10.02
Продължителност на измер	h	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0
Време на работа на инстала	h	24.0	24.0	24.0	24.0	24.0	16.9	19.2	20.4	21.4	19.8	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0
Открита площ на колектора	m^2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	3.2	3.2	3.2
Вложена ел. енергия	kWh	15.5	15.2	14.8	14.4	14.0	10.1	10.7	12.1	11.9	10.9	14.2	13.9	13.9	14.4	14.6	14.4	14.6	15.1	15.1	15.2	14.3	14.4	15.0	14.8	14.9	14.7	15.1	12.6	12.7	12.7
Отдадена енергия от инстал	kWh	29.3	29.0	29.8	24.5	23.8	9.3	12.5	8.3	16.4	11.0	25.9	25.1	22.7	24.2	24.3	25.1	29.2	24.8	25.3	22.5	25.3	30.0	26.5	25.1	22.5	22.5	22.4	23.2	17.9	18.0
COP - Цяла инсталация	-	1.89	1.91	2.01	1.70	1.70	0.93	1.16	0.68	1.37	1.01	1.82	1.81	1.64	1.68	1.67	1.75	2.00	1.64	1.68	1.48	1.77	2.08	1.76	1.70	1.51	1.53	1.49	1.84	1.41	1.42
COP - Термопомпата	-	2.46	2.50	2.65	2.26	2.28	1.24	1.59	0.91	1.88	1.39	2.43	2.43	2.20	2.24	2.21	2.32	2.65	2.15	2.20	1.94	2.36	2.77	2.32	2.24	1.99	2.03	1.95	2.57	1.97	1.97
$t_{вт}$ - зададено	°C	35	35	35	35	35	22	22	24	23	20	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
$t_{вт}$ - постигнато в работната з	°C	25.0	26.1	26.1	22.4	20.3	20.8	19.8	22.8	20.3	18.4	20.2	21.8	19.9	21.4	21.4	22.9	26.9	27.8	29.2	27.7	27.2	30.0	30.1	27.2	25.6	26.8	25.4	26.0	22.9	20.7
Външна температура	°C	3.8	4.3	4.3	-1.4	-2.2	4.7	-0.5	2.6	-0.5	-0.5	-2.0	-1.4	-6.9	-5.3	-3.7	-2.4	4.5	4.2	5.8	2.4	6.2	12.1	9.0	3.3	1.6	3.5	3.5	3.8	1.0	0.4
Отн. влажност на външния	%	84.4	79.9	79.9	85.6	77.6	71.7	61.8	65.0	91.6	86.9	76.3	72.7	77.5	77.9	78.1	79.8	65.9	69.8	59.6	73.2	66.9	54.6	72.9	62.8	72.7	73.2	87.0	82.9	86.6	89.1
Пълна сл. радиация - хориз	kWh/m^2	0.66	0.57	0.38	0.40	0.70	2.60	2.30	0.74	0.27	0.25	1.09	1.31	2.55	2.26	2.47	2.54	2.73	2.80	2.85	2.80	1.16	2.04	0.95	3.07	3.01	2.01	1.85	2.43	0.58	0.47
Сл. радиация паднала върху	kWh	2.13	2.00	1.22	1.31	2.68	16.19	15.27	4.25	1.06	1.37	4.80	5.97	15.31	12.12	13.19	13.98	16.99	7.38	8.11	7.82	4.18	4.04	1.59	6.38	5.98	3.39	3.31	8.18	1.89	1.73
Скорост на вятъра	m/s	0.4	0.3	0.3	1.3	1.1	0.9	0.9	0.5	0.4	1.5	0.8	0.5	0.2	0.2	0.1	0.2	0.8	0.6	0.9	0.4	0.6	1.5	1.5	1.3	0.3	1.5	0.8	0.8	0.4	0.8
Валеж от дъжд	l/m^2	0.0	0.0	1.2	0.4	0.0	2.6	0.0	0.0	0.0	0.8	0.0	0.6	0.4	1.2	1.0	0.6	0.2	0.0	0.0	0.0	0.0	0.0	0.0	3.8	0.0	0.0	0.0	3.0	0.0	3.6
Атмосферно налягане	kPa	102.2	101.3	101.8	102.3	102.5	101.5	100.8	101.3	101.2	100.8	101.0	102.0	103.1	102.9	102.6	102.9	103.2	102.9	102.5	102.4	101.6	101.4	100.7	101.0	102.1	102.0	101.8	101.3	101.5	101.1

Фигура 3. *Изменение на някои от параметрите на експерименталната система (за периода от 10.01.2018 г. до 11.02.2018 г.)*



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Външна температура	3.8	4.3	4.3	-1.4	-2.2	4.7	-0.5	2.6	-0.5	-0.5	-2.0	-1.4	-6.9	-5.3	-3.7	-2.4	4.5	4.2	5.8	2.4	6.2	12.1	9.0	3.3	1.6	3.5	3.5	3.8	1.0	0.4
tвт - постигнато в работната зона	25.0	26.1	26.1	22.4	20.3	20.8	19.8	22.8	20.3	18.4	20.2	21.8	19.9	21.4	21.4	22.9	26.9	27.8	29.2	27.7	27.2	30.0	30.1	27.2	25.6	26.8	25.4	26.0	22.9	20.7
tвт - зададено	35	35	35	35	35	22	22	24	23	20	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
Сл. радиация паднала върху колектора - 60°	2.13	2.00	1.22	1.31	2.68	16.19	15.27	4.25	1.06	1.37	4.80	5.97	15.31	12.12	13.19	13.98	16.99	7.38	8.11	7.82	4.18	4.04	1.59	6.38	5.98	3.39	3.31	8.18	1.89	1.73
COP - Цяла инсталация	1.89	1.91	2.01	1.70	1.70	0.93	1.16	0.68	1.37	1.01	1.82	1.81	1.64	1.68	1.67	1.75	2.00	1.64	1.68	1.48	1.77	2.08	1.76	1.70	1.51	1.53	1.49	1.84	1.41	1.42
Открита площ на колектора - 60°	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	3.2	3.2	3.2

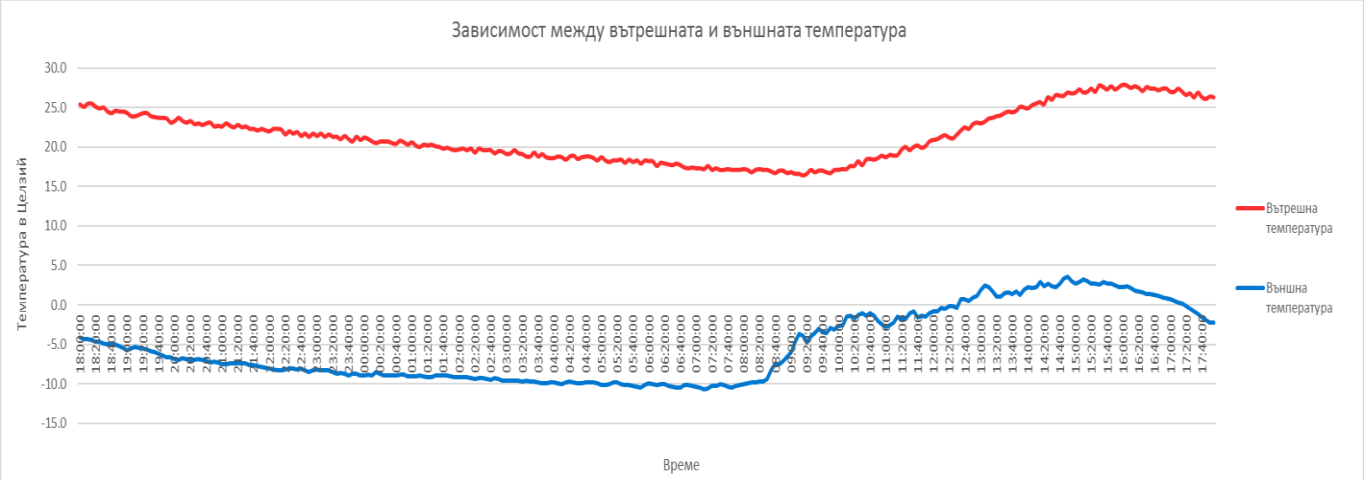
Фигура 4. *Изменение на някои от параметрите на експерименталната система (за периода от 10.01.2018 г. до 11.02.2018 г.)*

На фиг. 4 е показано в графичен вид, изменението на част от параметрите в периода 10.01.2018 – 11.02.2018г. При графичният анализ на експерименталните резултати в този период, още по-ясно се забелява връзката между слънчевата радиация, външната температура, COP на инсталацията и постигнатата вътрешна температура в работното помещение. От графиката показна на фиг. 4 се вижда ясно изразената зависимост на вътрешната температура както от външната температура, така и от слънчевата радиация, паднала върху радиационният изпарител. Впечатление правят резултатите от измерванията, проведени на 21.01.2018 г., на 24.01.2018 г. и на 03.02.2018 г.*Експериментално изследване на 21.01.2018 г.:* $t_{вн}$ = - 0,5°C; $t_{вт}$ = 18,4°C; G_T = 1.37 KWh;

- *Експериментално изследване на 24.01.2018 г.:* $t_{вн}$ = - 6,9°C; $t_{вт}$ = 19,9°C; G_T = 15.31 KWh;
- *Експериментално изследване на 03.02.2018 г.:* $t_{вн}$ = + 9,0°C; $t_{вт}$ = 30,1°C; G_T = 1.76 KWh.

Някои резултати от експерименталното изследване

На Фигура 5 е представена графика с изменение на стойностите на външната и температура в експерименталната къща. Ясно се забелязва пряката връзка между тях, като се установява, че закъснението на повишаването и достигане на максимална стойност на вътрешната температура е 1 час и 15 минути след това на външната температура.

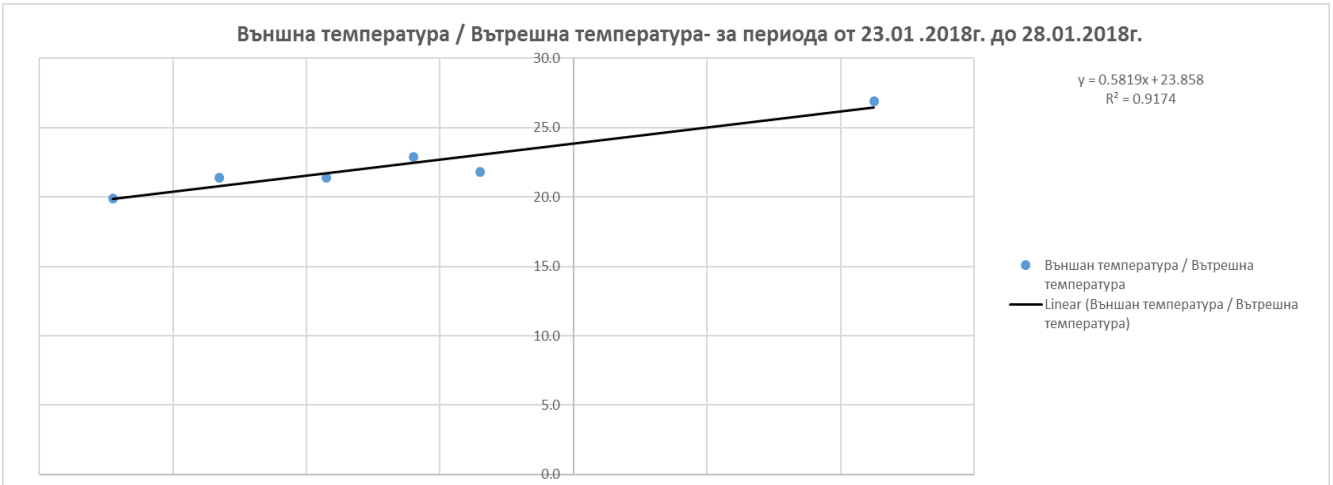


Фигура 5. *Изменение на външната и температурата в помещението (измерване на 25.01.2018 г.)*

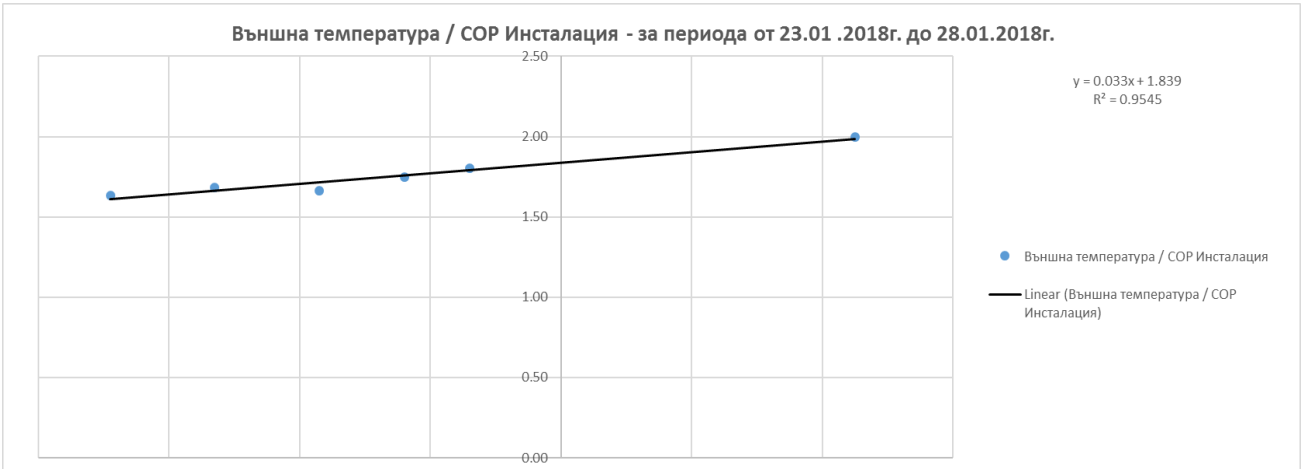
На Фигура 6 е показан ходът на пълната слънчева радиация, попаднала върху повърхнината на радиационния изпарител и зависещото от него изменение на температурата на топлоносителя на входа във вентилаторния конвектор.

Фигура 6. Изменение на пълната слънчева радиация върху на радиационния изпарител и температурата на топлоносителя към вентилаторния конвектор (измерване на 25.01.2018 г.)

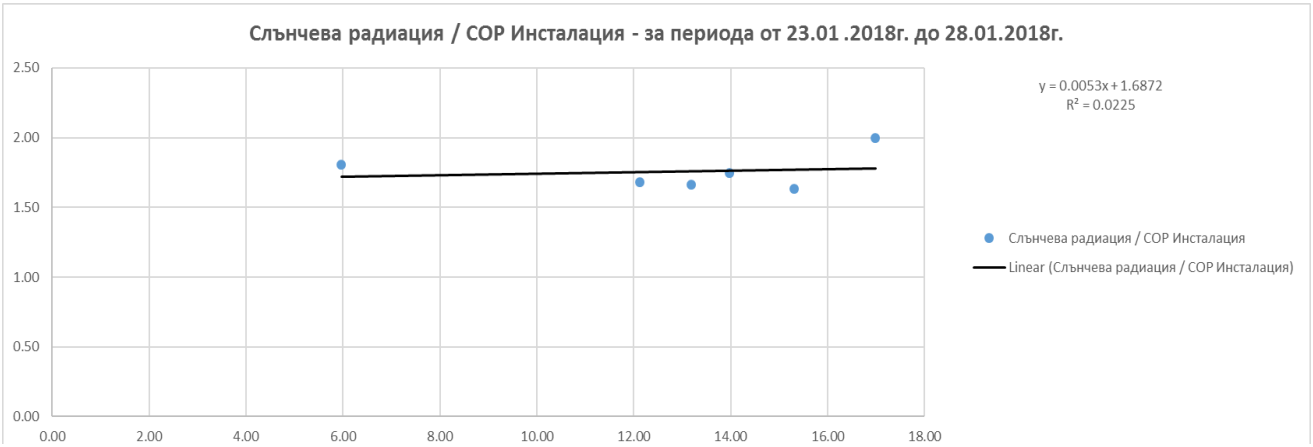
На фигура 7 е показана зависимостта между външната и температурата в отопляваното помещение при площ на радиационния изпарител 3,2 m^2, а на фигура 8 и фигура 9 – установените зависимости на коефициента на преобразуване на системата от външната температура и от интензитета на слънчевата радиация. Аналогични зависимости, но при площ на радиационния изпарител 1,6 m^2, са показани съответно на фигура 9 ÷ фигура 12.



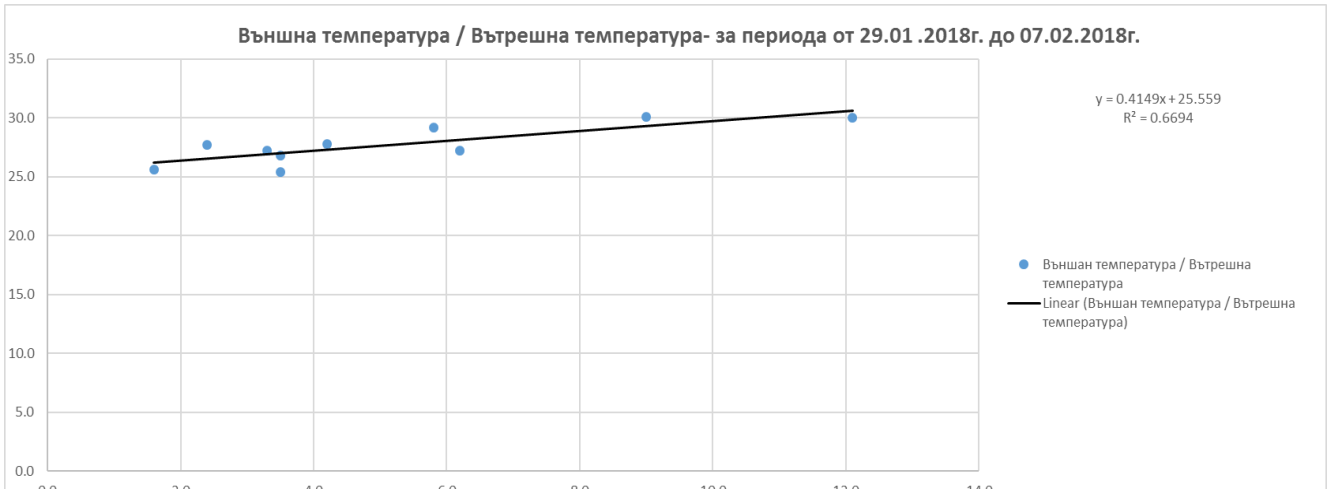
Фигура 7. *Функционална зависимост между външната и вътрешната температура при площ на радиационният изпарител 3,2 m^2 (измервания за периода от 23.01.2018 г. до 28.01.2018 г.)*



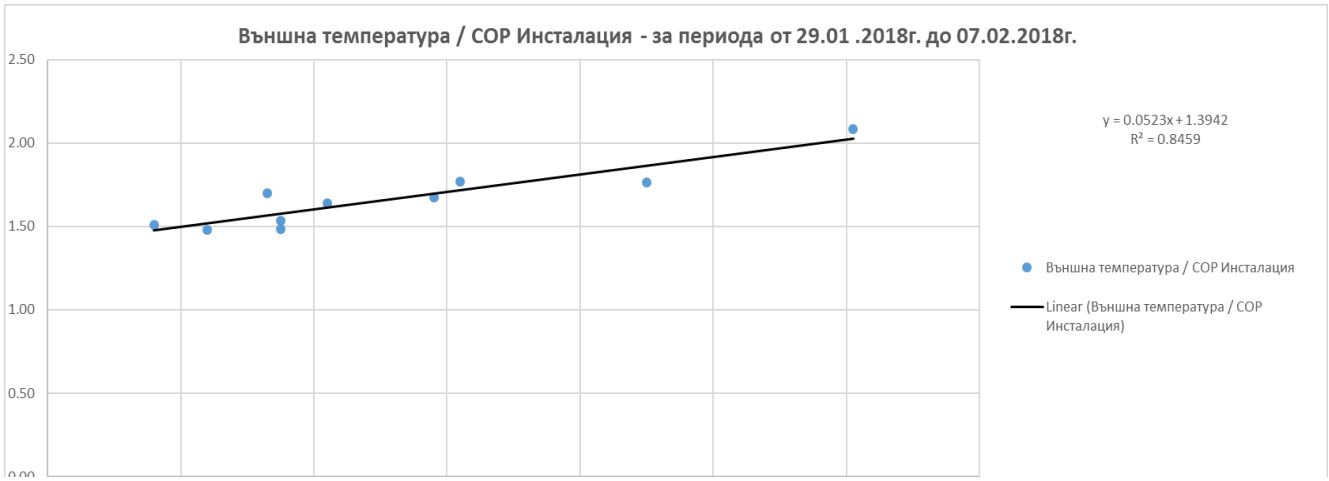
Фигура 8. *Функционална зависимост на COP на системата от външната температура при площ на радиационният изпарител 3,2 m^2 (измервания за периода от 23.01.2018 г. до 28.01.2018 г.)*



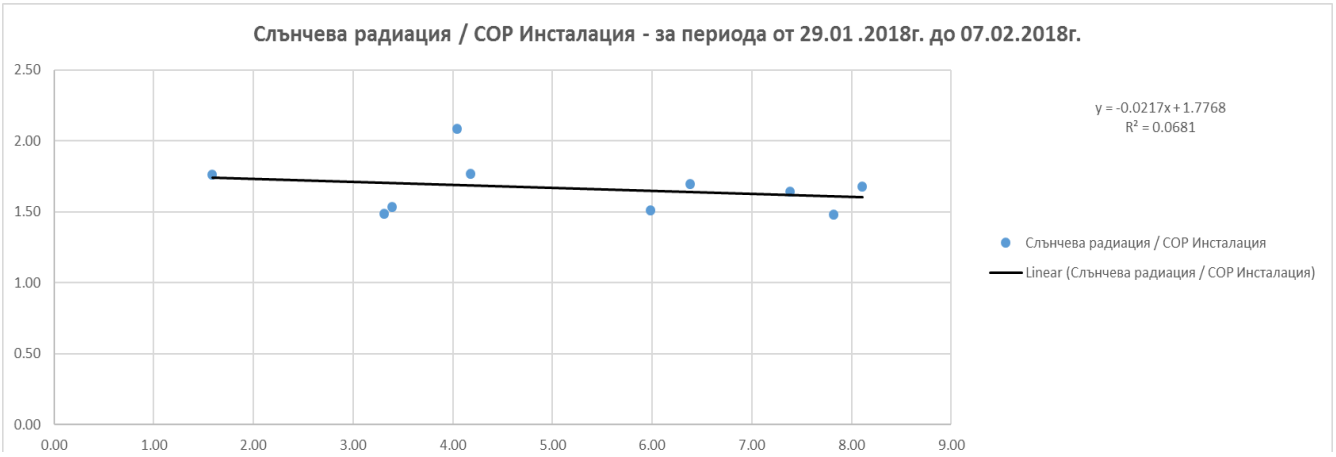
Фигура 9. *Функционална зависимост на COP на системата от пълната слънчева радиация при площ на радиационният изпарител 3,2 m^2 (измервания за периода от 23.01.2018 г. до 28.01.2018 г.)*



Фигура 10. *Функционална зависимост между външната и вътрешната температура при площ на радиационният изпарител 1,6 m^2 (измервания за периода от 29.01.2018 г. до 07.02.2018 г.)*



Фигура 11. *Функционална зависимост на COP на системата от външната температура при площ на радиационният изпарител 1,6 m^2 (измервания за периода от 29.01.2018 г. до 07.02.2018 г.)*



Фигура 12. *Функционална зависимост на COP на системата от пълната слънчева радиация при площ на радиационният изпарител 1,6 m^2 (измервания за периода от 29.01.2018 г. до 07.02.2018 г.)*

Изводи и заключение

Анализът на резултатите, представени на графиките, показва значимата корелация на достигнатите температури в експерименталната къща от външната температура. Стойностите на коефициента на преобразуване се изменят в границите от 1,64 до 2,00 (при площ на радиационния изпарител 3.2 m^2) и от 1,51 до 2,08 (при площ на радиационния изпарител 1.6 m^2). Ясно е изразена линейната му зависимост от външната температура (фигура 7 и фигура 10). Функционалната зависимост между коефициента на преобразуване и попадналата върху повърхнината на радиационния изпарител енергия се апроксимира с линейни функции с нисък коефициент на множествена корелация ($R^2 = 0.023$ при площ на радиационния изпарител 3,2 m^2 и $R^2 = 0.068$ при площ на радиационния изпарител 1,6 m^2).

От анализа на получените резултати може да бъде направен изводът, че толообменните процеси между радиационния изпарител и околната среда имат преобладаващо конвективен характер, както в режим на отопление, така и в режим на загряване на гореща вода за битови нужди, през летният период. Въпреки, че оказва доста голямо влияние, слънчевата радиация има по-малко значение за големината на COP и постигнатата вътрешна температура в експерименталната къща. Доказа се, че по-голямо влияние върху работата и ефективността на термопомпеният агрегат - оказва външната температура.

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MICRO-HARDNESS OF BORID DIFFUSION LAYERS FORMED OF SEMI PERMEABLE POWDER-METALURGICAL MATERIALS FROM THE SYSTEM Fe-C-Cu

Assoc Prof. Mitev, I., Ph.D*
Eng.Vinev.I., doktorant**
Faculty of Economics and Business Administration – Technical University of Gabrovo, Bulgaria*
Faculty of Mechanical Engineering – Technical University of Gabrovo, Bulgaria**
imitev@tugab.bg

Abstract: *Surface saturation with boron of Fe-C-Cu construction powder materials aims to improve the surface hardness of the articles and hence improve wear, contact strength and other mechanical properties. This study investigates the influence of single-component diffusion enrichment modes with boron of semi-permeable powder metallurgical samples from the Fe-C-Cu system. The powder samples on the basis of iron powders NC 100.24 to which 0,3 ÷ 2,5% Cu and 0,4% carbon were added were subjected to the study. Diffusion saturation with boron was carried out in semi-permeable saturation media with a composition of 84% $Na_2B_4O_7$ + 12% SiC + 4% $K_2Cr_2O_7$ at temperatures 850 ÷ 950 ° C for 2 ÷ 4 hours. Graphical dependencies are presented for the variation of the diffusion slit thickness in the longitudinal section of the test samples depending on their density, duration and saturation temperature. The experimental results obtained are compared with those obtained by combining pure iron samples with the same technological parameters.*

Keywords: BORONIZING. DIFFUSION BORIDED LAYER, MICROHARDNESS, POWDER METALURGY, IRON POWDER, DENSITY

1. Introduction

Powder metallurgy is currently developing sufficiently intensively, which is mainly due to its high economic efficiency and also to the possibility of obtaining materials with unique properties that are impossible to obtain through conventional technologies [3,5,6]. This is a technological process in which powders are used to obtain quality details through minimal material losses. Proper selection of powders and their technological properties can provide a wide range of mechanical and physical characteristics of the final product, which can be either metallic or ceramic or a combination of metal with non-metallic components. [2,6,12]

The main structural components in powder metallurgical materials are metallic phases, non-metallic inclusions, pores and others. Porestion in quantitative and qualitative terms is determined by the total pore volume, the ratio between open and closed pores, their size, shape and distribution in volume. There are three main types of pores: two-sided open; unilaterally open and closed pores. The ratio of the pores in the article depends on the general porosity. When the total porosity is less than 20%, the content of the pores found does not exceed 1 ÷ 2% and the relative share of unilateral pores is even smaller. [3,9,10] According to the ratio of open and closed pores, the powder metallurgical materials are divided into:

- impermeable - all pores are closed and the porosity is 7 ÷ 10%;
- permeable - all pores are found, and porosity is 20 ÷ 30%;
- semi-permeable - only a portion of the pores are found, and the total porosity is 15 ÷ 20%. [3,7,9,10]

The peculiarities in the structure of the powdered products imply the existence of peculiarities in their chemical-thermal treatment. Particularly important in chemico-thermal treatment is the information on the ratio between the open and the closed pores, as the main pores in the intensification of the diffusion processes of the porous materials are the pores found.

It has been shown that during sintering the internal surfaces of the pores change and in the case of porosity up to 15% their passage in closed form is observed. With greater porosity of 20% and sintering for four hours no closing of open pores is observed, which facilitates the flow of diffusion processes. Increasing the defect of the iron particles facilitates the formation of a larger amount of open pores and helps to accelerate the diffusion processes.

In this connection, the aim of the present study is to investigate the influence of surface diffusion enrichment with boron on semipermeable powder metallurgical specimens on their microtraviolet in the surface working area.

2. Experimental part

Surface enrichment with boron of Fe-C-Cu structural powder materials aims to improve the surface hardness of the products, hence increasing wear, contact strength and other mechanical properties.

The study is subjected to powder metallurgical specimens from the triple Fe-C-Cu system. The iron powder of type NC100.24 produced by „Höganäs“, Sweden, was used as the basis of the samples. This is one of the most widely used in the practice of powder metallurgical production iron powder obtained by the reduction method. Its compactness is very good, and thanks to the spongy particle structure their moldability is too high. The raw (after compression) and final (after sintering) strength of parts of these powders is very high and the hydrogen concentration therein is low.

The maximum particle size fraction of the iron powder used, its compaction at 420MPa, as well as the concentration of oxygen and carbon in the iron particles are presented in Table 1.

Table 1: *Characteristics of the iron powder used*

Type of iron powder /size, **µm**	Compaction at **420MPa**		**O_2, %**		**C, %**	
	average value	min.	average value	min.	average value	min.
NC 100.24/150	**6,45**	**6,40**	**0,20**	**0,30**	**0,01**	**0,02**

To the iron powders are also added 0.3 ÷ 2.4% copper powders obtained by the electrolysis method with an average size of 63 µm. [1,11]

The third component is carbon whose concentration in the samples is 0.4%. It is added in the form of UF 4 standard graphite powders, where the carbon concentration is in the 96 ÷ 97% range.

Boring is carried out for 2÷4h, at a temperature of 900÷1000°C in a semi-permeable saturation medium with composition 1. [8,9,10]

(1) $84\%Na_2B_4O_7 + 12\%SiC + 4\%K_2Cr_2O_7$

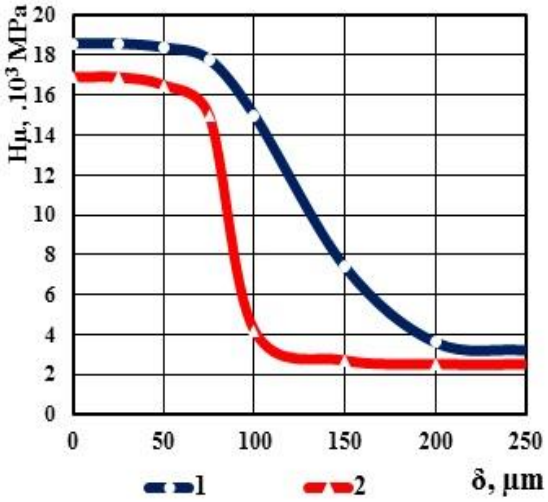

Fig. 1. *Micro-hardness distribution in samples with a density of 7.00g /cm³ after boronizing 4h at 950°C and composition:*
1 - NC100.24 + 0.4% C + 2.0% Cu; 2 - NC100.24

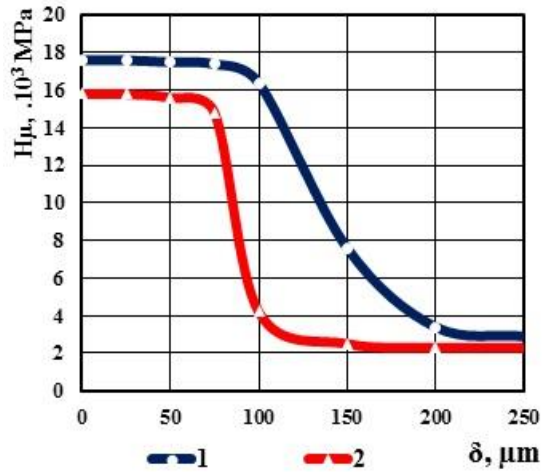

Fig. 2. *Micro-hardness distribution in samples with a density of 6.60g /cm³ after boronizing 4h at 950°C and composition:*
1 - NC100.24 + 0.4% C + 2.0% Cu; 2 - NC100.24

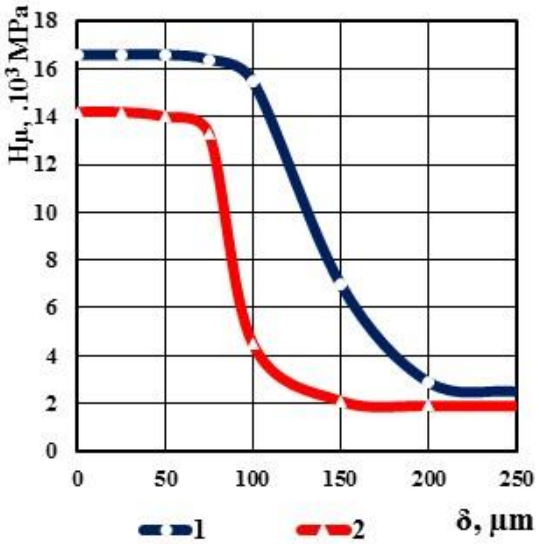

Fig. 3. *Micro-hardness distribution in samples with a density of 6.20g /cm³ after boronizing 4h at 950°C and composition:*
1 - NC100.24 + 0.4% C + 2.0% Cu; 2 - NC100.24

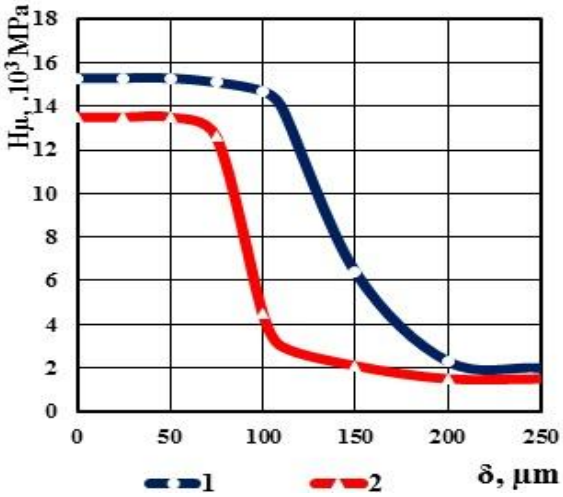

Fig. 4. *Micro-hardness distribution in samples with a density of 5,80g /cm³ after boronizing 4h at 950°C and composition:*
1 - NC100.24 + 0.4% C + 2.0% Cu; 2 - NC100.24

The micro-hardness of the materials we tested after the boring was determined according to standardized methodology. -BDS-EN-ISO-4498-2007. [4]

The experimental results for modification of the micro-hardness of samples of iron powder NC 100.24 + 0.4% C + 2.0% Cu with p=5.80÷7.00g/cm³ after saturation for 4h at 950°C is presented in graphical form in figures 1÷4.

The figure shows that maximum values for micro-hardness are recorded on the surface of the samples studied and the values remain constant in the areas of distribution of the boride phases. The values vary in the range 14500 ÷ 19000MPa and are determined by the type of saturated alloys - the amount of copper and the density of the samples, the higher values being measured on samples with a higher density - 6,60 ÷ 7,00g /cm³. After boring, the substrate of the saturation materials is a hard iron boron solution, a pearlitic structure with a carbon concentration of about 0.6%, and the ε-phase inclusions. Micro-hardness in this area ranges from 4500 ÷ 6200MPa. . This necessitates in cases where the product is to be subjected to a post-boring operation under the contact load conditions to be subjected to further processing to increase the hardness of the sublayer.

When increasing the saturation duration from 2 to 4h the character of the curves showing the micro-hardness distribution does not change, the maximum values in the layer - fig.5.

.Since the micro-sthardness of the boride layers is determined by their phase composition, the results obtained are evidence that the phases formed in the initial phase of saturation do not undergo substantial changes over time.

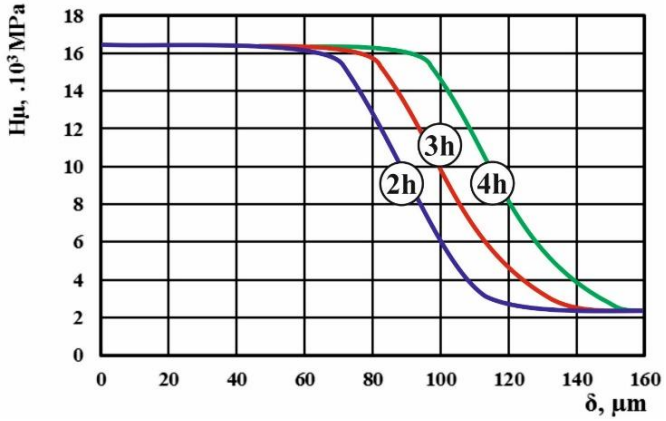

Fig.5. *Distribution of micro-hardness in samples with NC100.24 + 0.4% C + 2.0% Cu with p = 6.60 g/cm³ after boronizing at 950 ° C for 2 ÷ 4h.*

The high micro – hardness of the formed boride phases are results from the formation of a stable electronic configuration sp3 - d5 [10] in their structure. The stability of this configuration is one of the reasons for the borides to maintain its hardness even at high temperatures of heating up to 900°C.

Higher values for micro-hardness in larger densities - 6.0 ÷ 7.00g/cm^3 are the result of both reduced pores in these and the reduced formation of partial inclusions of FeB.

From the conducted tests it was found that the copper content in the samples practically does not effect of the micro-hardness of the boride layer - fig.6.

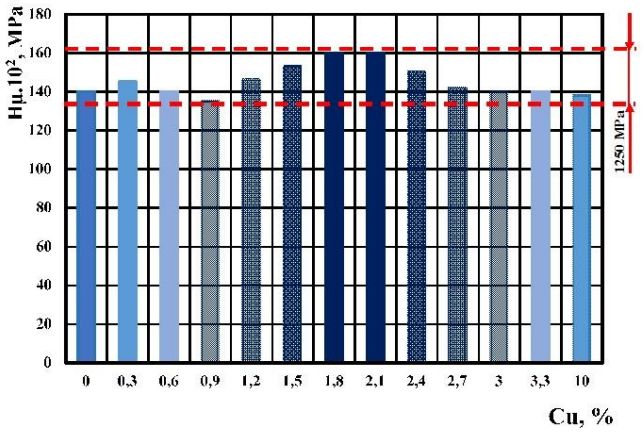

Fig.6. *Influence of copper on the micro-hardness of samples with ρ = 6.60g / cm^3 after boronizing at 950°C for 4h*

By lowering the saturation temperature under p.A$_1$ the character of distribution of micro-hardness in the boride coatings is preserved, but the values are decreased and vary in the range 14500 ÷ 16000MPa, which is also the result of the absence of high-boride phase - FeB inclusions, Fig.7.

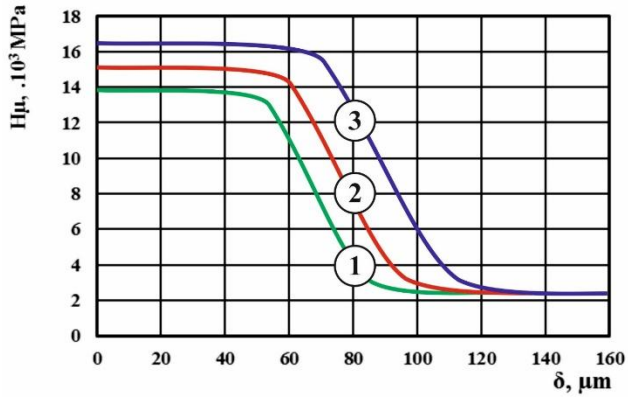

Fig.7. *Micro-hardness distribution in samples of NC100.24 + 0.4% C + 2.0% Cu with p = 6.60g / cm^3 after 2h boronizing at: 1 - 800°C; 2 - 850°C and 3 - 900°C.*

3. Conclusions

The following conclusions can be drawn from the research carried out and the results obtained:

- It is confirmed that the micro-hardness of the boride layers depends on the density of the saturation samples, their phase composition and changes in the range of 14 500 ÷ 19 00MPa.
- It has been shown that after boring in the substrate layer the solid iron boron solution is formed, a pearlitic structure with a carbon concentration of about 0.6% and ephase inclusions, and the micro-stability values in this region vary within the range 4500 ÷ 6200MPa.
- It has been shown that the change in the copper concentration in the matrix from 0 to 3.0% has virtually no effect on the micro-hardness values and they change by ± 620 ÷ 630MPa.

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EXPLORING THE POSSIBILITY OF LASER CUTTING WITH CO_2 LASER ON FELT IN THE RANGE FROM 1W TO 26W POWER*

Chief Ass. Prof. PhD eng. Dolchinkov N.[1,2]., Ass. Prof. PhD Shterev Y.[1],
Student Lilianova St[1], Student Boganova D.[1], Cadet Peneva M.[1], Cadet Linkov L.[1], Student Nedialkov D.[1],
[1]Land Forces Faculty, Veliko Tarnovo – „Vasil Levski" National Military University, Veliko Tarnovo, Bulgaria
[2] National Research University "Moscow Power Engineering Institute", Moscow, Russia

_dolchinkov@abv.bg, jshterev@abv.bg, stelena.lilqnova@abv.bg,
denica_a_b@abv.bg, merianp98@gmail.com, ddned@abv.bg, kubratovec@gmail.com

Abstract: *Describe the parameters influencing the depth of the laser marking of textile products. Experimental results are presented to determine the quality of cuts on felt surfaces of different colors at specific parameters - power and speed.*

Keywords: MARKING, CUTTING, ENGRAVING, FELT, LASER CO_2, POWER, VELOSITY.

1. Introduction

Felt is many versatile material. It is non-woven, which means it has no deformation, which makes it an ideal material for intricate garments. However, because it is thick cutting intricate patterns and structures into felt is difficult to do by hand. Precise cutting is usually done by means of an industrial mashine cutter. Using a laser to cut felt is great choose.

Felt is an inexpensive, versatile fabric that works with the laser [7,8,10,11]. Felt is made not by weaving but by pressing under steam or hot water and felting of animal fibers. It's also durable and when laser-cut, produces precise results [9,12]. That way felt is used about experimnts with laser marking and laser cutting. Laser marking and laser cutting technology is now widely associated with textiles and in particular with felt [2,10,15]. In this paper we present some experimental results from this area.

2. E*xperimental setting*

The possibility of marking and engraving on a standard felt in two colors - red and white with CO_2 laser was studied. For this purpose, an experimental methodology has been developed, which concludes in the following:

a matrix of 9 squares with 1: 1 cm is created. The speed and power range in the range of 100÷350 mm/s and 2, 10 and 26 W. The matrix scheme is shown in the figures:

Gas laser CHANXAN CW 1325 CO_2 active, 1-150 watts power, 1-400 mm / s, laser beam wavelength 10.6 μm, maximum marking area: 2500 x 1300 mm, maximum laser size focal spot is 100 μm and water cooling system was used – **Fig 1.**

The area of laser marking and cutting is showed on the figure. A considerable amount of heat is emitted in the marking and cutting processes, so the working area is cooled with air.

The surface power density SPD of the laser beam is determined by:

$$SPD = \frac{P}{S}$$

where P is the power of laser beam and S is the area of the laser beam section in focus. Laser control was performed using the RdWorks software [14].

3. Laser Marking

The common advantages of all laser marking techniques are [1]:

- permanent, high quality marks;
- high efficiency and low operation cost;
- good accessibility, even to irregular surface;
- non-contact marking and no special working environmental needed;
- easy to automate and integrate (using computer-controlled movement of the beam or sample);
- precise beam positioning and a beam highly localised energy transfer to the workpiece;
- high reproducibility and high speed ;
- contamination - free.

Fig. 1. The laser used for the experiments.

The quality of a mark is assessed by its legibility characteristics such as mark contrast, mark width, mark depth, and microstructures. The characteristics are usually evaluated using complementary techniques such as optical microscopy, ultrosonics microscopy, electron microscopy, surface roughness measurement. In beam deflected marking, the line width is mainly determined by the focused beam spot size, which varies between 20 - 100 μm. Other parameters: scanning speed, power density and material properties also affect the line width. [1].

The main factors that influence the contrast of laser marking are [3,4,5,6]:

- optical characteristics: power density, pulse energy (pulse lasers only), pulse duration of the laser beam, frequency, overlap factor;
- thermophysical characteristics: marking speed, laser beam pitch, laser beam defocus, number of repetitions, volumetric density of the absorbed energy.

In relation to the influence of the laser beam on the fabric, the linear energy density LED of the laser beam is defined on a unit length depending on the velocity:

$$LED = \frac{P}{v}$$

where P is the power of laser beam and v is the speed of laser beam movement on the felt.

Table 1 shows the linear energy density dependences of power P for 2 W, 10 W and 26 W and the variation of the speed 100, 150, 200, 250, 300 and 350 mm/s.

Table 1.

№	V, mm/s	P=2W	P=10 W	P=26 W
		LED, J/mm	LED, J/mm	LED, J/mm
1	100	0,02000	0,10000	0,26000
2	150	0,01333	0,06667	0,17333
3	200	0,01000	0,05000	0,13000
4	250	0,00800	0,04000	0,10400
5	300	0,00667	0,03333	0,08667
6	350	0,00571	0,02857	0,07429

Each processing area (each square) is implemented with the raster scan method. The line-to-line step is 0.1mm. The processing areas and the processing quality were analyzed by means of a AM4515ZTL digital microscope manufactured by DINO-LITE: https://www.dino-lite.eu/index.php/en/products/microscopes/long-working-distance with 1.3 MPx resolution, 10-140X zoom and polarizer.

The diagrams of the square matrices after experiments are shown on **Fig. 2**. The Markings 7, 8, 9 in Figure show respectively the energy of 2 W, 10 W, 26 W in percent, which is used for the interaction with a felt.

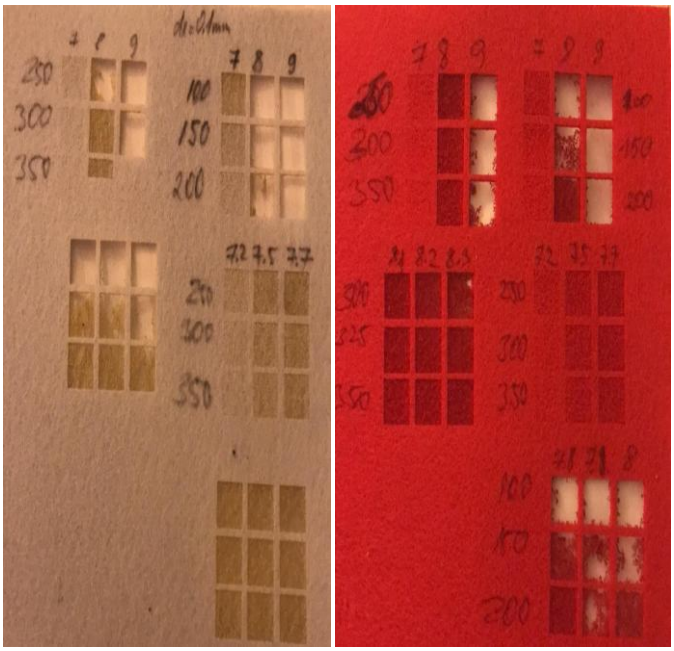

Fig. 2 The diagrams of the square matrices after experiments.

4. Laser cutting

The possibility of laser cutting on a CO_2 laser is investigated. For this purpose, an experimental methodology has been developed which consists of the following:

The processing areas and the processing quality with the help the microscope have been analyzed. Altogether, 90 processing areas were investigated. From the experiments made, the following conclusions can be drawn:

- a quality cut of the material is obtained with the following parameters: for white and red felt - a constant power of 26 W (9%) and a speed ranging 100, 150 and 200 mm/s and the LEDs are 0.26 J/mm, 0.17 J/mm 0.13 J/mm - **Fig. 4.** Quality cutting of the felt.;
- about the same power 26 W and a speed ranging 250, 300 and 350 mm/s and LEDs are 0.104 J/mm, 0.08667 J/mm 0.0749 J/mm the cutting is not full;
- good marking by lightening of the material (nearly 50%) is obtained with the following process parameters: P = 2W and V = 250, 300 and 300 mm/s, and the LEDs are 0.008, 0.00667 and 0.00571 as shown in the table 1 - **Fig. 3.** Red and white felt. Contrast measurements are performed using the Color Contrast Analyzer version: 2.5.0.0. [13];
- about the same power 2 W and a speed ranging 100, 150 and 200 mm/s and the LEDs are 0.20 J/mm, 0.01333 J/mm and 0.010 J/mm the marking is not so good, it is nearby cutting red and white felt;
- About power 10 W and speed 100, 150, 200 mm/s of laser beam the red felt and white felt have less partial cutting (less destroying felt) and the LEDs are 0.1, 0.06667, 0.0.50;
- About power 10 W and speed 250, 300 and 350 mm/s of laser beam the red felt and white felt have less partial cutting (less destroying felt) and the LEDs are 0.04, 0.03333, 0.02857;

About the next areas from all 90 processing areas can say the same analogy.

5. Conclusion

For all felt materials marking, engraving and cutting can be successfully applied. The choice of laser process is determined by the desired final result.

In this research, the laser applications for and felt processing are analyzed. The advantages of laser technology in felt fields were pointed. The linear energy density during marking and cutting by the laser beam was introduce.

With the help of a robotic automated line, the making of marking and cutting of felt results in the production of an obtained, attractive commercial product.

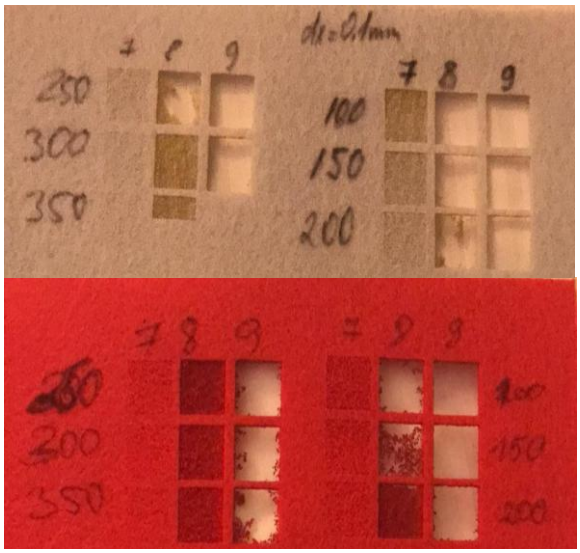

Fig. 3. Red and white felt

Fig. 4. Quality cutting of the felt.

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EXAMINING THE POSSIBILITY OF MARKING AND ENGRAVING OF TEXTIEL USING CO_2 LASER*

Ass. Prof. PhD Shterev Y.[1], Chief Ass. Prof. PhD eng. Dolchinkov N.[1,2].,
Student Lilianova St[1], Student Boganova D.[1], Cadet Peneva M.[1], Cadet Linkov L.[1], Student Nedialkov D.[1],
[1]Land Forces Faculty, Veliko Tarnovo – „Vasil Levski" National Military University, Veliko Tarnovo, Bulgaria
[2] National Research University "Moscow Power Engineering Institute", Moscow, Russia

jshterev@abv.bg, n_dolchinkov@abv.bg, stelena.lilqnova@abv.bg,
denica_a_b@abv.bg, merianp98@gmail.com, ddned@abv.bg, kubratovec@gmail.com

Abstract: *The possibility of marking and engraving on cloth with CO_2 laser has been studied. For this purpose a methodology of experiments was developed in which a matrix of nine squares measuring 1: 1 cm and a laser beam velocity and power of 2-26 W and 100-350 mm / s, respectively***.**

Keywords: MARKING, CUTTING, ENGRAVING, TEXTILE, LASER CO_2, POWER, VELOSITY.

1. Introduction

The laser is often grouped with the transistor and the computer as landmark inventions of the mid-20th century. All three technologies had deep conceptual roots, and grew and flowered rapidly in the years after the end of World War II [4].

Since the practical opening of the laser in the early 1960s, it has continuously improved and contributed to the development of industrial production - automotive, aircraft construction, shipbuilding, machine building in Bulgaria and the world. Laser sources emit radiations with wavelengths in a wide spectral range - from ultraviolet, visible and infrared to continuous and pulsed modes. Some of the laser technologies are: laser marking, cutting, engraving, welding, drilling of holes and many others. The laser marking systems using different lasers delivery systems can be used to mark too many materials including such as textile, plastics, metals, ceramics, glass, wood and leather [1,7,12]. Some information (alpha-numeric, graphics or encoded) is applied to almost all types of materials including textiles [2]. Laser marking and laser cutting technology is now widely associated with textiles [3,5].

There is a many ways in which laser cutting technology can be used within the field of textiles too [6]. In this we presente some results from this area.

2. Experimental setting

Gas laser CHANXAN CW 1325 CO2 active, 1-150 watts power, 1-400 mm / s, laser beam wavelength: 10.6 μm, maximum marking area: 2500 x 1300 mm, laser size focal spot 100 μm and water cooling system – Fig 1. On the figure "Materials" indicates the location where the sample is placed.

The surface power density SPD of the laser beam is determined by:

$$SPD = \frac{P}{S}$$

where P is the power of laser beam and S is the area of the laser beam section in focus. Laser control was performed using the RdWorks software [9,10].

3. Laser Marking

The common advantages of all laser marking techniques are [1]:

- permanent, high quality marks;
- high efficiency and low operation cost;
- good accessibility, even to irregular surface;
- non-contact marking and no special working environmental needed;
- easy to automate and integrate (using computer-controlled movement of the beam or sample);
- precise beam positioning and a beam highly localised energy transfer to the workpiece;
- high reproducibility and high speed ;
- contamination - free.

The quality of a mark is assessed by its legibility characteristics such as mark contrast, mark width, mark depth, and microstructures. The characteristics are usually evaluated using complementary techniques such as optical microscopy, ultrasonics microscopy, electron microscopy, surface roughness measurement. In beam deflected marking, the line width is mainly determined by the focused beam spot size, which varies between 20 - 100 μm. Other parameters: scanning speed, power density and material properties also affect the line width. [1].

The main factors that influence the contrast of laser marking are [7,8,9]:

- optical characteristics: power density, pulse energy (pulse lasers only), pulse duration of the laser beam, frequency, overlap factor;
- thermophysical characteristics: marking speed, laser beam pitch, laser beam defocus, number of repetitions, volumetric density of the absorbed energy.

The marking and engraving on fabric with a composition of 65/35% CO / polyester ± 3% determined according to EN ISO 1833 quantitative chemical standard with CO_2 laser was investigated and analyzed. For this purpose, an experimental methodology was developed, which concludes in the following:

a matrix of 9 squares with 1x1 cm is created. The power of the laser beam is in the range of 2÷26W and its speed is in the range of 100÷350 mm/s. A schematic of the six-square matrix after experiments is shown in Fig. 2.

In relation to the influence of the laser beam on the fabric, the linear energy density LED of the laser beam is defined on a unit length depending on the velocity:

$$LED = \frac{P}{v}$$

where P is the power of laser beam and v is the speed of laser beam movement on the textile.

Table 1 shows the variation of speed and power P for 2 W, 10 W and 26 W and the resulting linear energy density.

Each processing area (each square) is implemented with the raster scan method. The line-to-line step is 0.1mm. The processing areas and the processing quality were analyzed by means of a AM4515ZTL digital microscope manufactured by DINO-LITE:

https://www.dino-lite.eu/index.php/en/products/microscopes/long-working-distance with 1.3 MPx resolution, 10-140X zoom and polarizer. Total 28 treatment zones were investigated. From all the experiments we can draw the following conclusions:

– a good cutting of the material is obtained with the following parameters: constant power 26 watts and speed ranging from 100÷200 mm/s, with linear energy densities correspondingly 0.26, 0.17 and 0.13 J/mm.

– the quality marking is obtained in the range of LED values of $5*10^{-2} \div 3{,}8*10^{-2}$ J/mm for a power of 10 W where the velocity varies in the range of 200-260 mm/s. The remaining marking areas have a slight contrast that is between 5% and 10%. Contrast measurements are performed using the Color Contrast Analyzer version: 2.5.0.0. [10,11]. On Figure 3 are given two photos of marked areas with good contrast.

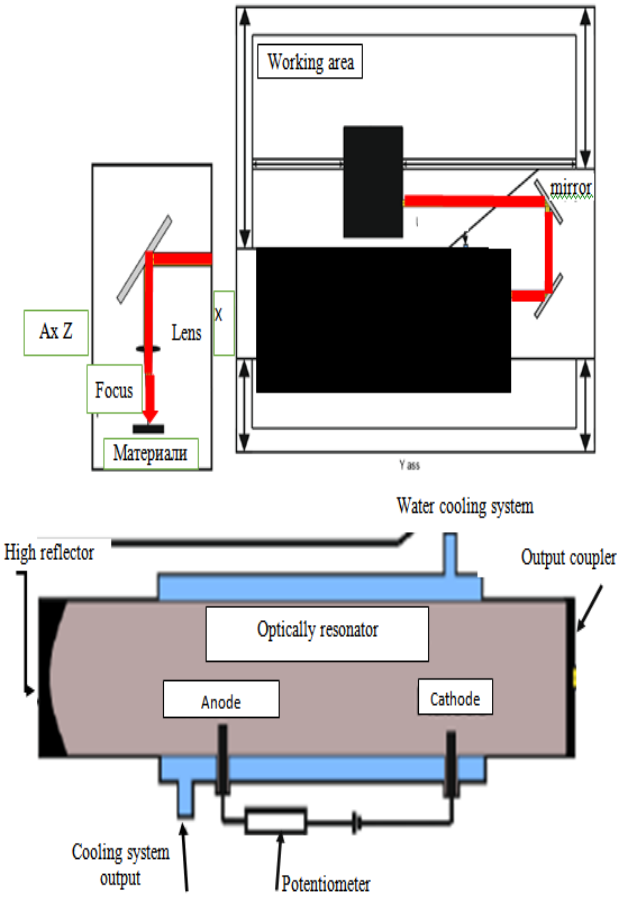

Fig. 1. *Scheme of the experimental setting.*

Table 1.

№	*v*, mm/s	P = 2W	P = 10W	P = 26W
		***LED*, J/mm**	***LED*, J/mm**	***LED*, J/mm**
1.	100	0,02	0,1	0,26
2.	150	0,013	0,06	0,17
3.	200	0,01	0,05	0,13
4.	235	-	0,043	-
5.	240	-	0,042	-
6.	245	-	0,041	-
7.	250	0,08	0,04	0,1
8.	255	-	0,039	-
9.	260	-	0,038	-
10.	300	0,06	0,033	0,086
11.	350	0,05	0,028	0,074

4. Laser cutting

The possibility of laser cutting on a CO_2 laser is investigated. For this purpose, an experimental methodology has been developed which consists of the following:

Lines of length 4 cm are applied to the textile at different speeds and power processing. Power ranges from 2÷20 W, and the speed is 10÷55 mm/s. Two sets of experiments with 10 lines were made. In one series the power was maintained constant - 10 W, and the speed varied in the range of 10÷55 mm/s. In the second series the speed is constant 10 mm/s and the power varies in the range of 2÷20 W – Table 2. The thickness of the textile is 0.41 mm.

The microscopic analysis of the shear lines shows that a good shear of the fabric is present on all 18 incisions in the range of LED (0.2÷2 J/mm for a constant rate of 10 mm/s and 1÷0.22 J/mm for a constant power 10 W) - Fig. 4. Quality cutting of the textile, and for two of the experiments at 0.2 J/mm and 0.18 J/m LED for a constant power of 10 W, a shear limit was found. The threshold of destruction is shown on Fig. 5.

Table 2.

№	P, W	V=10mm/s	V, mm/s	P = 10W
		LDE, J/mm		LDE, J/mm
1	2	0,2	10	*1*
2	4	0,4	15	*0,675*
3	6	0,6	20	0,20
4	8	0,8	25	0,40
5	10	1	30	0,33
6	12	1,2	35	0,29
7	14	1,4	40	0,25
8	16	1,6	45	0,22
9	18	1,8	50	0,2
10	20	2	55	0,18

5. Conclusion

The laser marking, engraving and cutting are complex physical processes with a great scientific and applied importance. Laser marks and cutting can be used for artistic decorating and unique design of any surfaces of textile products in the fashion industry.

For all textile materials and for leather materials, marking, engraving and cutting can be successfully applied. The choice of laser process is determined by the desired final result.

In this research, the laser applications for and textile processing are analyzed. The advantages of laser technology in textile fields were pointed. The linear energy density during marking and cutting by the laser beam was introduce.

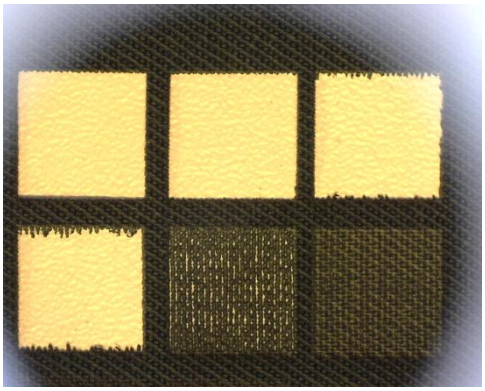

Fig. 2. A scheme of the matrix with 6

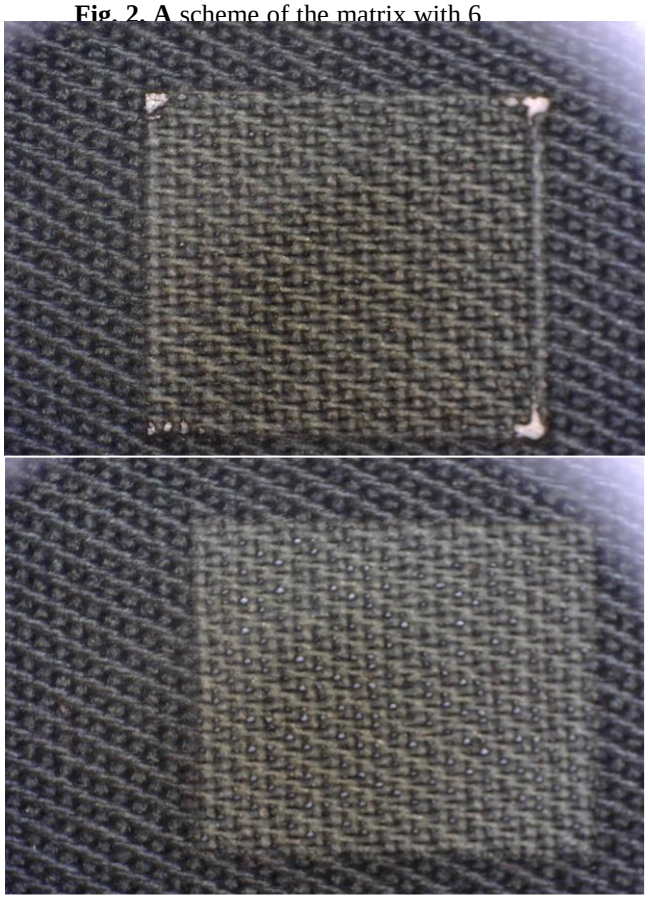

Fig. 3 *Two photos of marked areas with good contrast.*

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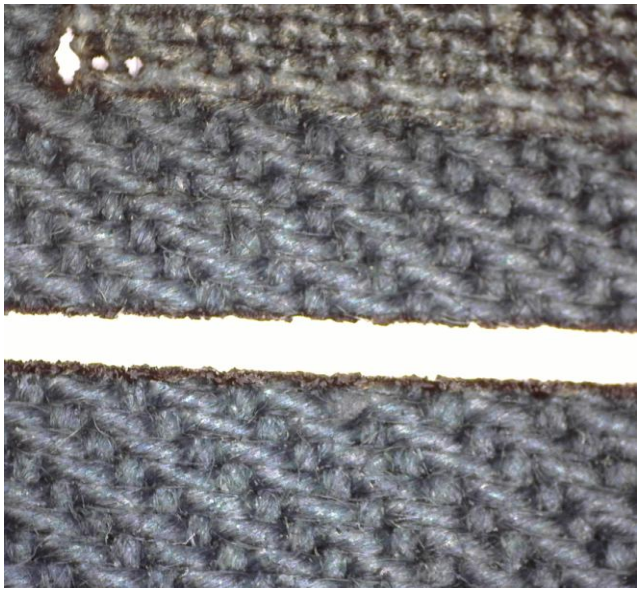

Fig. 4. *Quality cutting of the textile.*

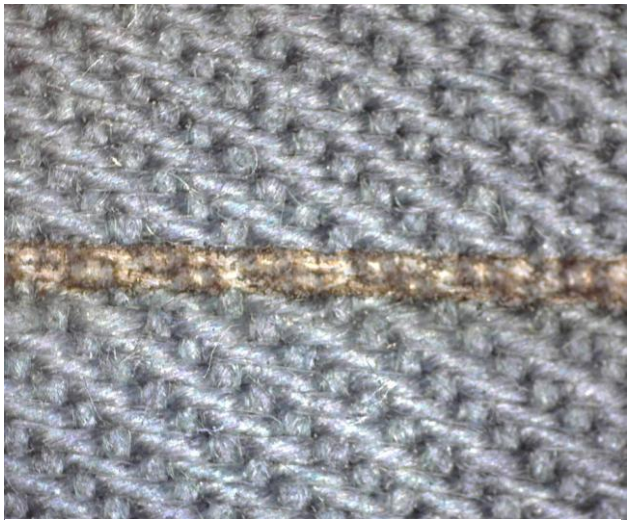

Fig. 5 *The threshold of destruction.*

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LASER MARKING AND CUTTING OF PLEXIGLAS WITH CO_2 *

Ass. Prof. PhD Shterev Y.[1], Chief Ass. Prof. PhD eng. Dolchinkov N.[1,2].,
Student Lilianova St[1], Student Boganova D.[1], Cadet Peneva M.[1], Cadet Linkov L.[1], Student Nedialkov D.[1],
[1]Land Forces Faculty, Veliko Tarnovo – „Vasil Levski" National Military University, Veliko Tarnovo, Bulgaria
[2] National Research University "Moscow Power Engineering Institute", Moscow, Russia

jshterev@abv.bg, n_dolchinkov@abv.bg, stelena.lilqnova@abv.bg,
denica_a_b@abv.bg, merianp98@gmail.com, ddned@abv.bg, kubratovec@gmail.com

Abstract: *The possibility of marking and engraving on plexiglas with CO_2 laser has been studied. The experiments conducted have determined the influence of laser radiation on the plexiglas.*
These methods deal with methods of processing metals with a high energy laser beam on a solid (liquid or diode) base. Laser marking systems using different lasers and optical transfer systems can be used to mark an almost endless sheet of materials including metals, plastics, ceramics, glass, wood and leather

Keywords: MARKING, CUTTING, ENGRAVING, PLEXIGLAS, LASER CO_2, POWER, VELOSITY.

1. Introduction

Laser technology refers to progressive materials handling methods. Laser marking systems using different lasers and optical transfer systems can be used to mark an almost endless sheet of materials including metals, plastics, ceramics, glass, wood and leather [1,2,3,4,5,6,7].

Laser marking and laser cutting technology is now widely associated with plastics.

The most common surface reaction mechanism is thermal chemical "carbonization" or "charring". The energy absorbed in the substrate raises the local temperature of the material surrounding the absorption place high enough. So it causes thermal degradation of the polymer [6,7,8,9,11]. In this paper we present some result in this contemporary area

2. Experimental setting

The wavelength (energy) is important. The materials have to absorb the laser energy if a good marking effect is to occur. The more plastic materials are able to absorb the laser energy at a wavelength of 1064 nm (which is the infrared band - Nd:YAG). Here is used CO_2, which is important because of different wavelength and the results.

Gas laser CHANXAN CW 1325 CO_2 active, 1-150 watts power, 1-400 mm / s, laser beam wavelength 10.6 μm, maximum marking area: 2500 x 1300 mm, maximum laser size focal spot is 100 μm and water cooling system was used.

The surface power density *SPD* of the laser beam is determined by:

$$SPD = \frac{P}{S}$$

where *P* is the power of laser beam and *S* is the area of the laser beam section in focus. Laser control was performed using the RdWorks software [10].

In relation to the influence of the laser beam on the plastic, the linear energy density *LED* of the laser beam is defined on a unit length depending on the velocity:

$$LED = \frac{P}{v}$$

where *P* is the power of laser beam and *v* is the speed of laser beam movement on the plastic.

The focusing system controls the laser beam spot direction is important system part. The area diameter of the focused laser beam defined marking line width and the real marking efficiency and the penetrating depth of the laser beam. The diameter depends of the lens focal length and the of the laser beam deviation.

Polymethylmethacrylate (PMMA) is a transparent thermoplastic material that is light and stable. As a multifunctional material used in a wide range of applications. The thickness of the plexiglass used is 10 mm.

3. Penetration of the laser beam into Plexiglas

Characteristics of plexiglas holes received with power laser beam 10 W are shown on Table 1: *Width* is the width of perforation on the plexiglas surface, *WHAAS* is the width of the heat-affected area on surface, *LED* - linear energy density and *EPD* - efficiency perforation depth. All these sharacteristics are measured by digital microscope. It is AM4515ZTL digital microscope manufactured by DINO-LITE:
https://www.dino-lite.eu/index.php/en/products/microscopes/long-working-distance with 1.3 MPx resolution, 10-140X zoom and polarizer – **Fig. 1**.

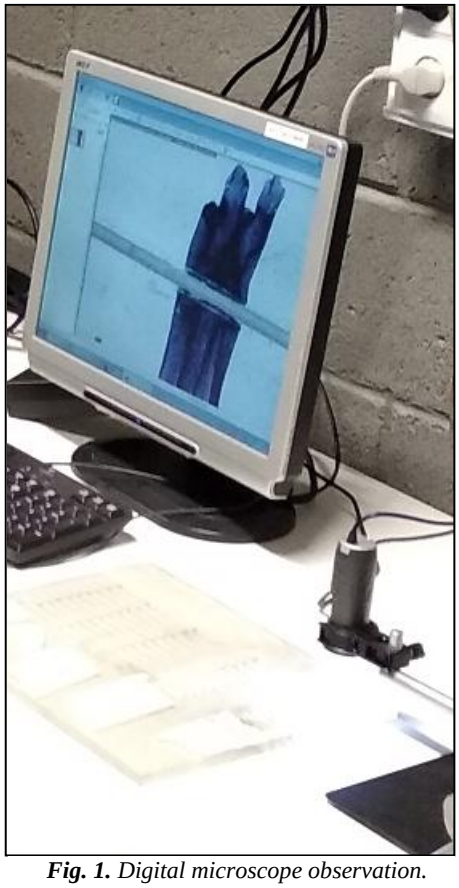

Fig. 1. *Digital microscope observation.*

The penetration of the laser beam power of 10 W and a speed of 30 mm/s and 10 mm/s is shown in **Fig. 2**. On the upper part is for 30 mm/s and down part for 10 mm/s. For 30 W and 50 W for the same speed position are shown on **Fig.3** and **Fig. 4**.

About 30 mm/s the line impact of laser beam is a little more clearly than 10 mm/s. It is more expression about 30 W. Efficiency perforation depth (EPD) depends on power and laser beam speed.

Characteristics of plexiglas holes received with power laser beam *10 W, 30 W and 50 W* are shown on **Table 1**, **Table 2** and **Table 3.** Tables about 20 W and 40 W are nod shown.

When the laser beam power is constant (10 W, 20 W, 30 W, 40 W or 50 W) width the increase of the beam speed from 5 mm/s to 30 mm/s the efficiency perforation depth measured is decreased Table 4. The efficiency perforation depth maximum is 8.324 mm for 50 W and speed of 5 mm/s Table 3 and Table 4. The efficiency perforation depth minimum is 0.188 mm for 10 W and speed of 30 mm/s Table 1 and Table 4. Besides that when linear energy density decreases the efficiency perforation depth decreases too – Table 1, Table 2 and Table 3.

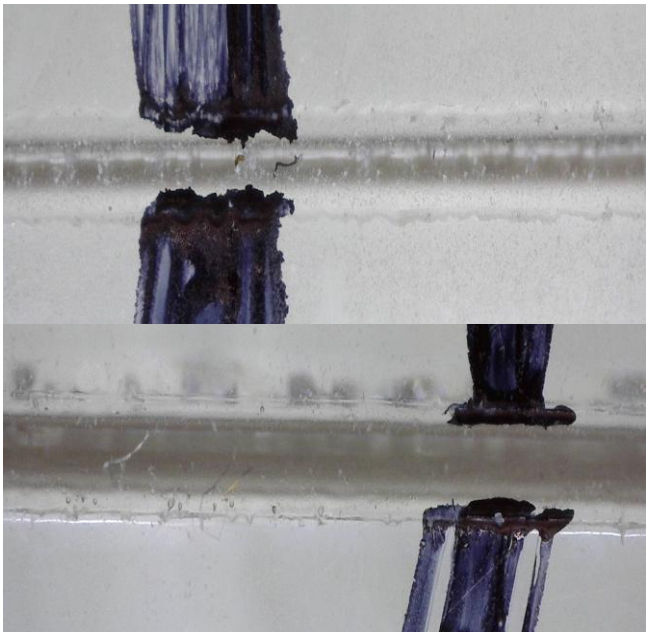

Fig 2. *up 10 W, 30 mm/s, down 5 mm/s*

Fig. 3. *30 W, up 30 mm/s, down 5 mm/s*

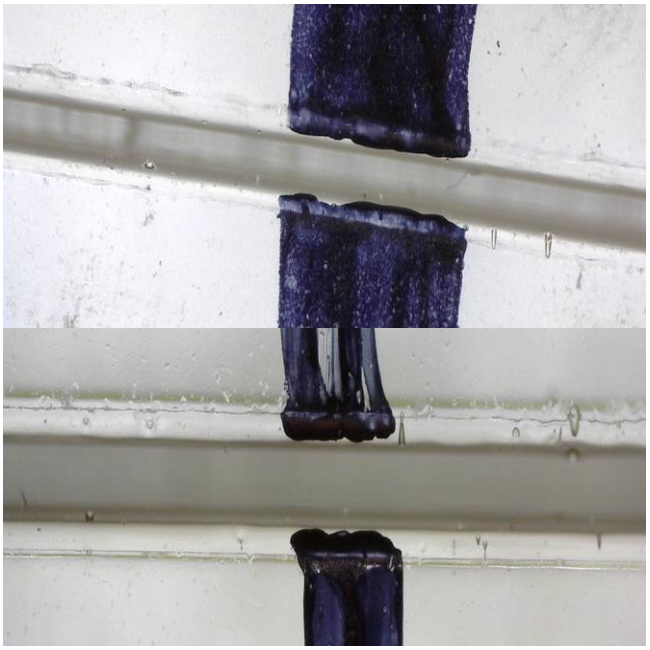

Fig 4 *50 W, 30 mm/s, 5 mm/s*

4 Conclusion

The current study shows that the CO2 laser can be used for marking, engraving, cutting Polymethylmethacrylate at the speeds used. Polymethylmethacrylate is used in too different area and its marking, engraving, cutting too: transparent glass substitute, daylight redirection, medical technologies and implants, uses in dentistry, electron micropsy, laserdisc optical media, as dosimeter devices during the gamma irradiation process and many others.

A future follow-up of the study here is experiments aimed at a specific application.

Table 1. *Characteristics of plexiglas holes received with power laser beam 10W.*

Speed, mm/s	Width, mm	WHAAS, mm	LED	EPD, mm
5	0,675	0.029	2,000	1,145
6	0,653	0.029	1,667	0,579
7	0,576	0.30	1,429	0,525
8	0,561	0.029	1,250	0,767
9	0,543	0.029	1,111	0,512
10	0,535	0.046	1,000	0,417
15	0,511	0.045	0,667	0,338
20	0,514	0.046	0,500	0,406
25	0,478	0.054	0,400	0,350
30	0,448	0.055	0,333	0,188

Table 2. *Characteristics of plexiglas holes received with power laser beam 30W.*

Speed, mm/s	Width, mm	WHAAS, mm	LED	EPD, mm
5	0,666	0.021	6,000	3,886
6	0,582	0.032	5,000	3,560
7	0,578	0.037	4,286	3,126
8	0,574	0.042	3,750	2,756
9	0,570	0.032	3,333	2,590
10	0,575	0.042	3,000	2,564
15	0,530	0.026	2,000	1,289
20	0,498	0.026	1,500	0,893
25	0,488	0.032	1,200	0,625
30	0,470	0.026	1,000	0,472

Table 3. Characteristics of plexiglas holes received with power laser beam *50W*

Speed, mm/s	Width, mm	WHAAS, mm	LED	EPD, mm
5	0,731	0,026	10,000	8,324
6	0,693	0,021	8,333	7,857
7	0,680	0,047	7,143	5,549
8	0,647	0,031	6,250	4,617
9	0,623	0,026	5,556	4,464
10	0,605	0,037	5,000	4,217
15	0,570	0,026	3,333	3,613
20	0,544	0,042	2,500	2,514
25	0,494	0,037	2,000	1,621
30	0,480	0,021	1,667	1,140

Table 4. Efficiency perforation depth (EPD) depends on power and laser beam speed.

Speed, mm/s	EPD, mm				
	10 W	20 W	30 W	40 W	50 W
5	1,145	3,875	3,886	5,539	8,324
6	0,579	3,113	3,560	4,788	7,857
7	0,525	2,538	3,126	4,490	5,549
8	0,517	2,231	2,756	3,621	4,617
9	0,500	1,964	2,590	3,681	4,464
10	0,417	1,737	2,564	3,490	4,217
15	0,338	0,899	1,289	2,692	3,613
20	0,406	0,523	0,893	0,941	2,514
25	0,350	0,510	0,625	0,881	1,621
30	0,188	0,483	0,472	0,869	1,140

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ИЗСЛЕДВАНЕ НАПРЕЖЕНИЯТА, ВЪЗНИКВАЩИ В РАМАТА НА РОЛКОВИ КЪНКИ ПРИ СВОБОДНО ПРИЗЕМЯВАНЕ.

STUDY OF STRESS OCCURING IN THE FRAME OF ROLLER SKATES IN FREE LANDING.

Инж. Асенов К., Проф.д-р Тодоров С., Институт по металознание, съоръжения и технологии с Център по хидро- и аеродинамика „Акад. А. Балевски“ – Българска Академия на Науките, гр. София, България

krasimirasenow@gmail.com

smt@ims.bas.bg

Summary: *As a result of the use of roller skates for recreation or sports on uneven surfaces other than a special one, there is a significant amount of mechanical energy absorbed by the joints of the users as a result of unevenness, as well as combinations of jumps and landings from different heights. Scientific study on this issue will provide an opportunity to gain an insight into how much mechanical stress is distributed to the skate frame for dynamic post-landing loads and the results will provide guidance on making technical solutions to reduce the amount of mechanical energy absorbed by human joints when using roller skating and providing innovative technical solutions in the construction of the product and tooling.*

Keywords: ROLLER SKATES, JOINTS, STRESS ABSORBTION,

1. Увод

В контекста на новото време, характеризиращо се с все повече улеснения в човешките дейности, с развитието на електронните устройства като смартфони, таблети, компютри и свързаните с тях игри, все по-заседналия начин на живот и влошеното здравословно състояние, което обхваща все по-млади възрастови групи, интересът на хората към подновяване и засилване на физическата активност като средство за профилактика срещу редица негативи, причинени от обездвижването, постепенно се завръща.

Въпреки, че активната почивка набира все по-голяма популярност, все още много хора предпочитат да не се движат и прекарват значителна част от свободното си време в седене пред компютър, таблет или смартфон, без да осъзнават вредните последствия за организма и живота им, като цяло, изразени в бъдещи проблеми с наднормено тегло, проблеми с очите, хипертония, повишен риск от сърдечно-съдови заболявания, разстройства на нервната и ендокринната система и други. За тази група от хора е необходим по-силен стимул, който да ги накара да са физически активни. При съчетание на тази необходимост с вродения стремеж у хората за търсене на нови и разнообразни преживявания, се изправяме пред предизвикателството да се изобрети атрактивно средство, пробуждащо интереса на повече хора към активната почивка, движението и спорта, което би довело до повече здрави и щастливи хора.

Желанието на хората да имат свободата да се придвижват с по-висока скорост от тази при ходене и същевременно да не се изморяват прекомерно, датира от столетия назад. Този стремеж е довел до появата на кънките, като средство за придвижване, атракция, игра и спорт. Поради фактът, че в наши дни пазарът е наситен с голямо разнообразие от кънки, велосипеди и други принципно сходни изделия, може да се заключи, че те поддържат интереса на хората към себе си до определено, сравнително постоянно, равнище.

Импулс на по-висок интерес към движението може да се постигне чрез иновация в конструкцията на изделие, което да предлага ново преживяване, което не би могло да се постигне чрез съшествуващите решения.

2. Предпоставки и начини за разрешаване на проблема.

В резултат от използването на ролкови кънки за развлечение или спорт по настилка с неравности, различна от специално обособена, се наблюдава значително количество механична енергия абсорбирана от ставите на потребителите, вследствие преминаването през неравности, както и изпълнението на съчетания от подскоци и приземявания от различни височини. Колкото по-голяма е масата на ползвателите на изделието, толкова повече механична енергия поемат те. Тази енергия има ударен характер, поради липсата на абсорбатори в познатите конструкции на ролкови кънки.

Проблемът може да се обобщи по следния начин:

Изследване на абсорбираната енергия в рамата на ролкови кънки, вследствие на динамично натоварване с ударен характер при приземяване.

3. Решение на проучения проблем.

В резултат на проучване относно използваните понастоящем ролкови кънки, се забелязва възможността за оптимизиране на конструкцията, чрез нови технически решения.

Научното изследване по този проблем ще даде възможността да се добие представа какви усилия възникват в рамата на кънките при динамично натоварване след приземяване, като резултатите ще дадат насоки към усъществяване на технически решения за намаляване на количеството механична енергия, абсорбирана от човешките стави при употреба на ролкови кънки и предоставяне на иновативни технически решения в конструкцията на изделието и инструменталната екипировка.

Изследването протича в следните стъпки:

3.1. Определяне числената стойност на кинетичната енергия, освободена при свободно приземяване (падане) на тяло с маса 70 кг (равна на приблизително 50-ти персентил мъж).

3.2. Определяне на механичната сила образувана в рамата на ролкови кънки вследствие изходните резултати от точка 2.1., чрез структурни симулации с компютърен изчислителен модул “NX NASTRAN”.

3.3. Дефиниране на възможности за намаляване на абсорбираната енергия от рамата на кънките и съответно човешките стави.

Свободното падане е равноускорително движение без начална скорост, чието ускорение е g, а траекторията му е отвесна права линия.

Следователно формулите за скоростта и пътя при равноускорителното движение са в сила и при свободното падане на телата, като ускорението **a** се замести с **g**, а изминатият път вместо с **s**, може да се означи с **h.**

Закон за скоростта при свободно падане: ***v =gt*** (1)

Закон за пътя при свободно падане: ***h = gt2/2*** (2)

От (1) и (2), като изключим времето **t**, получаваме зависимостите ***h = v2/2g*** (3) и ***v2 = 2gh*** (4).

Следователно при тяло с маса **70 кг**. и височина на падане **1 метър**, скоростта в момента на удар е **4,43 м/с** (**15.94 км/ч**), а **времето** на свободното падане е **0,45 секунди**.

Енергията в момента на удара се изчислява по формулата $\mathbf{1/2mv^2 = mgh,}$ където **m** е масата на обекта, **v** е скоростта на падане, **h** е височината, а **g** е земното ускорение.

В този случай, освободената енергия при свободно падане на тяло с маса 70 кг и височина 1 метър е **686 Джаула.**

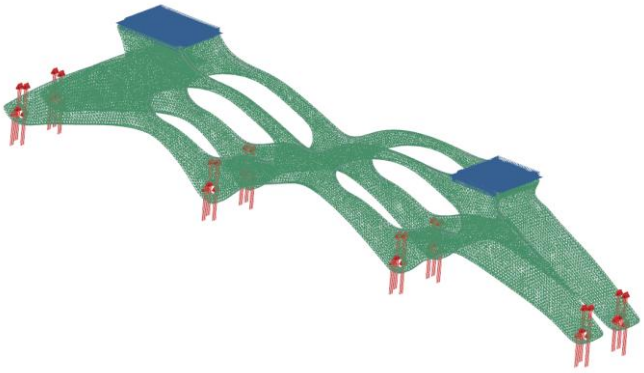
Изчисляването на ударната сила става по формулата **2mv/t**, където m е масата, **v** е скоростта, а **t** е времето на контакт по време на удара. Приемаме, че времето на контакт по време на удара е 0.5 секунди.

Тогава ударната сила е равна на **876 N.**

Тази сила ще бъде използвана при изчисляването на получените напрежения в рамата на ролкова кънка в изчислителния модул “NX NASTRAN”.

4. Резултати и дискусия.

На фигура 1 е изобразена схемата на изследването, като отбелязаните в синьо повърхнини са фиксирани, а червените стрелки указват местоположението и посоката на въздействащите сили. Материалът е стъклонапълнен полипропилен с 15% стъклени влакна.



Фигура 1. *Схема на изпитването.*

Изследването е проведено по Методът на Крайните Елементи.

Информация за омрежването на детайла (фиг.2):

Брой на елементите: 105071;

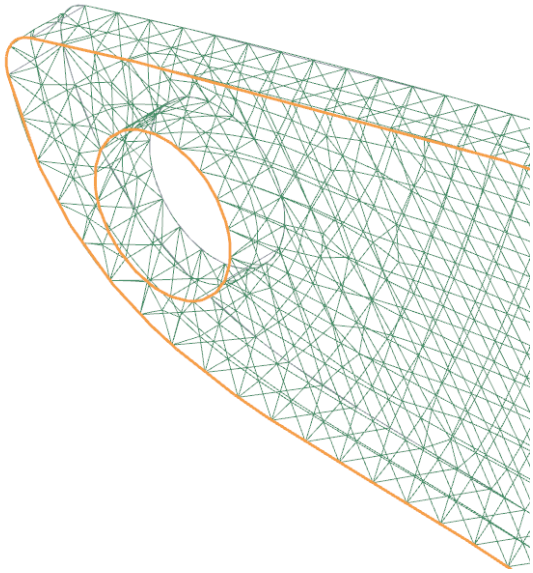
Брой на възлите: 193095;

Брой на елементите от тип Тетра10: 105071;

Тип на мрежата: 3Д мрежа, Тетра10;

Физични свойства на мрежата: PSOLID1;

Големина на тетраедралния елемент: 3мм.;



Фигура 2. *Форма на мрежата.*

Информация за материала:

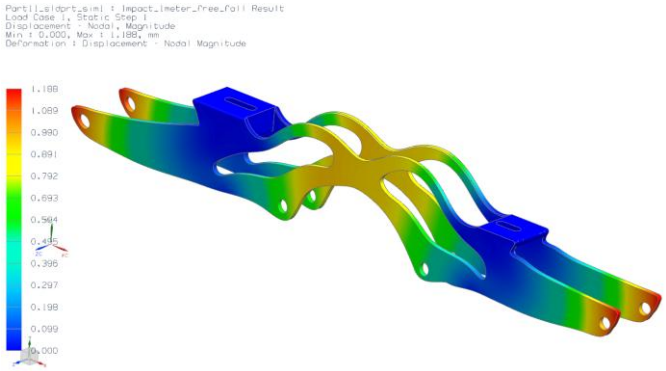
На фиг.3 е дадена обща информация за материала, извадена от библиотеката на програмния продукт.

```
Material : Polypropylene-GF

Material properties:
Referenced library material : physicalmateriallibrary.xml
Material Type:   Isotropic
Label:   1
    Category                              : PLASTIC
    Mass Density (RHO)                    : 1.2e-006 kg/mm^3

     ======== Mechanical
    Youngs Modulus (E)                    : 3e+006 mN/mm^2(kPa)
    Poissons Ratio (NU)                   : 0.4
    Shear Modulus (G)                     : Not defined
    Structural Damping Coefficient (GE)   : Not defined
    Stress-Strain (H)                     : Not defined
    Type of Nonlinearity (TYPE)           : PLASTIC
    Yield Function Criterion (YF)         : von Mises
    Hardening Rule (HR)                   : Isotropic
    Initial Yield Point (LIMIT1)          : Not defined
    Initial Friction Angle (LIMIT2)       : Not defined

     ======== Strength
    Yield Strength                        : 60000 mN/mm^2(kPa)
    Ultimate Tensile Strength             : Not defined
```

Фигура 3. Информация за материала.

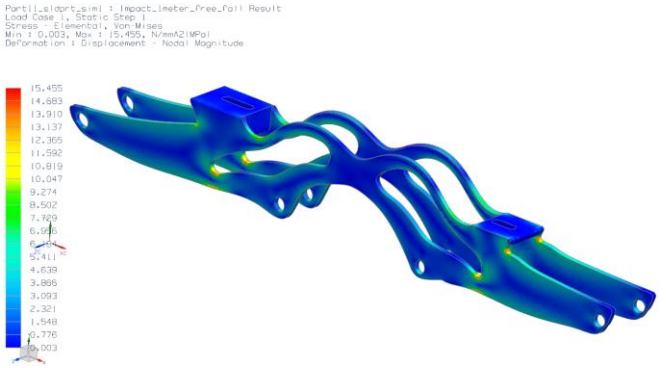
Резултатите от изследването и проведената симулация показват, че при сила от 876 Нютона, максималното резултантно преместване на зони от рамата възлиза на 1,18 мм (фиг.4).

Цветовата диаграма на фиг.4, нагледно показва кои участъци от детайла са с най-голямо отместване.



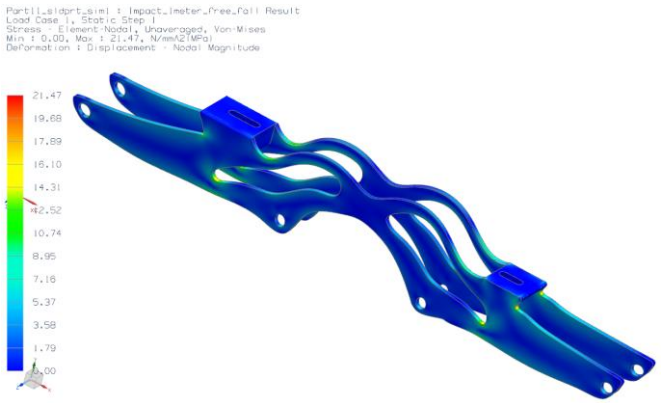
Фигура 4. *Резултантно преместване при статично натоварване със сила 876 Нютона.*

На фигура 5 са представени резултатиоте по отношение на възникнали еквивалентни напрежения по Фон Мизес в конструкцията на рамата. Макисмалната стойност е приблизително 15.5 МПа, което е под границата на провлачане на материала (30 МПа).



Фигура 5. *Резултат на еквивалентните напрежения.*

От тук следва да се заключи, че получените стойности за деформация остават в зоната на еластичната деформация и не биха довели до структурно разрушаване на детайла.



Фигура 6. *Резултат на еквивалентните напрежения във възлите на елементите.*

На фигура 6 се представят стойностите получени във възлите на елементите. В реалността, стойността на напреженията се намира между тези получени при Фон Мизес и тези при възлите на елементите, което отново е под границата на провлачане за материала, съответно деформацията е обратима и е в еластичната зона.

5. Заключение.

Това изследване предоставя информация относно числените стойности на механичните напрежения образувани в рамата на ролкови кънки при ударно натоварване, което е обвързано с максималното количеството енергия пренесено върху ставите и органите на потребителя при използване на изделието по неравна настилка и при изпълнение на техники, свързани с отскачане и приземяване от различна височина. Получените числени стойности трябва да служат като ориентир за подобряването им в бъдещия продукт.

Необходимо е подробно проучване за това по какъв начин най-ефективно би била редуцирана поетата енергия от човешките стави.

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MATERIAL-SCIENCE ASPECTS OF FORMATION AND EVOLUTION OF DAMAGES WHICH DEFINE THE RESOURCE EXPLOITATION OF ALUMINUM STRUCTURES OF AIRPLANES

МАТЕРИАЛНО-НАУЧНИ АСПЕКТИ НА ФОРМИРАНЕТО И ЕВОЛЮЦИЯТА НА ВРЕДИ, КОИТО ОПРЕДЕЛЯТ ИЗПОЛЗВАНЕТО НА РЕСУРСИТЕ НА АЛУМИНИЕВИТЕ СТРУКТУРИ НА САМОЛЕТИТЕ

Prof. Dr. Chernega S., eng. Abolihina H.
National Technical University of Ukraine "Igor Sikorsky Kiev Polytechnic Institute", Department of metal science and heat treatment,Ukraine, Kiev, st. Polytechnic, Bldg. 9, tel.: +38 (066) 990 - 90 - 35
e-mail: smchernega@ukr.net; hellenab17@gmail.com

Abstract
The work is devoted to the study of evolution of flaws in aluminium alloys of Al-Zn-Mg-Cu, Al-Cu-Mg-Mn alloying systems and to the determination of their connection with structural factors of the material such as the size and composition of intermetallic phases conditioned by heat treatment tempers, and also to the study of the effect of big number of physical factors on the long-term behaviour of structural elements of aluminium alloys, and to the determination of the rate of formation of corrosion damages in structural elements of the aircraft wing

KEYWORDS: *ALUMINIUM ALLOYS, CORROSION DAMAGES, INTERMETALLIC PHASES, COPPER, HEAT TREATMENT, MICROSTRUCTURE, CORROSION RESISTANCE, GRAIN BOUNDARIES, REGRESSION ANALYSIS*

Introduction

the study of evolution of flaws in aluminium alloys of Al-Zn-Mg-Cu**,** Al-Cu-Mg-Mn alloying systems and to the determination of their connection with structural factors of the material such as the size and composition of intermetallic phases conditioned by heat treatment tempers, and also to the study of the effect of big number of physical factors on the long-term behaviour of structural elements of aluminium alloys, and to the determination of the rate of formation of corrosion damages in structural elements of the aircraft wing. The work is aimed at securing the long-term safe operation of airplanes.

The issue of evolution of flaws and metal-science aspects of their formation was examined for B93T1, B93пчT1, 1933T3 forging aluminium alloys of Al-Zn-Mg-Cu alloying system which is applied in the aircraft primary structural elements where we face large concentration and localization of stresses that can lead to their very rapid failure. In this case, origination and propagation of a failure can occur even without the previous effect of corrosion. Susceptible areas are strictly regulated and they are first of all subject to monitoring during scheduled inspection of the airplane. Using the techniques of electronic microscopy and X-ray chemical microanalysis, it was determined that during industrial heat treatment of B93 alloy using T1 temper: quenching 450-465^{o}C and two-stage phase ageing 115^{o}-125^{o}C (6-10 hours), 165^{o}-175^{o}C (4-8 hours), chains of the phase with increased content of copper precipitated at the grain boundaries during quenching simultaneously with strengthening phases. The size of some links of the chains reached 1-5 mcm. Their presence stipulates for concentration of stresses which contribute to corrosion cracking. Precipitation of inclusions of intermetallic phases containing copper at the grain boundaries does not correspond to the statements of developers of the alloy.

It was proved that change of heat treatment temper to coagulation ageing (T3 temper: quenching 450-465^{o}C and two-stage ageing 115^{o}-125^{o}C (6-10 hours), 180^{o}-190^{o}C (6-10 hours)) contributed to higher corrosion resistance of B93пчT3 alloy compared to B93T1 alloy, that was conditioned by much smaller content of copper in precipitation of intermetallic phases after quenching, formation of strengthening phases after ageing which did not contain copper, higher fragmentation of particles of intermetallic phases, which precipitated during quenching.

During coagulation ageing of 1933T3 alloy, which differed from B93пчT3 alloy with the zirconium admixture, precipitation of particles of strengthening phases occurred mainly at the stage of coagulation ageing. At the grain boundaries we observed particles of $MgZn_2$, $Al_2Zn_3Mg_3$, Mg_2Si phases connected with the matrix in a coherent way. Precipitation of particles of intermetallic phases with copper content at the grain boundaries did not occur, that obviously stipulated for the highest corrosion resistance of the alloy. Such differences in the structure of alloys, conditioned by heat treatment, contributed to evolution of flaws during transition from B93T1 alloy to 1933T3 alloy and the increase of corrosion resistance, yield and plasticity while maintaining high strength.

Application of X-ray microanalysis techniques allowed to determine the presence of coarse inclusions of insoluble phases with the length of 10 to 300 mcm in the grain body of all three alloys, which presence contributes to the development of fatigue failure during long-term operation.

Monitoring of flaws which contributed to premature failure of parts showed that B93T1 alloy had low resistance to alternate and static loads, and was susceptible to corrosion cracking even under the absence of aggressive environments. 1933T3 alloy appeared to be the most resistant to static, dynamic and alternate loads, and not susceptible to corrosion cracking.

Further examination of the issue of evolution of flaws and their monitoring in service was continued for wing upper and lower panel skins which are the most responsible structural elements of the airplane though they are much less loaded if compared to structural elements produced of forging alloys. For the upper panels, which are in compressed state during the flight, we apply B95T1 high-strength alloy of Al-Zn-Mg-Cu alloying system, quenched and aged to the maximum strength. And for the lower panels, which experience tensile loads during the flight, we apply Д16T long-life alloy of Al-Cu-Mg-Mn alloying system. The skins are produced of long extruded or rolled products: sheets or plates, in which the direction of elongated grains is perpendicular to the acting loads (the area of action of the load coincides with the transversal-longitudinal area of fibres in the material). Taking into account the design features: considerable length of joints, big number of fastener holes and areas of permanent condensation in the torsion boxes of the wing centre section (closed cavities), the most probable areas of origin of corrosion damage are the grain boundaries located in problem areas perpendicular to the direction of application of loads. A critical factor which determines the life of skins is thinning of their crosscut due to corrosion damage. Stated features of evolution of flaws and also relatively easy access to damaged areas change the strategic approach to enhancement of durability of these structural elements. An emphasis is made on the increase of latent period of formation of corrosion damage and fatigue cracks that is achieved at the first stage by applying protective coatings and restoring them after certain interval of operation. However, this effective method does not

ensure 100% guarantee from appearance of corrosion spots in the metal matrix, that is why there is another and not less important way to delay the appearance of critical flaws called scheduled maintenance which ensures detection and elimination of flaws on external and internal surfaces of the wing. In this case, a critical condition is to provide the optimum amount of scheduled maintenance which from one side would ensure an accident-free operation and from the other side would minimize capital expenditures.

The paper addresses the main operating factors which influence the origin and growth of flaws on the surface of the aircraft wing skins, and determines characteristic areas which are susceptible to corrosion. The largest amount of statistical data is accumulated for two versions of An-24 and An-26 airplanes that allowed evaluating the damage growth rate in the centres of corrosion which appeared on upper and lower panel skins of B95T1 and Д16T alloys respectively. As a criterion there was taken the change of the maximum depth of damage on flawed surface areas which appeared in the interval between two successive inspections of panels, it means not considering the latent period of damage formation. It was shown that linear relation exists between the geometrical parameters of corrosion flaw and the time. The rate of corrosion is determined by the tangent of the angle of slope of the straight line.

Basing on the results of statistical analysis of a huge amount of data from inspections performed in certain climatic zones such as the size of corrosion damage, accumulated life, service life, intensity of flights, number of overhauls, etc., it was determined that climatic conditions and inspection intervals had the maximum effect on the corrosion damage growth rate (unlike the total time of operation).

Using the method of regression analysis, there were obtained the equations of regression which determined the corrosion damage growth rate for different climatic zones, and there was determined the maximum damageability of the aircraft wing skins during one year of operation: this data is shown below.

Lower panel skins of Д16T alloy:

Moderate climate - $y=(0.12\pm0.015)\ x_1$;

Continental climate - $y=(0.23\pm0.042)x_1$;

industrial zones - $y=(0.33\pm0.035)x_1$;

maritime climate - $y=(0.34\pm0.045)x_1$;

mixed operating conditions - $y=(0.28\pm0.037)x_1$;

humid tropics - $y=(0.47\pm0.056)x_1$.

where x_1 is the life between overhauls.

Upper panel skins of B95T1 alloy:

moderate climate - $y=(0.12\pm0.028)x_1$;

maritime and industrial zones - $y=(0.27\pm0.014)x_1$;

mixed tropical and moderate climate - $y=(0.37\pm0.025)x_1$;

humid tropical climate - $y=(0.51\pm0.022)x_1 + (0.00024\pm0.00018)x_2$

- where x_1 is the life between overhauls; x_2 is the intensity of flights.

There by, the increase of the time between overhauls by 1 year leads to the increase of the maximum depth of corrosion damage on the lower panel skins of the wing centre section by ~0.12 mm in moderate climate zones; by ~0.23 mm in continental climate zones; by ~0.33 mm in industrial zones; by ~0.34 mm in maritime climate zones; by ~0.28 mm under mixed operating conditions; by ~0.47 mm in humid tropics zones.

Using the similar procedure, there was determined the depth of corrosion damage of the external surface of the wing upper panel skins of B95T1 alloy. In this case we shall expect the increase in depth by ~0.12 mm in moderate climate zones; by ~0.27 mm in the zones of influence of maritime and industrial environments; by ~0.37 mm in the zones of mixed tropical and moderate climate; by ~0.58 mm in the zones of humid tropics with the intensity of flights of 300 flights/year.

Basing on the obtained results of the analysis, technical documentation was developed for ultrasonic inspection of the thickness of lower panels of the wing centre section of An-24 and An-26 airplanes and there were issued the recommendations for timely detection of damages of different structural elements. This will make it possible to operate these airplanes without disassembly of panels during not less than 10 years after preliminary inspection and despite the climatic zone where the airplane is based.

The results of corrosion growth rate analysis for different structural elements of the wing were used to adjust the inspection intervals and to determine the optimum time for renovation of anticorrosion protection of the analyzed area and group of airplanes, as well as other areas, groups and types of airplanes for which this area and group can be considered a prototype.

General scheme of acquisition and analysis of corrosion damage data based on service experience of the available aircraft fleet allows solving both the problems of its continued airworthiness, and the problems of reliable anticorrosion protection of newly designed aircraft based on available data.

Research of the microstructure of industrial aluminium alloys in terms of susceptibility to corrosion cracking is taken into account when evaluating the life of a separate element and that of the entire structure, and it is also used for successful selection of materials with required set of features for existing and future aircraft structures.

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EXPERIMENTAL AND SIMULATION DETERMINATION OF FRICTION COEFFICIENT BY USING THE RING COMPRESSION TEST

Assist. Prof. Yankov E., Ph.D

[1]University of Ruse, Dept. Material Science and Technology, Ruse, 8 Studentska Str., Bulgaria[1]
eyankov@uni-ruse.bg

Abstract:

One of the main problems in the plastic deformation of materials is the determination of the coefficient of friction as well as the subsequent application of the simulation for comparative analysis. However forecasting process and matching between simulation and experimental data is still a problem. Causes of this are factors such as roughness, mechanical properties of the material, chemical composition, etc. which strongly influence the behavior of the material in the simulation of the process.

In this study, an approach is proposed to determine the changeable coefficient of friction in the deformation process experimentally, taking into account implicitly the influence of surface roughness on the friction curves. For the comparative analysis between experiment and simulation of the process, the experimental data for objective assessment was introduced. Nevertheless, there are differences between experiment and simulation, which is most evident in high loads, using lubricants differing from more than 12 units for graphite lubricant, with more than 6 units with oil and with dry friction with 8 units.

Keywords: FRICTION, RING, COMPRESSION, SIMULATION, PLASTIC DEFORMATION

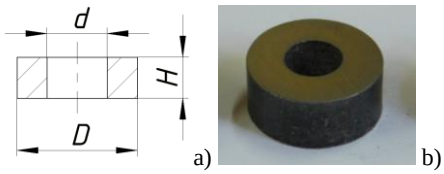
1. Introduction

Forecasting the coefficient of friction of plastic deformation of metals by means of software products is still a problem [1-4]. As is well known, it depends on a number of factors, such as the type of lubricant used and the roughness of the friction surfaces of the tool and the workpiece [5, 6]. Different software products are used to investigate the problem by introducing a set of experimental data for the purpose of adequate simulation and forecasting. For the majority of software products, the surface roughness parameter is not included as an input parameter, but it is part of a complex friction factor index - friction coefficient μ or friction factor m [7]. Both indicators friction usually introduced as constants in the models to simulate until they change the process of deformation. In such case interpretation of the results may lead to incorrect conclusions and significant deviations of the results of experiment and simulation. To obtain an objective solution to the problem, multiple repetition of simulation with different values of μ and m can be performed.

The aim of the present study is to establish the possibility of simulating the process of deformation of pressure rings (DPR) by applying experimentally established equations for the change of coefficient of friction.

2. Materials for Production of Prototype Parts[Грешка! Източникът на препратката не е намерен.]

For the purposes of the experimental study by the process DPR used steel bar material 10 sp. With a chemical composition in% (C - 0.9, Si - 0.26, Mn - 0.43, P – 0.08, S =0.03). The nominal dimensions of the rings with an outer diameter D = 16 mm, the inside diameter d = 6.5 mm and height H = 7 mm (Figure 1).

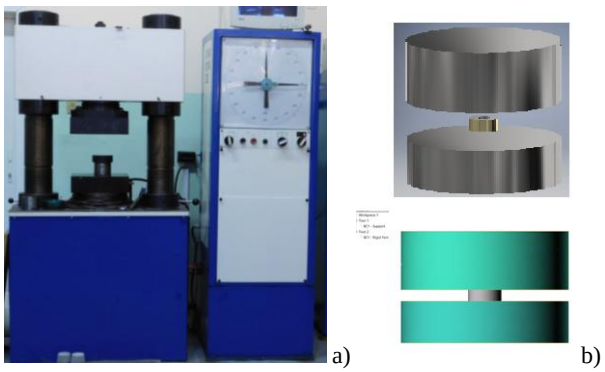


a) b)

Fig. 1*. Test bodies for the experimental determination of the coefficient of friction: (a) the dimensions of the test piece (b) the test piece*

The contact surfaces of the test specimens have a roughness Ra = 2.5 ÷ 1.25 μm, and the working surfaces of the tool are of Ra = 0.63 μm..

For the flattening of the test bodies was used a hydraulic press MC 2000 with mounted flat parallel boilers (fig.2). The study was performed under three friction conditions - dry, with oil MHL-34 and graphite powder.



a) b)

Fig. 2. *Used Testing Equipment (a) Testing Machine MS-2000; b) a digital simulation model*

The experimental test rings are flattened into three transitions with a loading force (F) of 100, 200 and 300 kN with a set load speed of 0.5 mm / min at room temperature. Upon reaching the specified load the sample is ejected, wherein using a load cell is recorded the maximum thrust force (T) - the criterion for the maximum friction. Before each deformation, the samples are cleaned, measured, and the test rings are lubricated by their working heads at a specific dose. Prior to each test, the working surfaces of the top and bottom lugs are also cleaned and lubricated with the lubricant for the lubricant tests. The dimensions of the rings before and after deformation are measured with an electronic caliper with an accuracy of 0.01 mm (Table 1, 2 and 3). From the obtained measurement data are calculated: the degree of deflection ε (1), the relative change of the inner diameter Δd / d, the force of ejection T between the ring sample and the two flat cylinders, the coefficient of friction μ (2) [8] are constructed experimental curves for the change of the coefficient of friction μ' (Fig.3). The calculated μ values for the different strain rates determine the coefficient of variation curve.

$$\varepsilon = (H_0 - H)/H_0 \times 100 \quad (1)$$

$$\mu = (2 \times T)/F \quad (2)$$

For the comparative analysis of the experimental data and simulation, the software product "QForm 3D" v.7.1 was used, in which the necessary data from the experiment was introduced, instead of introducing a constant coefficient of friction using the experimental curve for the change of the coefficient of friction, the presumed recovery curve from the material pressure test, the chemical composition, the type of lubricant, etc.

Data collection from the simulation was performed at a loading step of 100 kN. The study process continues until the maximum force of the hydraulic press 400 kN has been reached. The results of the simulation are presented in tables (tables 4, 5 and 6) and graphical dependencies are built (fig. 4).

3. Results and discussions

Figure 3 illustrates graphically the change of the experimentally established coefficient of friction for the three cases. At the initial deformation stage, the lowest internal diameter variation values are present for the non-lubricated sample. In fact the initial inner diameter under load of 100 kN is not altered (Table 1), while increasing only the outer diameter. Probably this is due to the fact that the roughness of the sample is greater than that of the tool, resulting in friction being associated with breaking the peaks of the roughness during the loading process.

Table 1. *No lubrication - Experimental data*

Measurement number	Load force	Height	Inner diameter	Strength of pushing	Relative amendment	Relative deformation	Coefficient of friction
	Fn (kN)	H (mm)	d (mm)	T (κN)	Δ d/do (%)	ε (%)	μ
0	0	7	6.55	0.00	0	0.00	
1	100	6.33	6.55	18.53	0	9.57	0.3705
2	200	4.43	6.4	26.70	2.29	36.71	0.2670
3	300	3.35	5.76	34.60	12.06	52.14	0.2307

Table 2. *With Oil - Experimental Data*

Measurement number	Load force	Height	Inner diameter	Strength of pushing	Relative amendment	Relative deformation	Coefficient of friction
	Fn (kN)	H (mm)	d (mm)	T (κN)	Δ d/do (%)	ε (%)	μ
0	0	7	6.55	0.00	0	0.00	
1	100	6.51	6.8	18.58	-3.82	7.00	0.3716
2	200	4.45	6.92	24.58	-5.65	36.43	0.2458
3	300	3.36	6.7	33.92	-2.29	52.00	0.2261

Table 3. *With graphite lubricant - Experimental data*

Measurement number	Load force	Height	Inner diameter	Strength of pushing	Relative amendment	Relative deformation	Coefficient of friction
	Fn (kN)	H (mm)	d (mm)	T (κN)	Δ d/do (%)	ε (%)	μ
0	0	7	6.55	0.00	0	0.00	
1	100	6.38	6.6	18.87	-0.76	8.86	0.3774
2	200	4.36	6.87	27.63	-4.89	37.71	0.2763
3	300	3.22	7.22	35.83	-10.23	54.00	0.2388

As a consequence of this effect the neutral surface has a radius less than the inner radius of the sample, which is typical of cases with a lubricant. The increase in load leads to a leveling of the micro-roughness and consequently increase the contact area with which the friction increases, the neutral surface radius increases its rn to values exceeding the inner radius of the sample (r <rn) and intensive reduction in the inner diameter. The application of lubricant to the other two samples, as well as expected, resulted in the arrangement of the curves in the lower quadrant (Figure 4). Due to reduced friction, the inner diameter (d) increases μ', as in the case of oil in the initial stage and in comparison with the graphite lubricant is lower. This difference may be explained by the complex influence of the lubricant and roughness in the friction zone.

Due to the fact that the roughness in the initial stage is high, friction occurs with a smaller contact area, which state can be said to correspond approximately to a case of border friction. As a result, the increase in the inner diameter is the greatest in comparison with the dry friction and the use of a graphite lubricant. With the increase of load d slightly changed until reaching a deformation of 36%, which is associated with the closure of the micro-volumes of oil between the roughness and thereby providing an increased contribution of the oil in the process of friction.

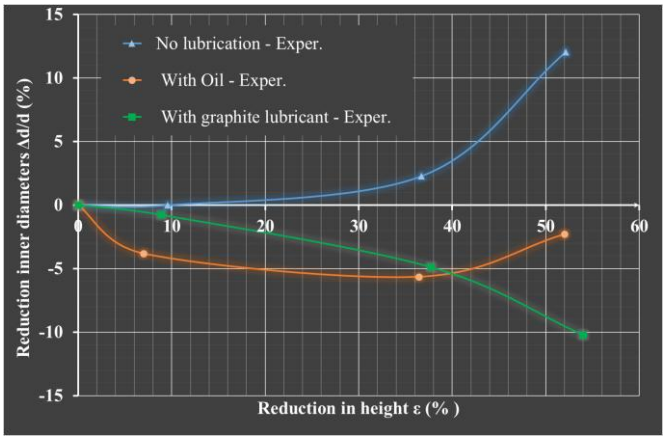


Fig. 3. *Friction curves μ' from experimental data*

The reduction of d in deformations of more than 38% is in accordance with the known regularity of increasing the coefficient of friction at high loads associated with the increase of the contact area and a significant increase of the inhomogeneity of distribution of the oil, accompanied by its displacement.

Table 4. *No lubrication - Simulation data*

Measurement number	Load force	Height	Inner diameter	Strength of pushing	Relative amendment	Relative deformation	Coefficient of friction
	Fn (kN)	H (mm)	d (mm)	T (κN)	Δ d/do (%)	ε (%)	μ
0	0.00	6.80	10.00	0.00	0.00		
1	96.34	6.80	9.88	23.44	1.20	0.00	0.4865
2	122.42	6.30	9.81	25.42	1.90	7.35	0.4152
3	153.38	5.89	9.74	27.52	2.60	13.38	0.3588
4	181.31	5.51	9.68	29.56	3.20	18.97	0.3260
5	210.39	5.15	9.54	31.56	4.60	24.26	0.3000
6	243.26	4.81	9.39	34.08	6.10	29.26	0.2802
7	278.49	4.48	9.18	36.83	8.20	34.12	0.2645
8	316.23	4.18	8.96	39.31	10.40	38.53	0.2486
9	360.26	3.91	8.63	42.11	13.70	42.50	0.2338

Table 5. *With Oil - Simulation Data*

Measurement number	Load force	Height	Inner diameter	Strength of pushing	Relative amendment	Relative deformation	Coefficient of friction
	Fn (kN)	H (mm)	d (mm)	T (κN)	Δ d/do (%)	ε (%)	μ
0	0.00	6.80	10.00	0.00	0.00	0.00	
1	88.12	6.80	9.86	23.34	1.40	0.00	0.5298
2	110.49	6.30	10.01	25.36	-0.10	7.35	0.4591
3	142.83	5.80	10.20	28.95	-2.00	14.71	0.4054
4	175.10	5.30	10.38	30.04	-3.80	22.06	0.3431
5	210.92	4.83	10.54	33.04	-5.40	28.97	0.3133
6	250.53	4.40	10.64	36.35	-6.40	35.29	0.2902
7	294.24	4.01	10.92	40.19	-9.20	41.03	0.2732
8	342.07	3.67	10.93	43.59	-9.30	46.03	0.2548
9	395.87	3.38	10.97	47.93	-9.70	50.29	0.2422

Table 6 *With graphite lubricant - Simulation data*

Measurement number	Load force	Height	Inner diameter	Strength of pushing	Relative amendment	Relative deformation	Coefficient of friction
	Fn (kN)	H (mm)	d (mm)	T (κN)	Δ d/do (%)	ε (%)	μ
0	0.00	6.80	10.00	0.00	0.00	0.00	
1	92.40	6.80	9.87	23.67	1.30	0.00	0.5124
2	116.52	6.30	9.80	25.46	2.00	7.35	0.4371
3	150.54	5.81	9.90	27.80	1.00	14.56	0.3694
4	181.01	5.37	9.92	30.22	0.80	21.03	0.3339
5	213.05	4.97	9.86	32.69	1.40	26.91	0.3069
6	247.77	4.60	9.88	35.63	1.20	32.35	0.2876
7	286.38	4.25	9.71	38.48	2.90	37.50	0.2687
8	325.62	3.96	9.60	41.46	4.00	41.76	0.2546
9	370.96	3.69	9.48	44.66	5.20	45.74	0.2408

Typical for lubrication with graphite lubricant is the increase of the internal diameter continuous from the beginning of the load. Compared to the effect of the oil, it is obvious that the graphite

grease eliminates the influence of roughness, which can be explained by better adhesion to them. In addition, the results of the experiment once again confirm the well-known fact for the good lubricating effect of graphite at high loads [9].

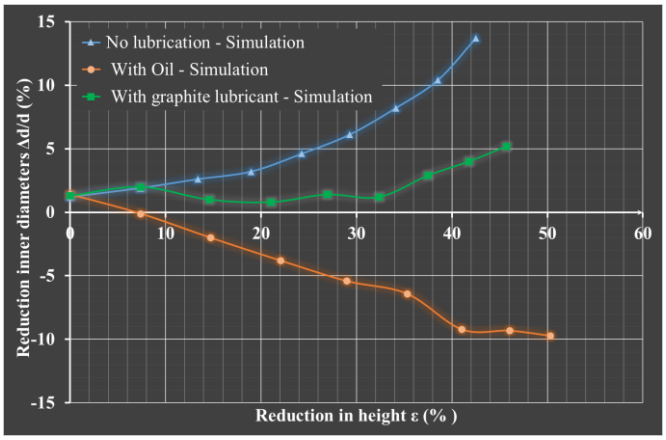


Fig. 4. *Friction curves μ" from simulation data*

The comparative analysis of the height variation for the three friction cases shows that for the small deformation rates, the strongest change occurs in dry friction, which can be explained by the influence of the roughness as mentioned above. Furthermore, the dry friction deformation is at the expense only of a change in the outer diameter D, whereas when using a lubricant, deformation occurs at the expense of the outer and inner diameters.

The simulation results show deviations in comparison with the experimental results obtained. The biggest deviation is obtained using a graphite lubricant. The simulation gives a curve to change the friction coefficient (μ") located above the zero line and up to 32% of the deformation degree, the internal diameter is almost unchanged, indicating that the deformation is largely at the expense of the outer diameter. The character of the curve shows that the software does not take into account the influence of surface roughness, although the input data from the experiment contain implicitly the roughness of the wells and samples. Moreover, in the area of large loads (over 32% deformation), the software provides a change in the direction opposite to the experimentally established. However, the deformation deflection of 46% represents a total of 12 units in the variation of d. These large deviations can not be explained except that graphite in the software is treated as solid particles leading to dry friction when the load is increased.

And when simulating the oil process in the initial stage, the curve of μ" indicates that the effect of roughness is not taken into account. And when simulating the curve shows that the inner diameter is amended practically linear law until a degree of deformation of 35%. In this range there is some coincidence with experimental curves, then there is a sharp decline in contrast to experiment. This means that the software treats friction at high loads, as if the oil is not thrusting but continues to lubricate, as with low loads.

Regarding dry friction, the simulation gives a comparatively satisfactory result, the curve being similar in character to the experimental but located above it. As the degree of deformation increases, the deviation increases, with 40% of the deformation reaching nearly 8 units. For the difference of lubricant cases, the results of the simulation are more reliable as the lubricant factor is eliminated.

These differences in friction variation also led to a difference in the flattening heights between experiment and simulation, most notably at high deformation rates. Highest values are achieved with dry friction - 9.64%, followed by graphite lubricant - 9% and the smallest with oil reaching 2%.

4.Conclusion

The simulation of the ring flattening process in the case of dry friction gives reliable results regardless of the established deviations. In the presence of a lubricant, the differences between the friction curves from the experiment and the simulation are significant, with the largest change being observed for the graphite lubricant. This is due to the incorrect reading of the influence of lubricants on the changes in roughness in the deformation process. By using oil, it is also accepted that friction continues to decrease with a deformation increase of over 40%, which results in contradiction to experimental data and unrecognized change in contact area. In order to correctly simulate the process of flattening of the underlying rings it is necessary to introduce the change of roughness in the process of deformation.

Acknowledgement

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THE ROLE OF RFID TECHNOLOGY IN THE INTELLIGENT MANUFACTURING

Asst. Prof. Zeba G. PhD[1], M.Sc. Čičak M. [1], Prof. Dabić M. PhD [2,3]
Mechanical Engineering Faculty in Slavonski Brod, J. J. Strossmayer University of Osijek, Republic of Croatia [1]
Faculty of Economics and Business, University of Zagreb, Republic of Croatia [2], Nottingham Trent University, Burton Street, Nottingham, United Kingdom [3]

gzeba@sfsb.hr

Abstract: *The manufacturing industry is facing high competitiveness from rivals and high demands from customers. Industry 4.0, as a new manufacturing paradigm, also imposes its demands. The main driver of Industry 4.0 is the development of new innovative technologies including information and communication technologies whose rapid development has given impetus to the development of automated data acquisition systems. The RFID technology is one of the key technologies for intelligent manufacturing that encompasses advanced information and manufacturing technologies. Although the RFID technology is used in Croatia (mostly for identifying persons, access control, payment control, etc.), there is no wider use of the RFID technology in the industry where the main problem of low competitiveness is caused by low levels of innovative capabilities and obsolete technological equipment. The EU strategic documents (e.g. Europe 2020, Digitising European Industry initiative) encourage the digital transformation of industry (with an emphasis on investment in technology and innovation). One of the goals of the Industrial Strategy of the Republic of Croatia 2014-2020 is to increase productivity. To achieve this goal and improve competitiveness it is necessary to increase the use of the RFID technology in industry as the basis for digital transformation.*

The goal of this paper is twofold: to present bibliometric literature review on the RFID technology, and to present advantages of the RFID technology in the context of intelligent manufacturing with reference to the case of Croatian economy.

Keywords: RFID, INTELLIGENT MANUFACTURING, INDUSTRY 4.0, INNOVATIVE TECHNOLOGIES

1. Introduction

Currently, the increased customer demands for high-quality customized and personalized products, with short delivery times, manufacturing companies need to respond quickly to these requirements, increase product efficiency and quality. Traditional production systems cannot respond to such requirements. In order to survive in the market and in view of the requirements of Industry 4.0, manufacturing companies must be digitally transformed and turn to a new paradigm, intelligent manufacturing.

Intelligent manufacturing with features such as learning, reasoning, and acting is closely related to Industry 4.0, as it is called the fourth industrial revolution [1]. Intelligent manufacturing depends on timely data acquisition, distribution and use of different types of data from production resources, products and production processes. The connection of all these elements enables manufacturing systems to become more agile, making decisions based on real-time information and being more adaptable to changing market demands. Technologies of manufacturing intelligence that can be linked to different enterprise information systems (e.g. Enterprise Resource Planning system (ERP), Supply Chain Management system (SCM) etc.) are being rapidly developed and facilitate improving timely decision-making based on real-time information of the actual state of manufacturing and supply chain processes. New innovative technologies that enable such transformation and intelligent manufacturing include: Information and Communication Technologies (ICT), Cloud Computing, Big Data Analysis, Artificial Intelligence. According to [2] there are the four key components of Industry 4.0 (based on literature review): Cyber-Physical Systems (CPS), Internet of Things (IoT), Internet of Services (IoS) and Smart Factory. The development of new, innovative technologies that support these components, especially IoT, leads to that a manufacturing in the context of Industry 4.0 will more and more intelligent [3]. One of the key technologies on which the Internet of Things is based is Radio Frequency Identification (RFID) technology.

Today, technologies of manufacturing intelligence that can be linked to different enterprise information systems are being rapidly developed and enable improving timely decision-making based on real time information of the actual state of manufacturing and supply chain processes.

2. RFID technology in manufacturing

The RFID technology for automatic identification and tracking facilities enables data acquisition in real time, which can significantly improve planning, scheduling and production monitoring. Using RFID technology, sensors and actuators, resources of an enterprise become smart objects. The RFID technology has a significant role in digital and intelligent manufacturing because it enables all production resources (machines, people, products, etc.) to communicate with the manufacturing system in real time, wirelessly using radio waves. Using RFID technology, real-time and accurate production data such as material consumption, data on workers, the status of machines, order progress, data on scheduling, product location, data on materials and tools monitoring are gathered [4]. The collected data is transformed into information and knowledge that makes manufacturing intelligent. The RFID technology enables automatic identification and monitoring of all resources in production and products in all phases of its lifecycle.

The RFID technology is already widely used in manufacturing, to assembly lines, in maintenance, warehousing, transportation etc. [5-9].

RFID systems consist of three basic components: a transponder consisting of a chip connected to the antenna, a reader that transmits radio signals and collects data from the transponders and enterprise applications (Fig. 1). By attaching transponders to objects (all resources in manufacturing), they become smart objects that are capable of communicating with the environment.

Fig. 1 *Simplified working principle of RFID system*

2.1 Literature review

There are many published papers on the RFID technology. Within the databases of the Web of Science (WoS) platform, the first indexed article was published in 1985. The authors of article [Ngai, 2008] provided an extensive overview of published journal articles and conference papers on RFID technology for the 1995-2005 period. The classification of RFID technology applied in manufacturing, according to the author's literature review, is presented in the article [9], the main application fields are: process management, tool management, warehouse management, supply chain management and life cycle management. The authors of the article [11] proposed a RFID-enabled real-time manufacturing model that would provide support to management to make the right decisions based on real time information. RFID, as one of the most significant technologies that enables mass personalized production in relation to mass customized production, is described in the article [12]. For the application of RFID technology in logistics, the Big Data Analysis methodology is suggested in the article [13]. The article [14] deals with RFID technology in terms of supply chain management. The opportunities for implementing the Just in Time principle in logistics using RFID technology are presented in the article [15]. Intelligent and integrated RFID (II-RFID) system that enhances traceability and visibility of products is presented in article [16]. The article [17] emphasizes the advantages of using RFID technology in manufacturing that have been reported in the literature: reducing WIP, increasing utilization of machines, real-time information, improved scheduling and monitoring production, reducing errors in data entries compared to other methods (especially manual), shortened production cycle, improved satisfaction of customer.

A review of the literature shows that the RFID technology in production is dealt with from various aspects, proposals of technical solutions, models, production management, and supply chain management. Therefore, bibliometric literature analysis was conducted in order to gain a clearer insight into the trends in the research and development of the RFID technology in manufacturing, especially in the context of intelligent manufacturing and Industry 4.0.

3. Bibliometric Literature Analysis

The research methodology included searching the citation and index databases of the Web of Science (WoS) platform for the 1955-2017period. The research involved only journal articles and proceeding papers, while other types of publications were excluded from the research. The first, search by keywords was conducted as:

- ("radio frequency identification" or RFID)
- ("intelligent manufacturing" or "smart manufacturing")
-"Industry 4.0".

Then, the databases of the WoS platform were searched to find overlappings of the main keywords in the articles, as stated below:

- The results derived from the keyword ("radio frequency identification" or RFID) were refined by the keywords: ("intelligent manufacturing" or "smart manufacturing") delivered 31 results.
- The results derived from the keyword ("radio frequency identification" or RFID) were refined by the keywords: "Industry 4.0" delivered 32 results.
- The results obtained by keyword search ("intelligent manufacturing" or "smart manufacturing") refined by the keyword: "Industry 4.0" yielded 112 results.
- The results obtained by keyword search ("radio frequency identification" or RFID) is refined by the keywords ("intelligent manufacturing" or "smart manufacturing") and "Industry 4.0") yielded 7 results.

Figure 2 shows the number of journal articles and proceedings papers found in the databases of WoS platform according to the defined keywords.

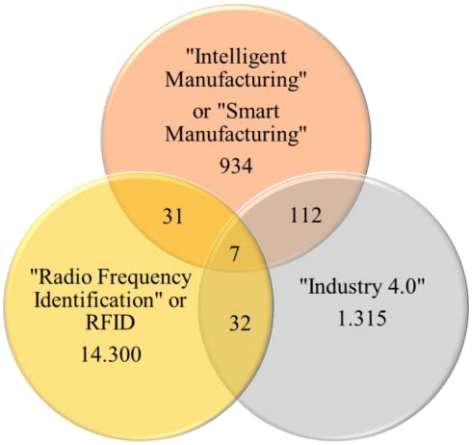

Fig. 2 *Number of articles and conference papers found within the WoS platform in accordance with the defined keyword.*

4. Case of Croatia – PEST analysis

The implementation of innovative technologies that enable intelligent manufacturing and Industry 4.0 in Croatia, with a special focus on RFID technology, depends on the impacts of the political, economic, social and technological environment. In order to determine which impacts were carried out, the PEST analysis was performed. Table 1 shows PEST indicators by categories (political, economic, social, technological).

Table 1: *PEST indicators*

	Indicators
Political	As an EU member Croatia complies with the governmental strategies: Industrial Strategy of the Republic of Croatia 2014-2020, Smart Specialization Strategy of the Republic of Croatia 2016-2020, Strategy of Fostering the Innovation of the Republic of Croatia 2014-2020. However, there is a discrepancy between the strategies and the real-life situations; and investments in research, development and innovation are already becoming insufficient, although they have been additionally reduced, high VAT.
Economic	Opportunities for benefiting from the use of EU funds; GDP is stagnating or growing slowly; reduced foreign direct investment, foreign debt has been growing steadily; there is a risk that a strong entrepreneurial culture in Croatia will lose out if there is no basis for sustainable economic development (digital infrastructure, digitally skilled professionals and access to finance); according to EU Digital Transformation Enablers' Index Croatia is very low (Croatia is only followed by Latvia and Romania).
Social	High unemployment; poverty; negative demographic trends and emigration; less and less skilled workforce; fewer students due to the emigration of young people; mismatch between education and labor market needs; low participation of population in lifelong learning; Croatia is among the most digitally aware countries in EU.
Technological	Obsolete technical equipment of the enterprises; lack of necessary knowledge and skills; level of innovation of the Croatian economy is low compared to the EU average; low level of business sector participation in research and development activities; slow progress on the integration of digital technology by businesses; low level of participation of researchers in the business sector; strong ICT industry; enterprises are above average users of cloud technologies.

According to the Eurostat data, the application of the RFID technology in the EU enterprises is on a steady rise. Compared to 2011, when the average RFID technology use for product identification in enterprises was 1.62% of enterprises, in 2017 it was 3.75% of enterprises. In Croatia, in 2017, or 4.54% of companies used RFID technology in product identification, compared to 2011 when only 2.49 % of enterprises used RFID for the same purpose.

In Bulgaria, the RFID technology was used for product identification in 9.18% of enterprises, more than in other EU member countries.

Figure 3 shows percentages of enterprises per EU member country that use Radio Frequency Identification (RFID) technology in 2018 as part of the production and service delivery or for the purpose of after sales product identification (data source: Eurostat). There are 4.5 % of enterprises that use RFID technology for these purposes in Croatia compared to the EU average of 28 countries (4.2 %).

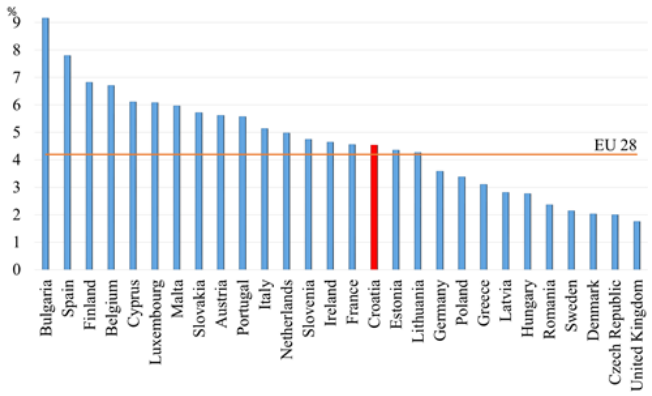

Fig. 3 *Percentage of enterprises per EU member, that use RFID technology in 2018 (as part of the production and service delivery or for purpose of after sales product identification).*

5. Results and discussion

According to the results of the bibliometric literature analysis on WoS platform, term ("intelligent manufacturing" or "smart manufacturing") first appeared in relevant literature in 1989. Since then researchers have shown continued interest in this topic, which grew rapidly after 2011 (see Fig. 4), which coincides with the emergence of the concept of Industry 4.0. There has been a significant increase in the number of relevant published articles and proceedings papers indexed in databases of the WoS platform.

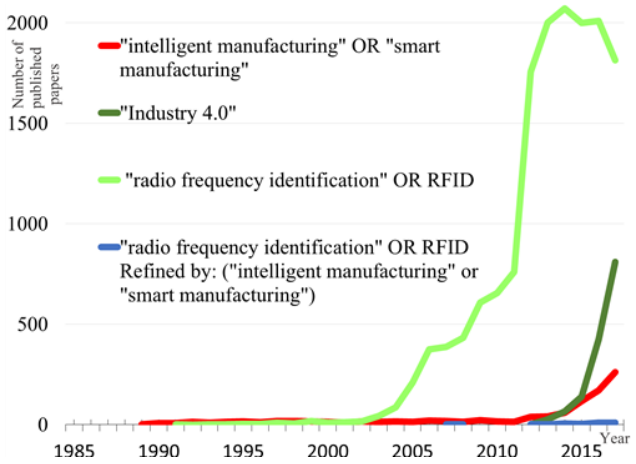

Fig. 4 *Number of articles and proceedings papers published per year (indexed within Web of Science platform).*

The number of publications on intelligent / smart manufacturing is the largest in the research areas: Engineering, Computer Science and Automation Control Systems.

There are many published papers on the RFID technology. The first article that was indexed in citation and index databases of the WoS platform was published in 1985, although the technology itself was developed during World War II. The rapid rise in the number of published articles and proceedings papers on RFID technology emerged at the beginning of 2000, after the Internet of Things was development. A new, even greater, hike in the number of published articles and papers came after the emergence of the new Industry 4.0 paradigm. The bibliometric literature analysis within the WoS platform shows that RFID researches are represented in many areas such as engineering, computer science, telecommunications, oceanography, biodiversity conservation and many others. The number of articles and conference papers on RFID topic according to research areas with the greatest number of journal articles and proceedings papers is presented on Fig. 5. Most of the research on the RFID technology is in the field of engineering, followed by computer science, telecommunication, automation control systems and other areas that are important for intelligent manufacturing.

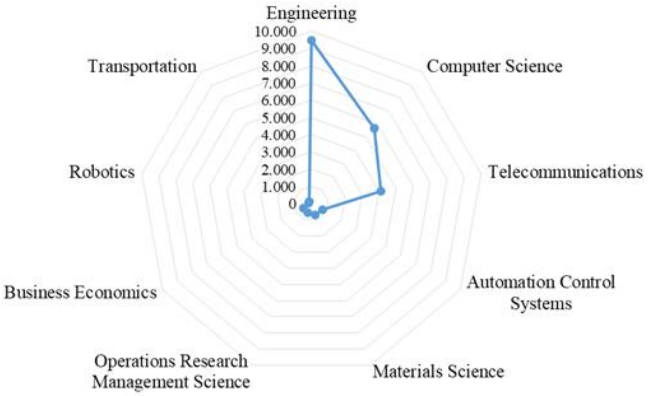

Fig. 5 *Number of articles and conference papers on RFID topic by research areas.*

After filtering the results on the RFID technology according to the "Countries/Regions" field in the WoS platform and only for the EU member states, the largest number of published articles and proceedings papers on RFID have Italy, Germany, United Kingdom, France and Spain (Fig. 6).

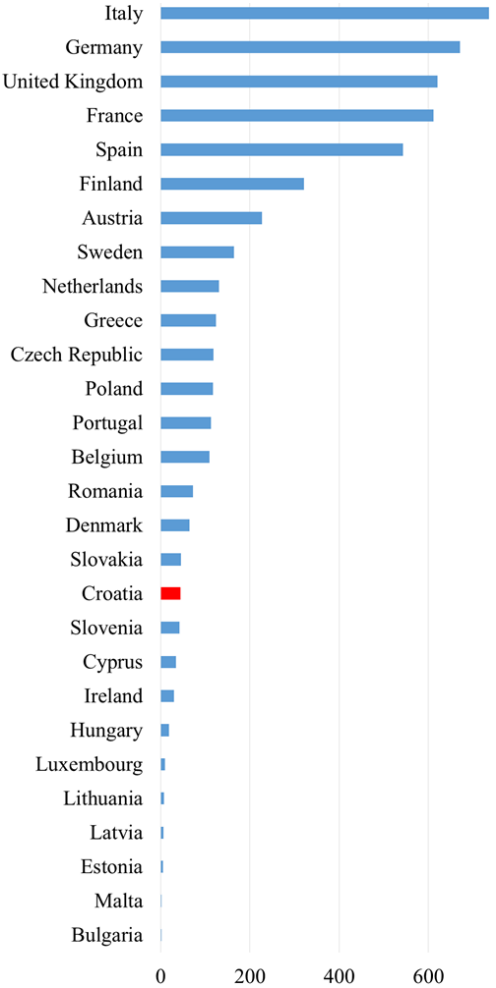

Fig. 6 *Number of articles and conference papers on RFID topic by countries – EU members (according to WoS platform).*

The analysis of the journal articles and conference papers indexed in the databases of WoS platforms, according to keywords

("radio frequency identification" or RFID) on the "Topic" field and according to the "Countries/Regions" field, it was found that most publications in the world were published by researchers from Peoples Republic of China (22.6%), the United States 16.0%, South Korea 6,6 % , Taiwan 6,5 %, , South Korea 6.6%, Taiwan 6.5%, followed by Italy with 5.1% of publications, as the most prolific EU member country with the most published articles and proceedings papers. The total number of research papers published in the EU member countries accounts for 35.8% of the total number of papers on RFID indexed in the WoS platform (Fig 7).

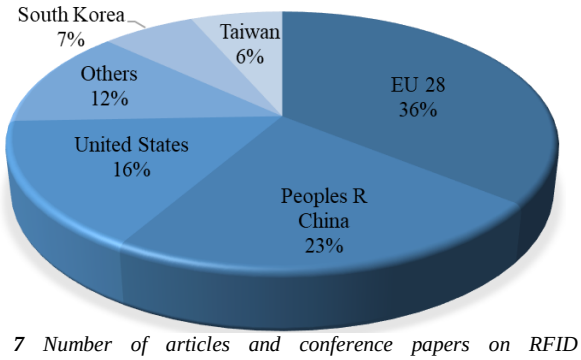

Fig. 7 *Number of articles and conference papers on RFID by Countries/Regions (according to WoS platform).*

The number of articles and proceedings papers, in which keywords ("radio frequency identification" or RFID), ("intelligent manufacturing" or "smart manufacturing") and "Industry 4.0" appear simultaneously, are small and appeared only in the past few years. This is understandable because it is a recent field of research. Certainly, an increase in the number of published papers in the context of Industry 4.0 and intelligent production is expected.

Table 2 lists the journals (within WOS platform) articles on topic: (RFID or "radio frequency identification") refined by: (manufacturing) and (intelligent or smart), with at least three articles on subject with their 5-year Impact Factor (IF).

Table 2: *Journals publishing articles on RFID in manufacturing*

Journal name	No. of articles	Impact factor
Journal of Intelligent Manufacturing	6	3.383
International Journal of Production Research	5	2.78
International Journal of Advanced Manufacturing Technology	3	2.748
International Journal of Production Economics	3	4.976
Journal of Cleaner Production	3	6.352
Robotics and Computer Integrated Manufacturing	3	4.031

The results of the analyses of journal articles and proceedings papers indexed in citation databases within the WoS platform on RFID, intelligent manufacturing and Industry 4.0 indicate that researchers in countries with stronger economies have better results in terms of number and quality of publication. It can be concluded that Croatia significantly lags behind the countries with stronger economies in terms of research and number of publications on the topics discussed in this paper. This is in line with the PEST analysis results: one of the identified indicators, which is at the same time the most important, is the low level of investment in research, innovation and development. The results of the bibliometric literature analysis also indicates that RFID is a research area of high interest, especially after the appearance of the concept of the Internet of Things and the development of intelligent manufacturing. It can be expected that the number of publications, as a result of great interest to the research area, will continue to increase.

6. Conclusion

Our research has highlighted the importance of the role of the RFID technology in manufacturing, which together with other new innovative technologies will facilitate the transformation of manufacturing into intelligent manufacturing.

The industrial sector makes an important share in GDP in Croatia (21.76 % in 2017, according to the World Bank). Therefore, it is important to invest in new innovative technologies in order to enable the Croatian enterprises to meet the requirements of Industry 4.0 and become competitive.

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THE DETERMINATION OF UTILIZATION LEVELS OF INDUSTRIAL 4.0 TECHNOLOGIES
A REVIEW ON GARMENT ENTERPRISES OPERATING IN TRABZON

Prof. Dr. Çankaya F[1]., Research A. Tiryaki D[2].
Faculty of Economics and Administrative Sciences-Karadeniz Technical University, Trabzon – Turkey[1]
Faculty of Economics and Administrative Sciences-Karadeniz Technical University, Trabzon – Turkey[1]

cankayaf@yahoo.com; denizhantiryaki@gmail.com

Abstract: The enterprises in today's competition environment should obtain and use the technological production systems, qualified, and proper information media that industry 4.0 conditions necessitate. Because a new rival firm may start to use smart factory technology in every new day. In this research, some of the ready-made enterprises in Trabzon were examined by semi-structured face to face interview and natural observation techniques to determine the utilization levels of industrial 4.0 technologies. Besides, this research made suggestions for those enterprises about the innovations that can perform in the future. In conclusion, it can be understood that whether the enterprises reviewed have the operation and employee structure to use the smart factory system. The enterprises need to apply the lean production necessities into internal processes by vertical integration; afterward, the same enterprises need to apply the agile manufacturing strategies in the external processes by the horizontal integration to start to use industry 4.0.

Keywords: LEAN PRODUCTION, AGILE PRODUCTION, HYBRID PRODUCTION, SUPPLY CHAIN MANAGEMENT, APPAREL INDUSTRY

1. Introduction

Production of textiles in Anatolia has almost a 3.000 years of history. After the silk and spice roads lost their significance and being used the cheap Chinese and Indian products by westerlies (Yüzel, 2010: 230), the products with high amount and low standard were started to be produced by the Far East, the products with small amount and high quality were started to be produced by the immediate circles. Textiles have grown in importance in the world trade and economy by improving the technology that is used in producing of the products whose raw material is the textiles.

Textiles and garment products constitute almost 6% of the world trade. While the developed countries benefited more from this trade, the developing countries have been superior today due to cheap labor, technology and energy costs (Erkan, 2013: 94).

Fast moving technology has increased the global competition and caused difficulties in satisfying the customer. Variety of products has increased; length of life has shortened; the number of orders and production parties has decreased (Apilioğulları, 2018: 89). Turkish textile and clothing sector has affected from this change and dispensed with producing products with high amounts, standard quality, and low costs. On the contrary, they started to produce multialternative products and deliver in short time as much as possible to remain in trade (Fırat and Ceyhan, 2015: 145).

Industry history can be divided into parts as industry 1.0, industry 2.0, industry 3.0, and industry 4.0 (Fig. 1);

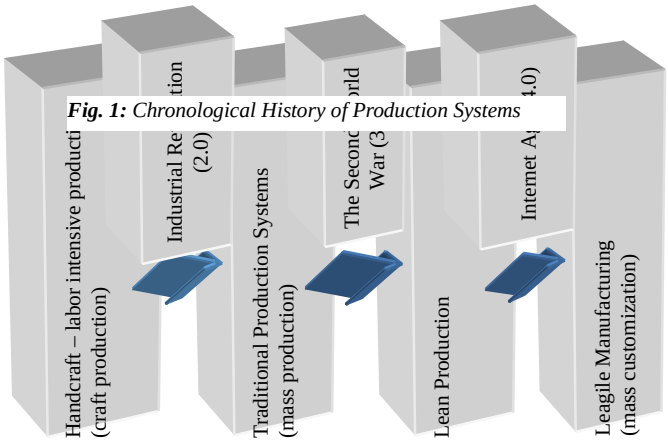

Fig. 1: *Chronological History of Production Systems*

The lean production that maintains its importance until the 1980s become insufficient by diversifying the customer demands; this circumstance caused the concept of agile production (Industry 4) to be developed. The variety in the customer demands that created the need for agile production brought serious conditions of competition and caused the concept of mass customization to emerge (Thilaket al., 2015: 1).

2. Lean, Agile and Hybrid Production Strategies

The lean system can be defined as removing the efforts that do not create a value in the period from ordering to distributing (Vincenti, 2002: 58). Value is described as the monetary value that is attributed to characteristics and components that need to be in a product. Accordingly, adding product specifications in a product that the customer does not like to pay is the waste of time and source (Moven and Hansen 2010: 728). In other words, it should be focused on the features that add value to the product and resources should be allocated; other factors as the waste need to be removed.While the companies which adopt lean production focus on the activities that do not add value in the production process, other companies deal with revenue (Apilioğulları, 2018).

The activities that add value and do not value are determined by creating a flow map. However, while some of the activities that do not add value can be eliminated by small arrangements, short-term arrangements are not sufficient some of the activities. Continuously eliminating non-value adding activities is called as kaizen technique in the literature (Apilioğulları, 2016: 80). Some of non-value adding activities cannot be removed in a short time because of the unsuitability of the production method and available technology (Hansen and Moven, 2010: 728). Labor quality and social culture constitute a significant topic among the factors that cannot be obtained and removes in a short time. Because, while the technology can be renewed in one or two years, being renewed the human factor can take long years. For this reason, the person is the most important value if he is qualified. Decisions in lean production need to be made by thinking deeply; however, the decisions should be rapidly applied. Speed means being agile and flexible (Apilioğulları, 2018).

Agile production was created to rapidly meet the pluriformity in customer demands (Vinodh et al., 2009: 6941). Agile production and lean production are the systems that established based on performance and mobility. However, the performance mentality of agile production is at an advanced level (Narasimhan et al., 2006: 441). This superiority provides agile production to be at the top of the agenda by increasing the diversity of customer demands.

Agile production is not only effectively and rapidly meeting the customer demands, but also includes proactively evaluating the

possible market opportunities (Brown and Bessant: 2003: 707; Al Samman, 2014: 1094)

Agile manufacturing is a production and supply system that is equipped by extraordinary competencies to meet the rapidly changing needs of the market in terms of flexibility, customers, competitors, suppliers, substructure, and responsiveness. The chief goal of this system is to answer the customer requests in minimum duration by rapidly reacting due to the available flexibility between the product models or the production lines (Yusuf et al., 1999: 36).

To be able to make customized production in serial production performance has brought speed and flexibility to the supply chain concept by the digital era (industry 4.0). If the agility is solely accepted as speed, it cannot be understood in real terms. Because agility is a system that necessitates fundamental structural changes including digital technology use that will provide the flexibility. While the agility means reaction quality, flexibility is a concept that means versatility that eases harmonizing. In other words, flexibility is the ability of a company to change a current project with another one in a short time or to shift it to other areas (Güzel, 2013: 184). Flexibility and speed necessitate transparent and reliable collaborations that will provide all the participators move together in the process in which the supply chain reaches ultimate customer from the point where the components of product arise.

Industry 3.0 should follow industry 4.0 during the transition process. Namely, first of all, the lean production requirements of 3.0 industry needs to be met; afterward, industry 4.0 should be materialized with significant changes in means of production and communication technologies by the investments. A number of technologies, computer-aided systems and methodologies need to be learned and utilized in the evolving process of the manufacturing enterprises to production agility (Toliušienė and Mankutė, 2013: 723).

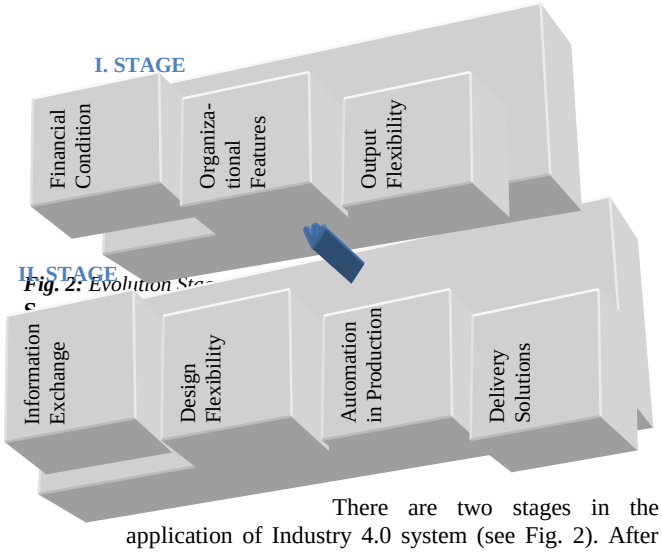

Fig. 2: *Evolution Sta*
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There are two stages in the application of Industry 4.0 system (see Fig. 2). After being completed these stages, the smart factory system is materialized in the enterprise.

Much as the agile production system is expressed as the final point of industrial 4.0 production system, it is not true to adopt only one strategy in the companies. A single strategy is not in accord with all the company structures. Therefore the hybrid strategies (using lean and agile strategies together) ought to be used. There are three different ways of using hybrid production strategies. I. classification of products at 80% to 20% (Pareto curve approach) according to their quantity and quality; II. the approach of adopting lean production strategies in the production process till the decoupling point; afterward, adopting agile strategies after this stage; III. using lean strategies in the normal flow of the products; however, using the external source in immediate changes in demand (Apilioğulları, 2017: 30-34; Al Samman; 2014: 94-95). Production structure, the area of activity, region, economic conditions determine the production strategy which the enterprise should adopt. In this research, the conditions above were considered when the production strategies of the enterprises that were subjected to this study were determined.

3. Purpose and Scope of the Research

Three companies that were subjected to this research are as follows; the company which perform contract manufacturing on outerwear for Turkey (Company I); the company which perform contract manufacturing on ladies' top clothing (Company II); the company that both perform contract manufacturing at certain times and make production and sale to the customers Turkey-wide by its own brand (Company III).

Kasap and Peker (2009) conducted studies on automotive companies; Fırat and Ceyhan (2015) conducted studies on a textile company; Kleszcz (2018) analyzed on the employees in a ceramic factory; Kumar et al., (2015) performed surveys on the simplicity and agility in the aviation sector. Accordingly, it is possible to research on a limited number of samples instead of a large number of studies for the qualitative surveys. Therefore, three garment enterprises which make production under different conditions and can reflect the general profile of Trabzon Province were received for consideration. The purpose of this research was to make suggestions about the strategies which make them more competitive and profitable by determining related companies' utilization level of industry 4.0.

Two studies were considered at the idea point of this research. One of these studies was conducted by Rachel et al., (2000). They explained lean, agile and lean-agile strategies which are proper for the product and market structure of the companies with the help of the examples about enterprises that are in service in different sectors. With reference to their expressions, lean production should be used in mechanical products; agile production should be utilized in carpet production; lean-agile production and supply chain system ought to be used in the electronic product. Bruce et al., (2004) conducted a survey on textile and garment companies which make production in different fields (1-high fashion products, 2-fabric products; 3- sports accessory design and 4-brand products) and sale in England. They pointed out at the end of the investigation that 1, 3 and 4 numbered companies are suitable for lean-agile; 2 numbered companies are suitable for lean production and supply chain systems.

However, the companies that compete with such efficient market factors are few in number in Trabzon. Thus, revealing how the companies in Trabzon should act and discussing the situation from different perspectives will bring a larger point of view to the literature. In this direction, we evaluated the enterprises as the garment companies which can do business for the region in Trabzon province and other regions (country-wide and/or Europe).

4. Method of the Research

Taylor (2005) defined qualitative research as the method that is used to reveal the theory behind the facts by observing the facts in their natural environments. These methods and techniques that are used more in numerical sciences, in the beginning, are now used as a flexible and low-cost method to discover the attitudes, experiences, and reactions of non-random samples obedient to a specific profile in social sciences as well (Sofaer, 2002: 330). Natural observation techniques and semi-structured face to face interview from the qualitative research models were utilized in this research to determine the utilization level of Industrial 4.0 technologies and explore the reasons behind the use at the same time.

According to Törnqvist and Fross (2018), the information from the general to the specific is tested and the new and unexplored information is obtained by working on a limited number of observations to make an in-depth analysis in qualitative studies. The current situation was specified in three enterprises in Trabzon by

determining their utilization level of industrial 4.0 technologies; suggestions were made for these companies to be more competitive in the future.

The questions in a semi-structured face to face interview method were collected from the studies in the literature. The reason for using semi-structured face to face interview method is to enable business owners and directors who conceptually do not know the strategical cost methods to express themselves easily by canalizing them into the issue. The interview results obtained were supported by the natural observations performed in the work environments of the enterprises.

5. Results of Discussion

It can be said that both three enterprises have made an effort to fulfill the requirements of Industry 4.0; however, the concepts of lean, agile and hybrid production are not known technically in these enterprises. Moreover, the garment companies that are generally small and medium-sized enterprises are managed based on family business structure. We can also express that they have the potentials to reach remarkable activity and production performance in case of taking professional support

The questions toward to determine the losses in production as a percentage, size of the party, product range and the qualification of the employees were asked during the semi-structured interviews. Besides, the questions endeavored to find whether the technological equipment and software such as computer-aided design (CAD), computer-aided manufacturing (CAM), material requirements planning (MRP), and computerized production planning (PPS) have been used.

The improvements in companies are limited to the economic power of the companies. In other words, the enterprises renew the technology in direct proportion to their available capital. However, they will not be able to keep up with the digital age as long as to fail at developing the human factor. So, the enterprises should make an effort as immediate as possible to renew the human factor that is pretty hard to be developed.

The company I needs lean production techniques because of a few numbers of product range; making contract manufacturing based on the order; the losses that exceed 40% in the manufacturing process; poor competence ratio of the employees. Company II should start to use agile production system due to the reasons that lean production system requirements have been applied in the intrabusiness processes; having a sufficient experience on exportation and also a sufficient number of qualified manpower; having an export realization plan under its own brand besides the available business segment. Company III should focus on being lean in internal processes and also being agile in the external affairs by adopting hybrid production strategy. The reason is that Company III can market the products that it produced under its own brand; Company III can use external source within the scope of the needs; Company III has qualified a productive worker.

6. Conclusion

With reference to the SWOT analysis in terms of the garment enterprises in Trabzon, there is no textile manufacturing enterprise as well as the number of enterprises that manufacture garment products is few. Distance to raw materials and customer market; difficulties in rivaling with real port and raw material cities; lack of qualified workforce, capital, and infrastructure by the region are the most important reasons of the issue above. However, despite everything, there are enterprises that can be an irreplaceable supplier in comparison with Far East countries in terms of the EU to gain the agility; the new ones can be added to available ones in the same time. It is a stubborn fact that the companies will not have to make contract manufacturing by becoming more modern; they will be able to market themselves to Europe and Turkey's eastern and southeastern regions

It is frequently seen in the literature that the agile production system is an inevitable strategy especially for textile and garment companies. However, according to the results obtained, this circumstance is proper for the enterprises that have an individual brand, high financial turnover, series competitors. Besides, these enterprises are the companies which need to follow fashion continuously, concentrate on the design and R&D activities at the same time. The conditions in the Trabzon region reflect the profile of garment in terms of the region of the eastern black sea; those conditions are different from the companies in which the study was actualized. Namely, it is pretty hard for companies in which the study was actualized to rival enterprises get busy in İstanbul. Producing under their own brands is also difficult for companies by geographical, economic and human position. In short, the problems experienced in reaching available infrastructure and required sources in this region bring extremely negative conditions about applying the agile production system. Moreover, it can be reached the conclusion that the companies in the region are proper to the lean production system structures by the nature of their activity.

The essential results of this research are that the companies under the region and company conditions will not be able to make production under the conditions of industry 4.0. Therefore, the enterprises ought to provide vertical integration and intrabusiness conditions so as to be required by lean production. After, they should focus on improving the horizontal integration (agile production) by the experience, competence and economic conditions that they will obtain by providing vertical integration and intrabusiness conditions. These enterprises need a remarkable capital and qualified manpower to achieve the goals above.

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SMART MANUFACTURING AND CLOUD COMPUTING: VISION AND STATE-OF-THE-ART

Assoc. Prof. Pavel Vitliemov PhD
Faculty of Business and Management – University of Ruse "Angel Kanchev", Ruse, Bulgaria
pvitliemov@uni-ruse.bg

Abstract: *Industry analysts are predicting that the next decade of innovation, productivity and growth in manufacturing will be driven by the demand for mass customization and the convergence of technologies that will enable a new generation manufacturing IT platform for "smart manufacturing" which includes advances in connected factory automation, robotics, additive manufacturing, mobile, cloud, social, and digital 3D product definition. The new generation of smart machines for manufacturing will have on board computers that will directly support internet protocols and direct communication with enterprise applications. Cloud computing is one of the technology stacks of Smart manufacturing and a service delivery model that is opening new opportunities for manufacturers. This paper describes what is "Smart manufacturing" that goes beyond smart machines, Industrial Internet of Things (IIoT) and Industry 4.0 and explores how cloud computing can help achieve Smart Manufacturing goals to optimize processes inside the factory.*

Keywords: SMART MANUFACTURING, CLOUD COMPUTING, STATE-OF-THE-ART

1. Foreword

Emerging capabilities in additive manufacturing, advanced robotics, sensor-enabled equipment and other new approaches to fabrication, open new process improvement opportunities both in the plant and across the supply chain. Sophisticated computer modeling and simulation tools are evolving to give engineers far greater scope in designing a manufacturing process before building the production lines. These new technologies and capabilities are dramatically changing the management of manufacturing operations.

The next-generation Smart Factory feeds real-time information to a more empowered workforce through a combination of smart facilities, machines and equipment with built-in sensors, self-diagnostics and connection to other smart systems. Production processes in the Smart Factory can be optimized for best use of manpower, equipment and energy resources through simulation with digital representations and models. Smart Manufacturing encompasses and goes beyond smart machines, Industrial Internet of Things (IIoT) and the Smart Factory, recognizing that manufacturing processes in the 21st century go beyond the plant floor and must integrate the entire value chain that creates the final product. Smarter Digital Threads of product and process definitions and smarter connected manufacturing machines will come together with smarter manufacturing business processes to achieve the Smart Manufacturing enterprise [5] [2] [12].

This paper describes what is "Smart manufacturing" that goes beyond smart machines, IIoT and Industry 4.0 and explores how cloud computing can help achieve Smart Manufacturing goals to optimize processes inside the factory.

2. The Goals of Smart Manufacturing

Smart Manufacturing is the endeavor to design, deploy and manage enterprise manufacturing operations and systems that enable proactive management of the manufacturing enterprise through informed, timely (as close to real-time as possible), in-depth decision execution. Systems with Smart Manufacturing capabilities are realized through the application of advanced information, communication and manufacturing process technologies to create new and/or extend existing manufacturing system components that are then synergistically integrated to create new or extend existing manufacturing systems that possess the desired advanced automation, analysis and integration capabilities. To reach the goals of Smart Manufacturing, manufacturing resources (machines, equipment, people and factories) and the processes they carry out must be better when automated, integrated, monitored and continuously evaluated to enable people to work smarter, make timely informed decisions and run operations that are more efficient.

Smart Manufacturing can be applied more broadly and less costly if implemented on top of enhanced manufacturing-IT platforms with capabilities such as the ability to receive published data from equipment using secure open standards, analyze and aggregate the data, and trigger process controls to record the history and implementation of workflows.

The ultimate outcome of applying the Smart Manufacturing concept can be: [6]

- Efficient distributed production systems that connect any number of global plants and suppliers into an integrated value chain for each product line.
- Autonomous and distributed decision support at the device, machine and factory level.
- New levels of efficiency to support new business models, including mass customization and product-as-a-service.
- Efficient flexibility for plants that can build products in small batches or even build one product at a time as ordered and configured by each customer.
- Design anywhere and build anywhere strategies with robust change management practices that guarantee fidelity to product design specifications.
- Enhanced information-based decision-making and analytics based on large amounts of raw data gathered from the Smart Manufacturing equipment and processes.
- Enhanced product genealogy traceability for critical materials and components into higher levels of components, all the way to the final product.

3. Introduction to cloud computing and cloud services

A common misconception about the cloud is that "There is no such thing as cloud; it is just someone else's computer." While there is some truth to this statement, it is also misleading. Thanks to internet connectivity, organizations can leverage many services provided by service providers on their cloud computing frameworks within their own internal IT systems architecture. The National Institute of Standards and Technology (NIST) offers the following characteristics of the cloud: [7]

- On-demand self-service: An end user can sign up and receive services without the long delays that have characterized traditional IT;
- Broad network access: The service is accessible via standard platforms (desktop, laptop, mobile, etc.);
- Resource pooling: Resources are pooled across multiple user organizations;
- Rapid elasticity: Capability can scale to cope with demand peaks;
- Measured service: Billing is metered and delivered as a utility service.

The cloud is much more than someone else's computer. It is a collection of tools and techniques to thread together internal and external hardware and software technologies to create an enhanced IT infrastructure for the organization at a reduced cost of ownership.

Many new machines come ready to integrate via APIs. New Industrial Internet of Things (IIoT) and edge devices are creating bridges to enterprise systems and cloud services for older equipment. These new capabilities help render the old division between Operational Technology (OT) and IT Enterprise Systems obsolete. The question is not whether a manufacturing system will be on the cloud, but instead how much of the manufacturing system will be on the cloud to maximize the benefits to each organization and its customers.

Cloud computing is changing the landscape of enterprise IT architecture. Organizations of all sizes are adopting SaaS solutions to simplify their need for internal IT resources while accelerating the pace of enterprise systems adoption. Possible first steps to adopting cloud computing is to move one or more enterprise systems to the cloud: [8]

- ✓ Customer relationship management (CRM): CRM is how a sales team manages its market and customer data, and the engagement of the sales process. CRM solutions promote the SaaS model with low risk adoption. This application offers easy worldwide remote access through a central company system via the internet. For this reason, SaaS solutions have become the default in this arena;
- ✓ Product Lifecycle Management (PLM): PLM solutions allow manufacturers to create and manage product structures and product family, and successfully implement change control processes for their products. Because many manufacturers need to work closely with their supply chain partners in the collaborative design of products, PLM has become another target for movement to the cloud in order to provide easy access to suppliers and customers for collaboration in engineering processes;
- ✓ Advanced planning systems: Advanced planning systems are solutions used to effectively plan and schedule parts and materials in the supply chain. By integrating these solutions into supply chain "control tower" software offered in the cloud, suppliers link into a demand-driven supply chain and distribution network;
- ✓ Enterprise Resource Planning (ERP): ERP is the heart of most manufacturers' transaction management for financials, order entry, purchasing, work order management and scheduling. Organizations have been slow to trust the security of their financials and contract details to cloud solutions, but adoption is increasing. ERP procurement and inventory management functions can benefit from easier supplier and multiple location connectivity via a cloud solution;
- ✓ Manufacturing Execution Systems (MES): MES is the last enterprise system considered for a move to the cloud. Small and medium manufacturers interested in the low risk and quick startup proposition are adopting MES cloud solutions. Cloud-based MES solutions make it easier to rollup metrics across a network of distributed manufacturing plants.

4. Impact of smart manufacturing to the IT architecture under the fourth industrial revolution

The era of "one-size-fits-all" mass production is behind us. We are looking ahead at a new era of manufacturing that supports mass customization and products sold as a service. Industry analysts and visionaries have identified this era as a next Industrial Revolution. Here is historical context for the Fourth Industrial Revolution [11].

The Fourth Industrial Revolution, dubbed the Digital or Cyber-physical Revolution, is starting now in the 21st century. In 2015, the expected investment is an estimated $120 billion to connect operations, building systems, mobile equipment in the field and more to the IoT, up 18 percent from 2014, according to IDC, a technology market consultancy. In 2014, 278 million factory machines, construction vehicles and other pieces of industrial equipment connected to the IoT, 10.2 percent more than in 2013, according to technology research consultant Gartner Inc. By 2020, Gartner [3] expects 526 million pieces of equipment to be connected. According to McKinsey [12], the IoT will unleash $6.2 trillion in new global economic value annually by 2025, with $2.3 trillion coming from the global manufacturing industry alone. To put this into perspective, the total global gross domestic product for 2013 was approximately $75 trillion. Companies that quickly leverage the full opportunity presented by the IoT will seize the greatest value, and assume market-leader status in the next decade.

It is difficult to manage the Manufacturing Operations department as an island, isolated from other enterprise departments like Engineering, Supplier Management, Quality Management, Human Resources, Facilities Management and Financial Management. Effective ways are needed to create information threads for business processes across departments that do not depend on manual translation of information. Currently, many interdepartmental business processes operate via email and with frequent manual interpretations and translations of data inputs to outputs along the way. These manual interdepartmental business processes are prone to error and cannot scale to handle a higher volume of transactions. [9]

An ideal Smart Manufacturing system platform would facilitate (a) a Smart Factory where there is integration throughout different data and functional layers, providing insights to improve safety, quality, cost and schedule, (b) Digital Thread where engineering design follows the entire product lifecycle, (c) Value Chain Management where a fully connected supply chain and customer management combine seamlessly.

Part of Smart Manufacturing is the IIoT (Industrial Internet of Things). IIoT leads to the proliferation of connected smart machines, devices and sensors that result in an explosion of data. The Internet of Things (IoT) is a term coined in 1999 by Kevin Ashton [1] to refer to networks of physical objects, or "things," embedded with electronics, software, sensors and connectivity to exchange data in support of business processes. All IIoT- and Smart Manufacturing-related efforts have a similar vision: to improve manufacturing operations and collaboration between partners in the manufacturing value chain. In order to achieve this, manufacturers want to see industrial automation use standards and mechanisms similar to home and office equipment integration. Manufacturers would like to see applications (aka apps) on their phones giving them the ability to view, interact and control the shop like the apps they have today to control their home or car.

For existing manufacturing environments, especially in highly-automated, process-intensive industries (e.g. chemicals, food processing), much of the data one would consider "IoT" data is already being captured today by existing SCADA (Supervisory Control and Data Acquisition) and DCS (distributed control system) software, so sensor integration is a smaller challenge in those types of environments. A bigger challenge is switching those integration methods to open industry standards, and modeling those industrial "things" as cyber physical systems that knit together the information about existing assets with service layers and analytics engines that really bring the "smart" into Smart Manufacturing.

However, Smart Manufacturing is more than optimizing specific machine processes or each manufacturing plant in the enterprise. That might be a good start, but to realize the vision means a need to connect and optimize the processes across the entire value. There is a need to look at plant systems in each node of the multi-tier value chain to understand how they connect and interact across the entire value chain with systems, including customer and supply chain management across different companies to deliver the final products and services to the end-user customer.

A 2017 Gartner survey [4] discovered that 70 percent of manufacturers are working Smart Manufacturing efforts in parallel and not integrated with their digital supply chain endeavors. This needs to change to achieve the revolutionary productivity gains required for a fourth industrial revolution.

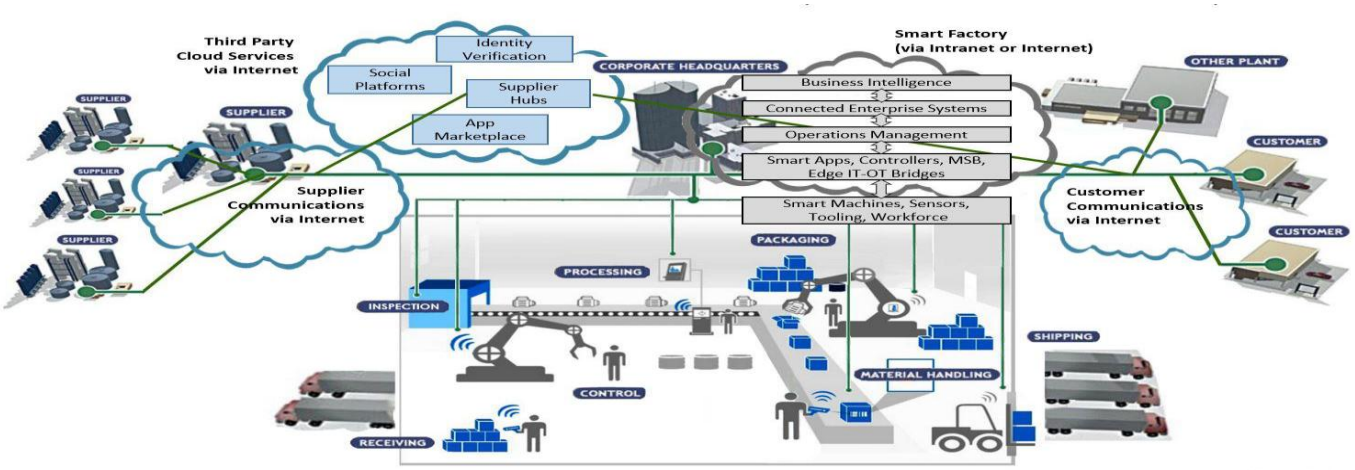

Fig. 1 Smart Manufacturing systems connect multiple clouds and cloud services to realize the connected value chain [10]

Figure 1 illustrates how internal and external systems in the cloud help connect the multi-tier network of multiple plants, suppliers and customers in the new Smart Manufacturing ecosystem. Connecting these new ecosystems is how to realize the most value from cloud computing to Smart Manufacturing endeavors.

Conclusion

Change is a constant in life and manufacturing is no exception. The manufacturing industry is at an inflection point with major advances in enabling innovations and a proliferation of smarter end points that are both valuable and vulnerable. Smart Manufacturing includes the Internet of Things (IoT), cyber security, network convergence, cloud computing, data and analytics, virtualization and mobility.

It is clear that manufacturing will serve as a key driver of research, innovation, productivity, job creation and export growth. The Smart Manufacturing future ties inextricably to the rise of Internet Protocol (IP) technology.

Smart Manufacturing will address some of the challenges facing the world today such as resource and energy efficiency, urban production and demographic change. Smart Manufacturing delivers continuous resource productivity and efficiency gains across the entire value network. It organizes work in a way that takes demographic change and social responsibility into account.

Both Smart Manufacturing and cloud computing are here to stay. Cloud computing is opening new infrastructure, systems and connectivity opportunities for manufacturers to help realize a Smart Manufacturing vision. This is especially important because Smart Manufacturing does not stop at the factory walls; it connects and optimizes the entire value chain.

Each manufacturer will draw the line differently between on premise and on-cloud services, depending on their unique needs. For some organizations, the choice will be to shift IT systems completely to the cloud; for others, hybrid scenarios might be a better path forward.

Whether the organization is contemplating a complete rip and replace of systems or simply wants to strategically leverage cloud services in some specific areas, it is clear the organization should consider cloud computing as it puts together the roadmap for evolving IT infrastructure and achieving the goals established for its Smart Manufacturing vision.

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INTELLIGENT KNOWLEDGE MANAGEMENT IN THE SECTOR OF WASTE DISPOSAL ENTERPRISES

Prof. dr hab. Sztangret I.
University of Economics in Katowice, Poland
izabela.sztangret@ue.katowice.pl

Abstract :*Information is perceived as the resource, that constitutes relationships in the network of enterprises and their customers, as well as extra-marketing value, which can be successfully implemented in IT environment, for example in the sector of waste disposal enterprises. That is why, the interactive contact and involvement of the stream supplier in researched sector, the intelligent processes of selection and recycling of communal waste, and commercial and marketing value of waste can be interesting as a source of marketing information for researchers and readers of this article. Therefore, smart methods of knowledge management, including marketing knowledge in the sector of waste management enterprises in the environment of IT solutions raise interest. The goal of the paper is to present three-sphere business model based on intelligent management of knowledge and competences in enterprises of the waste management sector. The main part of the paper will be focused on one of the sub-areas of the model, i.e. the subarea of knowledge commercialisation. This will be implemented through in-depth case study analysis.*

KEY WORDS*: INTELLIGENT MANAGEMENT, GARBOLOGY, SMART MANAGEMENT, WASTE DISPOSAL ENTERPRISES, WASTE MARKETING-VALUE,*

1.Introduction

The concept of **intelligent knowledge management** occurred as a result of the process of transformation of traditional business relationships into specific type of cooperation of enterprises, based on circulation of knowledge, in most situations in innovative way, in a wide range of activities. It also concerns studied companies of the sector of waste collection and recycling, as well as their partners and customers. Peculiar character of cooperation is associated with the fact of approaching information as resource constituting relationships in the network of enterprises and their customers, which can be successfully implemented in IT environment. **Technological tools** enable smart management of communal waste through effective division into stream fractions, which consequently allows for separation of the material for recycling and reuse, management of the fraction obtained from mechanical-biological waste treatment, and first, minimising the amount of non-productively stored waste. Knowledge about chemical composition of packaging getting into the waste stream, tightens the process of precise selection. **Commercial use** of information automatically registered by separator scanners of specific fractions of communal waste is another operational sub-area of smart knowledge management, i.e. marketing knowledge in this case, which has been neglected before. Information included in the barcode is important for identification and registering a specific type of product. Thereby, it has marketing value, useful in market research in functional approach to management in a company. In the studied case, intellectual value (knowledge, skills and competencies) is created by enterprises, their cooperants and customers for further satisfaction of target market needs, in at least **three-spherical business model**. This model often has multi-concept, or holistic nature while combining relationship marketing, supply marketing, integral, internal, systemic, strategic as well as social marketing. Companies representing the sector of waste management apply intelligent knowledge-based solutions which result in interactive formation of market value.

2. Management of knowledge – holistic approach - identification of research category and review of literature

According to one of the first holistic approaches, in Alavi's and Leidner's view, knowledge management is defined as systematic and specific process of acquiring, organising and communicating workers' implicit and explicit knowledge in organisational terms, for the purpose of increasing effectiveness of productivity of other involved entities, while showing the presence of „other entities" of the environment in the process in a quite concise way (Alavi, Leidner, 1999). KM is more broadly perceived by Bounfour who approached it as a set of procedures, infrastructure, technical and management tools created for forming, sharing and expanding knowledge resources inside and outside organisation (Bounfour, 2003).

A holistic approach to knowledge management is undoubtedly presented by Demerest's model. The structure of this model shows not only a scientific expression of knowledge, but also social aspects of knowledge formation. It is not limited to the stage of knowledge externalisation, but concerns repeated social interactions. Knowledge management ought to be supported by all organisation stakeholders, which, consequently will be reflected in results of all involved parties. This is about a complementary approach to knowledge management as scientific and social category.

Holistic approach to knowledge management is based on three pillars: (1) company strategy, i.e. strategic organisational concept of knowledge and learning, both intra- and inter-organizationally, (2) environment of creation, co-sharing and application of knowledge, dependent on the company and objective determinants in direct and indirect relations, (3) knowledge tools supporting the process of effective knowledge management, i.e. platform of intra-organizational, network and commercial knowledge of the company, supported by IT tools (Choo, 1998; Nonaka Konno, 1998; Von Krogh, Ichijo, Nonaka, 2000; Alvarenge Neto, 2008).

According to Choo's views, the company functioning as knowledge-based is an enterprise that approaches knowledge in strategic dimension (1), through the prism of its significance in a specific context of creation and decision making. The awareness of the importance of knowledge in a definite dynamic and complex environment of company functioning, the ability to search for and interpret appropriate information that allows for understanding of trends and scenarios of the environment that is made of customers, cooperating entities as well as competitors and other entities, constitutes the strategic goal of the company. Knowledge creation is a process of forming and / or acquiring knowledge, or information organising and processing for generation of new knowledge through dispersion and learning in organisation. Now, generated knowledge, constitutes foundations for assumptions aiming at creation of new knowledge and thereby development of new skills and competences inside the company, and among other participants in the so-called knowledge-community (community of knowledge), in which the different entities can be the participants.

Nonaka and Konno are the authors of the concept of knowledge creation environment (2) (Nonaka, Konno, 1998) and Nonaka, Tsoukas and Snowden are still its promoters. Knowledge environment is a context in which knowledge is created and applied. This environment can have a real nature (that is office area, organisational units in company and entities

in the network), and / or virtual nature (that is the form of e-mail, videoconferencing, online relations), and / or psychical nature (that is expressed in ideas and concepts). Knowledge environment can be created by individuals, task groups, project teams or informal groups of entities. Knowledge environment is made of sub-spheres of creation, interaction and dialogue, as well as systematization and the process using and accessing. This corresponds to each of the elements of SECI Model by Nonaka and Takeuchi. The aforementioned concept of knowledge environment ought to be enhanced by elements inside the organisation that support creativity. They include trust, tolerance and care. According to Alvarenga Neto, „favouring conditions" are necessary on tactical level as an element combining strategic dimension of knowledge management with its operational implementation. In this context, knowledge management should not represent its control, but promoting creation and making it available within knowledge-based organisation, that is the ecosystem of knowledge.

IT tools, as well as practices and processes serving implementation of the concept in actual operations are the third sphere of holistic model of knowledge management (3), that provide its intelligent nature. They differ depending on the level of implementation of knowledge management. This is because strategic level is focused on formation of knowledge community (i.e. community of practice/knowledge), space for organisational learning and tools of strategic concept of knowledge formation. Operational level rather concerns coordination in implementation of tasks resulting from strategic concept of knowledge management, application of competitive competences and market research.

3. Regional Municipal Waste Treatment Facilities – legal background for creation of the researched entities and methodology

Regional Municipal Waste Treatment Facilities are described in the Law on waste of 14th December 2012 and the Directive 2002/83/EC that determines the minimum requirements for establishment of such an entity. The documents also describe hierarchical method of waste management through:

- prevention of waste generation,
- preparation of its reuse,
- recycling,
- other processes of recovery,
- disposal.[1]

The law provides the possibility to divide voivodeships, in voivodeship plans of waste management (VPWM) into regions, if they comply with the minimum requirements as determined in clause 35 section 5 of the law. It states that the region of municipal waste management constitutes an area of neighbouring communes that comprise in total at least 150 thousand inhabitants and is operated by facilities referred to in section 6. The area of a commune of 500 thousand inhabitants can also be the region of municipal waste management. New regulations included in the amendment to the law on waste of 22nd January 2015 define a regional facility for municipal waste processing as the waste management plant of the capacity sufficient to collect and process waste from the area inhabited by at least 120 thousand inhabitants. Also, it must comply with the requirements of the best available technology referred to in clause 207 of the law of 27th April 2001 – Environmental protection law, or technology referred to in clause 143 of this law, including those applying new available technologies of waste processing, or providing:

- mechanical and biological treatment of mixed municipal waste and separation from mixed municipal waste the fractions that are suitable for recovery in whole or in part, or,
- processing of separately collected green waste and other bio-waste, and producing from them a product of fertilising qualities, or substances supporting plant cultivation that comply with requirements as determined in separate regulations, or other material after the process of composting or fermentation admitted for recovery in the R10 recovery process that meets the requirements determined in regulations issued on the basis of clause 30 section 4, or,
- landfilling of waste generated in the process of mechanical and biological treatment of mixed municipal waste and remains from segregation of municipal waste of the capacity that allows for reception of waste for the period of at least 15 years, in the amount not smaller than generated in the facility for mechanical and biological treatment of mixed municipal waste[2].

Furthermore, the region of municipal waste management may comprise neighbouring communes of various voivodeships if it is provided for by voivodeship waste management plans of these voivodeships.[3] Another important provision of the quoted law concerns introduction of the notion of transregional facility which can be an incineration plant for municipal waste with the capacity sufficient for reception and treatment of mixed municipal waste collected from the area inhabited by at least 500 thousand residents, that meets the requirements of the best available technology called "transregional municipal waste incineration plants".

The paper applies the methods of conceptual research, and qualitative empirical research (case study) [4]. Analysis of the literature of the subject as well as research based on secondary and primary sources was performed.

Table 1. Basic information about conducted research

Specification	
research technique	analysis of the literature and sectoral magazines, analysis of webpages, analysis of sponsored interviews, direct interviews
sample selection	targeted selection of typical units
sample size	Leader[5] of waste management sector in Region III, by the criterion of facility machinery and 20 representatives of RIPOK [*Regional Municipal Waste Treatment Facility*] in Poland
	Over 10 trade webpages related to waste management sector
geographical range	regional range
time range	2014-2018

Source: own case study

[1] The Act of 14th December 2012, Law on waste, clause 17

[2] The Act of 27th April 2001. Environmental Protection Law, clause 35, 143 of the Act on waste

[3] The Act of 15th January 2015 on amendments to the act on waste and other acts.

[4] Application of the method seems justified because:

- research concerns contemporary, dynamic phenomena and knowledge about these phenomena that is created;
- they concern research of actual contexts of these phenomena at rather large ambiguity of borders between their contexts and the very phenomena;
- the subject of research is too complicated to explain the cause and effect relationships by means of the survey method or experiment. (Perry, Ch. 2001; Żabińska, Żabiński, 2007, p. 83),

[5] MASTER Odpady i Energia Sp. Z o.o. enterprise [MASTER Waste and Energy limited liability company], being one of 3 similar facilities constructed in Poland that have the latest plant ensuring mechanical and biological treatment of mixed municipal waste and separation of fractions, from mixed municipal waste, that are recyclable in whole or in part, of the of the capacity of 120 000 Mg/year. The plant, together with the landfill constitutes an integral part of communal waste management system in Region III.

For the needs of the research, the entities that have the status of RIPOK [*Regional Municipal Waste Treatment Facility*] by the criterion of indication by a leader and position according to secondary sources of the sector were selected for the analysis of expanded case study[6].

4. Business model based on intelligent management of knowledge and competences in enterprises of the waste management sector

The information and knowledge acquired for the competent, multi-faceted and multi-concept activities of waste sector entities establish systemic relationships with stream providers in the process of direct and indirect knowledge diffusion in the subsystem of interactive relations with these entities (Figure 1). Intraorganisational knowledge and competences for implementation of effective technologies foster smart segregation and waste processing operations, which is the aim of waste commercialization and knowledge commercialisation, in relations with recipients of processed waste and raw materials, as well as marketing agencies. This knowledge can offer the extra marketing value for firms and their cooperants (Sztangret, 2016a). In the model, knowledge is a linking element between systemic customer relationships and waste stream suppliers in direct and indirect way, through policy implemented by municipal authorities within the guidelines of the Act on Maintaining Cleanliness and Order in Municipalities, and thanks to interactive educational and promoting actions, most often in IT environment. Knowledge is a determinant of effective logistic processes including the intraorganisational ones when parameters of appropriate waste streams, desired because of applied technological solutions in the plant are determined. Interprocessing of technological knowledge enables meeting customer needs in relationships with recipient of raw materials on secondary market, which is a symptom of integral marketing concept of these entities. Furthermore, it is a method of very aware and committed implementation of social marketing concept following the concept of sustainable development of studied entities. Social dimension of knowledge management in entities of the sector is also important because of creation of broadly understood eco-value and eco-awareness in two further subareas of the model, including such and image in strategic perspective. Moreover, the information acquired on the basis of analysis of collected waste is starting to gain new commercial dimension and offers a broad area for cooperation on functional level of management, i.e. marketing research. Garbology is the area that is still not enough appreciated by entities of both sectors. Marketing knowledge about and from customers, included in the structure of generated waste may constitute the basis for marketing decisions of product suppliers, but also the basis for the analysis of overconsumption, deficiencies and wastage. Three subspheres of smart model of knowledge management are linked with knowledge diffusion, expected from operational point of view of each of them, and complementary with applied technological solutions.

5. Information as municipal waste marketing value

The information contained in, or on waste, that constitutes the stream, and is obtained by an enterprise of studied sector can be used effectively to streamline the selection process, on the level of segregation of raw material to be processed or sold. Furthermore, they can provide information about buying and consumption behaviours of creators/suppliers of waste stream.

According to the Ordinance of the Minister of the Environment on packaging design patterns of 23 April 2004, **the marking of the packaging of goods** is determined by their chemical composition. The packages which have a significant environmental impact have been distinguished. This allows for identification, with the use of optoelectronic and laser separators, of waste streams for example for pyrolysis, self-depolymerisation or sales on the secondary market. The most important markings are shown in table 2.

6. Summary

Knowledge is a linking element in customer relationships, but also a determinant of efficient logistics processes, including intraorganisational ones, in formulating the parameters of appropriate waste streams, desirable because of technological solutions used in the plant. The knowledge acquired in this way provides the material for the concept of integral marketing of these entities, in their relations with the recipient of raw materials, on the secondary market. In addition, obtained information based on the analysis of acquired waste starts to gain a new commercial dimension and opens a broad field of cooperation on functional basis of management, i.e. marketing research. It is not enough appreciated by entities of both sectors yet. The social dimension of knowledge management of the sector actors is also important, given the creation of broadly understood eco-values and eco-consciousness, as well as its image, in the long perspective, in technologically engaged environment of knowledge diffusion.
It can be stated that the outlined three-sphere Business model based on intelligent management of knowledge and competences in enterprises of the waste management sector is of innovative and prospective characteristics, which encourages further research analyses in this area.

Waste Transfer Card (KPO) is another source of information and intraorganisational knowledge, also offering the possibility of its commercial use. This card is the evidence for appropriate disposal of waste by the entity / supplier of the stream, while omitting a natural person, at entitled recipients, according to the waste code as specified in the Code Catalogue[7]. The waste catalogue divides the waste according to the source of its formation into 20 groups as shown in table 3.

[6] Sample selection was performed on the basis of leader's indication and on the basis of indications in final report of III stage expert opinion aiming at performance of waste examination in 20 waste mechanical and biological treatment plants financed from resources of the project no POPT.03.01.00-00-375/13-00, „Wsparcie na działania sieci organów środowiskowych i instytucji zarządzających funduszami unijnymi" "Partnerstwo: Środowisko dla Rozwoju" ["*Support for activities of the environmental networks and institutions managing EU funds." "Partnership: environment for development*"] in 2014 from Resources of 2014 Technical Assistance Operational Programme 2007-2013 within Priority III – Support for execution of structural funds operation; Action 3.1. – „Functioning of institutions involved in NSRF". Executor: Consortium: Uniwersytet Zielonogórski i Zakład Utylizacji Odpadów Spółka z o.o., [*University of Zielona Góra and Waste Disposal Facility limited liability company*] Zielona Góra 2015, www.ekspertyzambp.com.pl (online: 1.12.2016).

[7] Regulation of the Minister of the Environment of 27 September 2001 on the waste catalogue - Dz.U. [*Journal of Law*] No. 112/2001, item. 1206

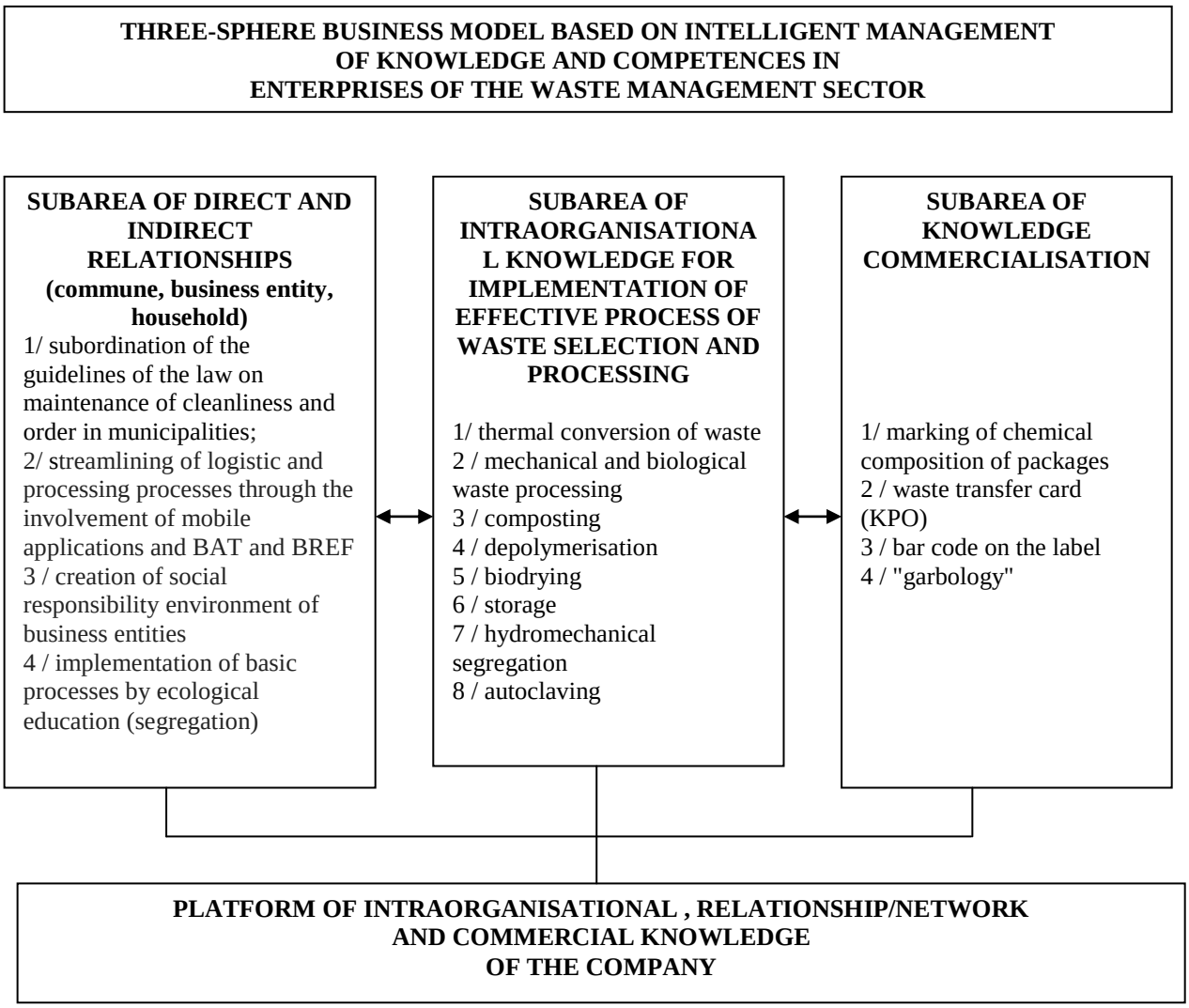
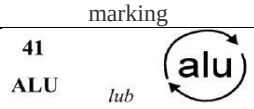
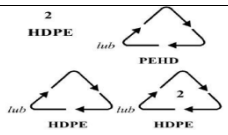
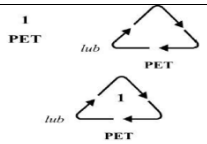
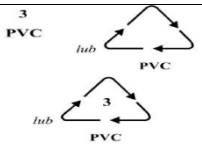
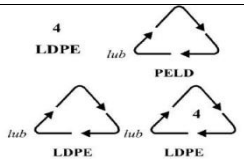
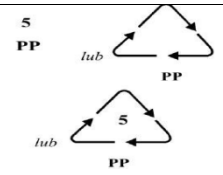
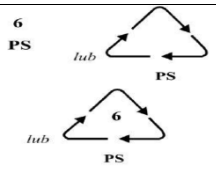


Fig 1 Business model based on intelligent management of knowledge and competences in enterprises of the waste management sector
Source: own case studv

Table 2. Marking of packaging by chemical composition

composition	marking
aluminium, found in for example cans and disposable crockery	
polyethylene terephthalate - PET, found for example in plastic bottles, dishes, packages, and housings of household appliances	
high density polyethylene - PEHD, HDPE, used for example for production of foils, packaging, garbage bags, sewage pipes, rainwater tanks and garbage containers	
polyvinyl chloride - PVC, contained for example in syringes, liners and insulation of cables	
low density polyethylene - LDPE, PELD, which is contained in plastic bags	
polypropylene - PP, used for example in foam insulation, floor coverings, toys, household appliances	
Polystyrene - PS, contained for example in Styrofoam, fancy goods and toys	

Source: Ordinance of the Minister of the Environment on packaging design patterns of 23 April 2004; http://wlaczoszczedzanie.pl/znaki-ekologiczne/oznaczenia-produktow-ekologicznych/oznaczenie-opakowan-ze-wzgledu-na-sklad-chemiczny/ (online: 15.03.2017)

Table 3. Catalogue of waste by groups

Waste type	marking
waste arising from the search, extraction, physical and chemical processing of ores and other minerals	01
agricultural, horticultural, hydroponic, fishery, forestry, hunting and food processing waste	02
waste from wood processing and from the manufacture of boards and furniture, cellulose pulp, paper and cardboard	03
waste from the leather, fur and textile industries	04
waste from crude oil processing, natural gas purification and pyrolytic coal processing	05
waste from the manufacture, preparation, marketing and use of nonorganic chemical products	06
waste from the production, preparation, marketing and use of products of the organic chemistry industry	07
waste from the manufacture, preparation, marketing and use of protective coatings (paints, varnish, ceramic enamels), putty, adhesives, sealants and printing inks	08
waste from the photographic industry and services	09
waste from thermal processes	10
waste from chemical treatment and coating of metals and other materials, and from non-ferrous metal hydrometallurgical processes	11
waste from shaping and physical and mechanical processing of metals and plastics	12
waste oils and liquid fuel waste (excluding edible oils and groups 05, 12 and 19)	13
wastes from organic solvents, coolants and propellants (excluding groups 07 and 08)	14
packaging waste; sorbents, wiping cloths, filter materials and protective clothing not included in other groups	15
waste not included in other groups	16
waste from the construction, repair and dismantling of buildings and road infrastructure (including soil and soil from contaminated sites)	17
medical and veterinary waste	18
waste from installations and equipment for the management of waste, sewage treatment plants and the treatment of drinking water and water for industrial purposes	19
municipal waste including selectively collected fractions	20

Source: Regulation of the Minister of the Environment of 27 September 2001 on the waste catalogue (Dz.U. [*Journal of Law*] 2001.112.1206).

The waste code defining the type of waste consists of six digits. Hazardous waste is indicated in the catalogue by the top index in the form of a "*" star.

The results of the analysis of the information contained in the barcode label of municipal waste and so-called analysis of the contents of the trash can have a marketing value and can be the basis for the marketing decisions of the suppliers of a specific type of product on the market. Therefore, they may be the subject of knowledge commercialization in relationships between enterprises operating in waste management sector as well as companies or research agencies.

The barcode is a graphical representation of information through a combination of dark and light elements, determined by the code symbols of the code structure. Graphics correspond to a sequence of numbers, each of which is the carrier of specific information. Two or three initial digits are the country of origin (the country code is 590), the next five digits are the manufacturer's code assigned by the Universal Copyright Convention (UCC). The next digit is the product code assigned by the manufacturers, and the control digit confirming the correctness of the scan. The digital representation of what the code contained is intended to allow to manually enter the code, if the reader is unable to read the information. The code has the informational value when it is automatically read by the electronic reader (laser, diode or camera), which allows for the product to be identified.

On the other hand, the information from the analysis of **"trash can content" (the so-called garbology[8] analysis"**) refers to household shopping and consumption habits, which can be the subject of comparative analysis in the category of the subject (residential and non-residential areas, including industrial areas), geographic location (international, regional, local), territorial unit (city, village), type of residential unit (single or multi-family buildings), or time, with the distinction of "special periods" (e.g. holidays, holidays period etc.). Analysis of the content of trash can may concern:

- the structure of purchased and consumed goods in the household, by residents of a building, estate, district, companies of their groups, in a specific area;
- eco-habits, manifested in purchasing behaviour and tendency to segregate waste;
- quantity of consumed / consumed good of a specific category, in a given unit of time and the amount of single purchase expressed for example by the size of the package;
- intensity of consumption, expressed as the time of filling the trash and the frequency of emptying;
- social level of the household;
- information about consumer habits concerning consumption of highly processed products or products / raw materials;
- information about preferences regarding local, national or foreign product preferences;
- the degree of waste of purchased products: food, household and TV appliances and electronics.

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MARKET ORIENTATION AND BUSINESS PERFORMANCE FROM BEHAVIOURAL PERSPECTIVE - THE CASE OF SLOVAKIA

Dr. Budinska, S., Associate Prof. Taborecka-Petrovicova, J.
Faculty of Economics – Matej Bel University in Banska Bystrica, Slovakia
janka.taborecka@umb.sk

Abstract: *In the context of highly competitive global markets, challenging customer needs and increasing dynamics of business environment, businesses try to identify and apply the most effective practices whose enforcement will lead to superior performance. It becomes necessary for businesses operating in competitive environment to efficiently generate, disseminate and respond to market information. Market orientation is a concept that has appeared as a significant predictor of business performance. The main aim of the paper is to examine market orientation of businesses operating in Slovakia through MARKOR measurement method with the respect to business performance measured through the financial and non-financial indicators. The MARKOR method enables to gain information about specific behavioural reactions of business on critical aspects of a market such as competition, customers, regulation, social and macroeconomic forces. Research findings may help businesses to identify the most relevant elements that subsequently could be implemented with the intention of reaching better position on the market.*

Keywords: MARKET ORIENTATION, BUSINESS PERFORMANCE, BEHAVIOURAL PERSPECTIVE, MARKOR, FINANCIAL AND NON-FINANCIAL INDICATORS

1. Introduction

Market orientation became a center of studies for more than 30 years (Parasuraman, 1983; Greenley and Matcham, 1986; Naidu and Narayana, 1991). In marketing literature (Narver and Slater, 1990; Ngai and Ellis, 1998) the importance of market orientation is emphasized mainly as the key aspect for increasing businesses profitability. Implementation of marketing activities results in outperforming of businesses performance (Day and Nedungadi, 1994). McCarthy and Perreault (1990) understand market orientation as implementation of marketing concept. Deshpandé and Farley (1999) consider market orientation as a significant predictor of business performance whose implementation lead to achievement of long-term profitability.

Market orientation could be understood from both *behavioural and cultural perspective* (Kirca et al., 2005). Behavioural perspective is presented by the works of scholars Kohli and Jaworski. Narver and Slater are scholars who have developed cultural perspective. Researches of these authors are considered as a key in developing the market orientation issue. Their different definitions of market orientation have become cited by many authors up to these days (Rojas-Méndez and Rod, 2012; Shin, 2012; Guo and Wang, 2013; Eslahnia, 2014; Kajalo and Lindblom, 2015; Long, 2015; Widana et al. 2015).

A. K. Kohli and B. J. Jaworski (1990), the main representatives of *behavioural perspective*, in one of the first research found that market orientation entails more precise and detailed view on customer focus and coordination. Firstly, it involves one or more departments engaging in activities concentrated on the development of understanding of current and future customer needs and recognizing the factors that affecting them. Secondly, the market orientation is characterized by sharing the understanding of customer needs and wants across all departments in business unit. Thirdly, the various departments are involved in realizing activities devised to come across select customer needs. Authors synthesized their findings into the formal definition of market orientation as an "organization-wide generation of market intelligence, pertaining to current and future customer needs, dissemination of the intelligence across departments, and organization-wide responsiveness to it" (Kohli, Jaworski, 1990, p. 6). Understanding of these three dimensions requires more detailed description of operations performed within the business as follow (Varela, Río, 2003):

Generation of market information refers to the degree to which business systematically collects and processes information about current and future needs of consumers and industrial end-users, as well as external factors, such as competition, technological and environmental changes, etc. Into this task should be involved all departments because of their special relationships with the market agents. The speed dimension of market information generation is crucial; *Dissemination of market information* is accomplished through the three operations within the business. Firstly, through the interdepartmental meetings or informal chats about the tendencies of the market and its changes; secondly, through the generalized discussion about customers and competition, and thirdly, through the interactions and communications of marketing department members with the other departments in order to examine future needs of customers. Quick distribution of information and involvement of all member of business unit is the way how to maximize the value of generated information; *Responsiveness* to market information means to implement marketing activities consistent with the accumulated market information about customer, competition and environmental factors, and planning the supply according to the customers' preferences and wants. The changes detected in customers' and competitors' behaviour should be implemented into business decisions.

In our paper we occupy with the impact of market orientation on business performance, which can be expressed through financial or non-financial indicators. Performance measurement is a key activity of gauging the set objectives. Outputs obtained by measuring the performance of the business provide a picture about overall situation of business to owners and potential investors and also allow managers to take different actions. Lesáková (2004) defines the performance as the business ability to achieve the desired effects or outcomes, and possibly in measurable units. Business performance can be measured through the key performance indicators that serve to evaluation of actual development of the business in comparison with objectives and targets that it has set (Kabát, et al., 2013). Several authors (Rajnoha et al., 2013; Marinič, 2008) agree that the performance evaluation approaches are essentially based on two groups of indicators: financial performance indicators and non-financial performance indicators. Thus, performance criteria can be set for both financial and non-financial area.

Kirca and Hult (2009) refer that expansion in market orientation research has accelerated in the last two decades. Especially, there are three groups of models proposed and tested by researchers. There are models focused on conceptualization and measuring the market orientation of business (Kohli and Jaworski, 1990; Narver and Slater, 1990), models directed on identifying of antecedents and consequences of market orientation (Matsuno et al., 2002) and models investigating the mediators and moderators that influence relationship between market orientation and business performance (Slater and Narver, 1994). For the purpose of our research we will dedicate with models measuring market orientation of business and models investigating *relationship between market orientation and business performance*.

2. Methodology

The main aim of the paper was to examine market orientation of businesses operating in Slovakia through MARKOR measurement method with the respect to business performance represented by financial and non-financial indicators. We assumed that the relationship between market orientation and business performance indicators will be confirmed. Our research sample involved 230 completed questionnaires from businesses operating in Slovakia (realized in 2017). These businesses had to meet the conditions of profit-orientation and number of employees (10 employees and more). Our research sample copy the structure of population in the terms of legal form, number of employees, and region. We can generalize statistically verified result on whole population due to representative character of research sample. The topic is part of the research project VEGA 1/0686/16 Marketing orientation of businesses as a tool of increasing business competitiveness and performance, 2016-2018

Kohli and Jaworski (1993) developed MARKOR method as a tool for measuring market orientation from behavioural perspective. It includes three components – *generation of market information, dissemination of information and responsiveness capacity* with 20 items (detailed statements can be seen in Results). The MARKOR method appears to be able to gain information about specific behavioural reactions of business on critical aspects of a market such as competition, customers, regulation, social and macroeconomic forces (Day and Wensley, 1988; Jaworski and Kohli, 1993; Kohli, Jaworski, Kumar, 1993). Questionnaire contains Likert-scales items which have positive or negative character. Negative formulation is used as a control tool for sustaining attention of respondent. We used 7-point Likert-scale items and followed the studies of several authors (Narver, Slater, 1990; Pitt a kol., 1996; Puledran a kol., 2003; Hooley a kol., 2003). Moreover, we slightly modified some items on the basis of qualitative pre-research realized with marketing managers of businesses.

In our research we investigated business performance measured through the financial and non-financial indicators. Business performance is more frequently measured through the *financial indicators* (Table 1). In our questionnaire we investigated the impact of market orientation on traditional indicators, such as profit, sales, return on sales, return on assets, return on investment or return on equity and so on. Moreover, we extended our measuring methods through the modern indicators. We have decided to get involved net present value, economic value added, cash flow return on investment, market value added, and Balanced Scorecard (involved on the basis of qualitative pre-research).

Table 1 *Financial Indicators of Business Performance*

I.	**Business Performance**
1.	Our overall financial performance has increased over the last three years.
2.	Our market share has increased over the last three years.
3.	Our profit has increased over the last three years.
4.	Our sales have increased over the last three years.
5.	Sales generated by new products have increased over the last three years.
6.	Return on sales (ROS) has increased over the last three years.
7.	Return on assets (ROA) has increased over the last three years.
8.	Return on investments (ROI) has increased over the last three years.
9.	Return on equity (ROE) has increased over the last three years.
10.	Return on marketing investments (ROMI) has increased over the last three years.
11.	Net present value (NPV) has increased over the last three years.
12.	Economic value added (EVA) has increased over the last three years.
13.	Cash flow return on investments (CFROI) has increased over the last three years.
14.	Market value added (MVA) has increased over the last three years.
15.	Based on method Balanced Scorecard our performance has increased over the last three years.

Source: Modified according to Kohli and Jaworski. 1990.

Non-financial indicators defined by Kohli and Jaworski (1993) created the statements for measuring outcomes of market orientation within the organizational commitment, esprit de corps, and customer satisfaction. We added to these groups several statements which we consider as important (according to the pre-research results). They are highlighted by dark grey colour in table 2.

Table 2 *Non-financial Indicators of Business Performance*

I.	**Organizational Commitment**
1.	Employees feel as though their future is intimately linked to that of this organization.
2.	Employees would be happy to make personal sacrifices if it were important for the business unit's well-being.
3.	The bonds between this organization and its employees are weak.
4.	In general, employees are proud to work for this business unit.
5.	Employees often go above and beyond the call of duty to en sure this business unit's well-being.
6.	Our people have little or no commitment to this business unit
7.	It is clear that employees are fond of this business unit.
8.	In our business unit there is low fluctuation of employees.
9.	Based on the assessment of individual statements we can say that our employees are generally satisfied.
I.	**Esprit de Corps**
1.	People in this business unit are genuinely concerned about the needs and problems of each other.
2.	A team spirit pervades all ranks in this business unit.
3.	Working for this business unit is like being a part of a big family
4.	People in this business unit feel emotionally attached to each other.
5.	People in this organization feel like they are "in it together."
6.	This business unit lacks an "esprit de corps."
7.	People in this business unit view themselves as independent individuals who have to tolerate others around them
8.	Based on the assessment of individual statements we can say that our employees are loyal to our business.
I.	**Customer Satisfaction**
1.	Customers are satisfied with the quality of our products.
2.	Customers are satisfied with the prices of our products.
3.	We rarely receive complaints from our customers.
4.	We are easily getting new customers.
5.	We serve many of the same customers we have served in the past.
6.	Our customers are often returning to us.
7.	We have more loyal customers than our competitors.
8.	Based on the assessment of individual statements we can say that our customers are generally satisfied.

Source: Modified according to Kohli and Jaworski. 1990.

3. Results and Discussion

We measured market orientation through 20-item MARKOR method. These items were thematically divided into three groups – intelligence generation, intelligence dissemination, and responsiveness. In table 3 are presented mean values of respondents' answers to individual items which measure *intelligence generation*. Respondents achieved the highest values in items number 1 (i.e. 5.74) and number 4 (i.e. 5.54). It means that businesses from our sample use mainly the assessment of quality of products and services from end-users as the activity in order to gain market information and consequently they meet with customers to find out their future needs. Contrary, the lowest mean value was reached in item number 6 (i.e. 4.53). Thus, the respondents give smaller attention to periodic review of effect of changes in business environment on consumers.

Table 3 *Mean Values of Items Connected to the Intelligence Generation*

I.	**Intelligence Generation**	**Mean**
1.	In this business unit, we meet with customers at least once a year to find out what products or services they will need in the future.	**5.74**
2.	In this business unit, we do a lot of in-house market research.	**4.69**
3.	We are slow to detect changes in our customers' product preferences.	**4.62**
4.	We poll end users at least once a year to assess the quality of our products and services.	**5.54**
5.	We are slow to detect fundamental shifts in our industry (e.g., competition, technology).	**4.87**
6.	We periodically review the likely effect of changes in our business environment (e.g. regulation) on customers.	**4.53**
	Mean value of group	**5.00**

The second group of items referred to the *market intelligence dissemination*. We can see from the table 4 that respondents reached highest mean values in items number 9 (i.e. 5.21) and number 10 (i.e. 5.09). These two items are connected to the dissemination of information about customers. The lowest mean value reached respondents in item number 8 (i.e. 4.35) which was focused on the effort of marketing personnel to discuss about future needs of customer with the other departments.

Table 4 *Mean Values of Items Connected to the Intelligence Dissemination*

I.	Intelligence Dissemination	Mean
7.	We have interdepartmental meetings at least once a quarter to discuss market trends and developments.	**4.72**
8.	Marketing personnel in our business unit spend time discussing customers' future needs with other functional departments.	**4.35**
9.	When something important happens to a major customer of market, the whole business unit knows about it within a short period.	**5.21**
10.	Data on customer satisfaction are disseminated at all levels in this business on a regular basis.	**5.09**
11.	When one department finds out something important about competitors, it is slow to alert other departments.	**4.39**
	Mean value of group	**4.75**

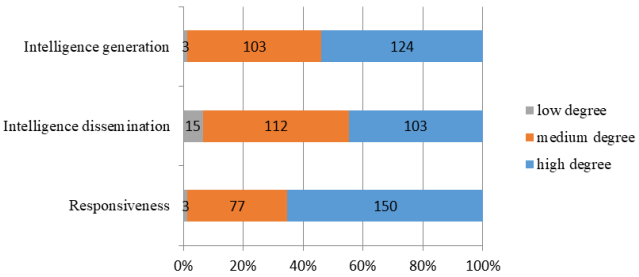
The third group of items referred to the *responsiveness to market information* (see Table 5). These items assess the speed and quality of reaction to achieved information about customers, competitors, and market. Two highest mean values were reached by respondents in item number 13 (i.e. 5.89) and item number 18 (i.e. 5.77). High mean values of both items speak about the fact that respondents definitely do not ignore customer complaints and the changes in their needs.

Table 5 *Mean Values of Items Connected to the Responsiveness*

I.	Responsiveness	Mean
12.	It takes us forever to decide how to respond to our competitor's price changes.	**5.15**
13.	For one reason or another we tend to ignore changes in customer's product or service needs.	**5.89**
14.	We periodically review our product development efforts to ensure that they are in line with what customers want.	**5.06**
15.	Several departments get together periodically to plan a response to changes taking place in our business environment.	**4.66**
16.	If a major competitor were to launch an intensive campaign targeted at our customers, we would implement a response immediately.	**5.32**
17.	The activities of the different departments in this business unit are well coordinated.	**5.17**
18.	Customer complaints fall on deaf ears in this business unit.	**5.77**
19.	Even if we came up with a great marketing plan, we probably would not be able to implement it in a timely fashion.	**4.65**
20.	When we find that customers would like us to modify a product of service, the departments involved make concerted efforts to do so.	**5.03**
	Mean value of group	**5.19**

Graph 1 presents the results of three elements of market orientation from behavioural perspective.

Graph 1 *Values of Market Orientation from Behavioural Perspective*



According to the achieved value we divided businesses into 3 groups: 1.00 to 2.99 – low market orientation; 3.00 to 4.99 – medium market orientation; 5.00 to 7.00 – high market orientation. Respondents achieved highest mean values in responsiveness to the market information, because 65.22 % of respondents reached high market orientation and 33.48 % of respondents reached medium market orientation. 53.91 % of respondents reached high market orientation in the items connected to the intelligence generation and 44.78 % of respondents reached medium market orientation. The lowest mean values of market orientation achieved respondents in intelligence dissemination (6.51 % of respondents achieved low market orientation, 48.70 % of respondents achieved medium market orientation, and 44.78 % of respondents achieved the high market orientation).

The next step in our research was to test statistically correlation between market orientation and all indicators of business performance (Table 6). As we can see in this table, there is statistically significant middle-strong positive dependence between market orientation and almost all financial indicators and also non-financial indicators.

Table 6 *The Effect of Market Orientation on Non-financial and Financial Indicators of Business Performance*

	MARKOR	
	p-value	Spearman's rho
Employees Commitment	0.000	0.476
Esprit de Corps	0.000	0.418
Customer Satisfaction	0.000	0.369
Overall Performance	0.000	0.359
Market Share	0.000	0.282
Profit	0.000	0.313
Sales	0.000	0.386
Sales Generated by New Products	0.000	0.291
Return on Sales (ROS)	0.000	0.386
Return on Assets (ROA)	0.000	0.285
Return on Investment (ROI)	0.000	0.293
Return on Equity (ROE)	0.001	0.231
Return on Marketing Investment (ROMI)	0.017	0.197
Net Present Value (NPV)	0.000	0.421
Economic Value Added (EVA)	0.000	0.399
Cash Flow Return on Investment (CFROI)	0.000	0.282
Market Value Added (MVA)	0.000	0.340
Balanced Scorecard	0.000	0.391

Finally, we were interested in more detailed analysis regarding market orientation dimensions. We tested the dependence between all three dimensions of behavioural market orientation perspective and business performance indicators. Dependence between intelligence generation and business performance was confirmed in linkage to all financial and non-financial indicators. Then, we focused our interest on intelligence dissemination. Correlation was not confirmed in linkage to return on assets (Sig.=0.239), return on equity (Sig.=0.095), cash flow return on investment (Sig.=0.196), and market value added (Sig.=0.140). Only one financial indicator – return on marketing investments (Sig.=0.437) – is not correlated to the third element – responsiveness. In all other cases the dependence was confirmed. More thorough analysis of the effect of components of market orientation from behavioural perspective on business performance indicators is introduced in table 7.

In the following text we proceed to the comparison of results of our primary research to the results of researches realized abroad. From the geographical, historical, and sociological point of view is Slovak market the most similar to the market of Czech Republic. Tomášková (2009) in her research investigated the relationship between market orientation, customer orientation, employees' orientation, and business performance of hi-tech businesses in Czech Republic confirmed the positive correlation between market orientation and business performance of hi-tech businesses. Market orientation has the positive influence on business performance in the terms of market and finance performance. The results of this research are in accordance with the results of our primary research in which we also confirmed the positive influence of market orientation on business performance measured through the financial and non-financial indicators. The increasing of business performance contributes to the achieving or sustaining the competitive advantage and thus affects the overall competitiveness of business. Nožička and Grosová (2012) who used the New method developed especially for the conditions of Czech businesses, examined the market orientation in the context of innovative small and medium businesses. The results of correlation analysis in this research proved very strong correlation between market orientation and business performance.

There were processed several meta-analyses reflecting the overview of research finding all over the world (Kirca et al., 2005; Jaramillo et al., 2007; Vieira, 2010). For example, Vieira (2010) conducted the Brazilian meta-analysis of 27 papers which aggregate the sample size of 4537 businesses. The results proved the positive and strong relationship between market orientation and business performance. Moreover, they realized the international mega-analysis consists of seven meta-analyses on market orientation and the results showed that there exists strong, positive and consistent relationship between market orientation and business performance across countries. Majority of analyzed researches confirmed the positive relationship between market orientation and business performance (e.g. Talaja et al., 2017; Hussain et al., 2016; Dubihlela and Dhurup, 2013; Alizadeh et al., 2013; Nožička and Grosová, 2012; Tomášková, 2009, Kara et al., 2005; Avlonitis and Gounaris, 1997, Šályová and Táborecká-Petrovičová (2016), Šályová and Táborecká-Petrovičová (2017b)).

Table 7 *The Effect of Behavioural Components of Market Orientation on Business Performance Indicators*

	MARKOR					
	Intelligence Generation		Intelligence Dissemination		Responsiveness	
	p-value	Spearman's rho	p-value	Spearman's rho	p-value	Spearman's rho
Employees Commitment	0.000	0.369	0.000	0.320	0.000	0.373
Esprit de Corps	0.000	0.335	0.000	0.325	0.000	0.336
Customer Satisfaction	0.000	0.397	0.023	0.150	0.000	0.315
Overall Performance	0.000	0.289	0.006	0.189	0.000	0.330
Market Share	0.003	0.208	0.012	0.176	0.000	0.244
Profit	0.013	0.169	0.033	0.146	0.000	0.289
Sales	0.000	0.263	0.002	0.216	0.000	0.358
Sales Generated by New Products	0.015	0.170	0.001	0.222	0.000	0.248
Return on Sales (ROS)	0.000	0.292	0.011	0.182	0.000	0.335
Return on Assets (ROA)	0.000	0.288	0.239	-	0.002	0.217
Return on Investment (ROI)	0.001	0.225	0.045	0.144	0.000	0.257
Return on Equity (ROE)	0.004	0.206	0.095	-	0.009	0.187
Return on Marketing Investment (ROMI)	0.041	0.168	0.047	0.163	0.437	-
Net Present Value (NPV)	0.000	0.317	0.017	0.203	0.000	0.365
Economic Value Added (EVA)	0.001	0.280	0.009	0.217	0.000	0.327
Cash Flow Return on Investment (CFROI)	0.001	0.269	0.196	-	0.008	0.209
Market Value Added (MVA)	0.000	0.371	0.140	-	0.003	0.243
Balanced Scorecard	0.001	0.309	0.005	0.264	0.004	0.272

Source: Own elaboration according to SPSS output.

Our research results contributed to the current knowledge and are in line with the findings present across a wide variety of countries and contexts.

4. Conclusions and Managerial Implications

According to the research results we conclude that the relationship between the market orientation of businesses in Slovakia and their performance expressed through financial and non-financial indicators was confirmed. The existence of this relationship is proved for the decades by results of enormous number of researches implemented in different countries all around the world, on the sample of businesses of different sizes and operating in various sectors of economy Based on our findings, we formulate proposals for businesses operating in Slovakia which go evidently beyond the borders of marketing. Market orientation has interdisciplinary character therefore our suggestions touch upon management, human resources or corporate culture. In terms of implementation of the marketing concept in the whole business and irreplaceable role of inter-function coordination within the market orientation, the application of the proposals across all functions and departments of business is directly induced.

From the behavioural perspective, in the phase of generation market intelligence the businesses with the best results meet with customers at least once a year to find out what products or services they will need in the future. The next activity is polling end users at least once a year to assess the quality of our products and services. Regarding this, the most important for market-oriented business is to meet with customers regularly in order to find out their opinion about products. In the phase of dissemination market intelligence the best market-oriented businesses focus on organizing interdepartmental meetings at least once a quarter to discuss market trends and developments. In connection to this, marketing personnel in these businesses spend time discussing customers' future needs with other functional departments. Thus, we can state that it is important to communicate about market information within the all departments of business. In the phase of responsiveness to market intelligence the best businesses focus on several activities. They definitely do not ignore changes in customers' product or service needs and periodically review product development efforts to ensure that they are in line with what customers want. In the connection to the customers, the businesses react and solve the complaints of customers. In the field of competition, these business immediately implement the response to the intensive campaign targeted at their customers launched by major competitor. They are also very flexible and quick in implementing the marketing plans. Response to changes taking place in business environment are periodically planned by several departments.

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BUSINESS SUCCESS OF INCUBATED STARTUPS

Ing. Richard Bednár, PhD.
richardpapa@gmail.com

Abstract:. *A startup is starting an innovative enterprise that has in establishing greater business risk and successful beginning is likely its rapid growth. Exponential growth is an attraction for many investors who are actively searching for new startups and investing in them with the hope of going to be another Google, Facebook or Twitter. The paper describes the incubation program of WAYRA, which is one of the world's largest business incubators. We have been dealing not only with the exited startup but also with the currently incubated WAYRA CEE in Prague. We evaluate their potential, strengths and weaknesses, opportunities and threats in the discussion.* [1]

Keywords*: STARTUP, WAYRA, INCUBATION, INVESTOR*

1. Introduction

The development of new technologies and the rapid development of the Internet have brought the trend of global businesses that have managed to sell their products and services throughout the world over a short period of time. These businesses are called startups. According to the Euroekonom Portal, start-up is the organization that is currently in the process of establishing a new product (service). A typical example of startup is the so-called new technology-based companies whose core business is the development, marketing or use of equipment or technology. (Euroekonom, 2014) The Ministry of Finance of the Slovak Republic defines startup as a "newly established enterprise or foundation enterprise that attempts to materialize or materialize a certain idea into a product form, the added value of which lies in the exceptional market and the solution of a problem not yet known". In the long run, such an enterprise must be scalable. This means that its products and services start to be produced to a large extent to address the shortage of the widest social group or have the potential to have a rapid economic impact. The startup product or service must have a technology and / or research base, must use IT for branding, product / service development, and must address services that have a chance to succeed in market conditions from the start of business in the interest of clients. (Buchlakova, 2014) We think startup is any start-up company that already exists on the market and shapes the blue ocean in the industry, has a higher business risk compared to a standard firm in market setting, and is likely to grow rapidly after a successful start.

The main objective of the research was to describe the business models of startups incubated in Wayra Academy, identify their strengths and weaknesses as well as the opportunities and threats of the market. Another goal was to make an estimate of their potential. Some of the startups have already succeeded in establishing themselves on the market and others are still in the experiment stage and their success is uncertain. Data were gathered from personal interviews directly from startup founders, conferences, presentations to investors, and online resources.

2. Aim of the paper

The main aim of the research was to identify the factors leading to the success of incubated startups. The result has been to create an overview of the those startups, which were incubated and tried to be successful. We divided the main goal into testing three hypotheses in which we analyzed possible success indicators:

1. Incubation program Wayra helps startups and bring measured success.
2. Startups do now know how to correctly estimate customer, target group and market potential in the industry.
3. Successful startups has the same features.

3. Methodology

In the first phase we compared current knowledge in scientific literature, using resources in the ScienceDirect, Springer and RePEc databases and Google Scholar Search. Afterwards we analyzed startups, which were in program Wayra in years 2014-2016

4. Results

Wayra is an incubation program (2014) funded by investors, the most significant of which is Telefónica Digital. Wayra was founded in 2011 in Latin America, where it met with great success, and a year later came to Europe. Its goal is to support innovation and talent search in Latin America and Europe. The program specializes in Internet and Communication Technologies (ICT). This global accelerator helps entrepreneurs with development and provides the necessary technology, mentoring, inspiring work environment and financing. Currently it operates in Argentina, Brazil, Chile, Columbia, Mexico, Peru, Venezuela, Ireland, the UK and the Czech Republic. It is one of the largest acceleration programs in the world. Registering entries for more than 20,000 startups, of which 315 were incubated. Wayra has invested € 43 million to date, of which € 13 million was provided by Telefónica, and € 30 million was external financing.

In the Czech Republic, Wayra CEE is a well-known accelerator based in Wenceslas Square in Prague. Startup offers an eight-month mentoring program, open-office, an investment of € 40,000, and access to 300 million customers. This requires a 5% stake in business. Money is designed to develop the product; the cost of the whole team must be covered from savings or other sources.

The first group of ten startups was incubated at Wayra CEE Academy from April 2013 to February 2014. Of these, 9 were Slovak and one Czech. According to Wayra's managers, Slovaks appear to be more prey with a greater risk.

Big Launcher (Details of BL, 2014) is an alternative Android interface with optimization for people with worse eyesight, reduced motoring or less technical skills. It is taught especially for seniors. The design is characterized by large buttons, contrasting colors and large fonts. After unlocking the user's phone, a simple screen is waiting for basic choices and information about time, date, battery status and signal. At the same time, there is a direct screen option to enter a call, SMS interface, camera, or gallery. However, the number of areas can be changed to accommodate the main screen. Font and contrast options are also adjustable. (Dolejš, 2014) The whole system is focused on the basic features of the phone. It is available in 40 languages.

It all started (Zaharia, 2014), when the cell phone of one of the founders went wrong and wanted to buy a new one. At that time, there were not many phones for seniors. The ones available were so ugly and less user-friendly that they did not want them. She needed just a few features like messages, call, internet, and camera. Tolo quite a lot of Android phones, so the founders decided to create a simple platform available to the general public. They worked on it during the weekends. BigLauncher has won the Vodafone Smart Accessibility Awards 2011 and WebExpo Start-up Show 2012. To date, it has 50,000 downloads (Details of BL, 2017).

Strengths: simple implementation on advanced Android, low price, applicability to any smartphone with Android, high quality processing, clear definition of the target group

Weaknesses: applicability only for Android

Opportunities: aging population, especially in CEE, expanding the use of smartphones in the 65+ target group

Threats: Samsung and its new platform

Datamolino (2017) is a b2b startup that simplifies accounting. In the world, 100 billion invoices are created per year (Wayra

Global 2017),of which 16 billion in the EU. According to the founder, if he has 200 clients, he produces about 10,000 invoices per year. When posting, each invoice must be manually overwritten by the computer, causing approximately 10% of errors. At the same time, this transcript of 12 people takes 5 days.

The first idea of the founders was to add QR codes to invoices, but this method was unrealistic for many businesses. Later Andrej Glézl and Ján Korecký created the Datamolino system, which is the optical recognition of symbols and their transformation into digital form. The entire process is set up so that the company sends its invoices to Datamolina, they are processed and data is linked directly to the accounting software. The platform is encrypted with the SSL protocol and 128-bit system, and the data is stored on the Amazon cloud.

The first success of the company was the investment and incubation program from Wayra CEE. The biggest investment, however, was the sum of 500,000 euros from the Innovation and Technology Fund in Slovakia. At present, the company has 17 employees and is based in Bratislava, The Spot. Sales were launched in the summer of 2014. Currently, the company plans to export to the UK. The price of one invoice transformation is 0.40 euros or a flat rate of 6 euros per month for 40 invoices (for each additional 0.15 euros).

Strengths: strong data encryption solves the real problem of large businesses

Weaknesses: high price, the invoice is outside the enterprise

Opportunities: outsourcing of businesses

Threats: hacking system, data leakage

Mapilary (Bednár, 2017) captures movement of people and goods in real time. It is designed for companies looking for a system for the distribution of goods to the "last minute". The idea arose during meetings with friends of the founder, many of whom often were late, so everyone had to call each other. The primary app was to show how people are approaching the meeting point. While working in Wayra, the whole team decided to change their focus and solve a similar problem, such as eternal waiting for the courier, long time to deliver the shipment, and telephone dispatching of the place and time of delivery. Finally, delivery companies have shown several problems. Many of them have been resolved using Mapilary.

Wayra helped the founders in particular with marketing, the preparation of a business plan, a database of interesting people contacts, and presentation skills. They also met a number of great startup players. Every day they received feedback from mentors and colleagues from other startups. In their case, this led to a pilot project from b2c to b2b solution. An important part of this was a financial investment in an enterprise that enabled the founder to work full time in the Mapilary and extend it to new, smart people. This has greatly accelerated development and improved marketing.

Mapilary is more than a localization service. It reduces the costs of the delivery company and increases the comfort and satisfaction of the end customer. It offers efficient dispatching, greatly simplifies and improves the job of the courier. The addressee brings a new delivery experience when ordering goods from the Internet as well as when delivering food. Online shopping is rapidly gaining popularity. Quality carriers with new technologies will be preferred by e-shops, the end customer will also prefer an e-shop that gives him more than just the product he has just bought. Mapilary allows you to view the recipient's location and the courier on the map. In order to be visible, it specifies the delivery time in minutes, automates communication between dispatcher, courier and addressee. By using Mapilary, the number of successful deliveries increases for the first time, benefiting all stakeholders.

The service consists of several independent apps that communicate via the API (App programming interface). This allows the delivery company to choose the part it is interested in. The whole system is harmoniously tuned and provides complete comfort as a whole. Mapilary Dispatcher is a web-based solution for managing field workers. Allows assignment of tasks to the worker's time axis, optimizes the route, displays the immediate position of workers and tasks on a dynamic map. An automated system recommends the most appropriate couriers to the task, possibly assigning shipments without the need for human intervention. Mapilary Courier is a mobile application that allows couriers to deliver delivery efficiently. Automates communication with the addressees, thereby increasing the number of successful delivery on the first attempt and increases work safety courier. It also navigates and helps to optimize the route. Mapilary Tracker is a mobile application where the addressee sees delivery time in minutes. The Tracker also enables other activities that greatly enhance customer comfort.

According to the founder, we will no longer be able to imagine a 4-hour delivery delay in a few years. We will find it normal to know the exact time of arrival of the courier. This will allow us to better plan our own time. As the service, will be more efficient and more comfortable, we'll order more goods through the internet. This will allow the growth of delivery companies.

In the near future, the company plans to penetrate the market in Central Europe, thinking in the long run to enter the global market. Expansion, however, requires considerable financial investment, and therefore another investor is contemplated. The company has an experienced team that works very agile to develop and sell a quality product that addresses the real problem.

Strengths: quality product processing, tailored customer service, experienced team

Weaknesses: -

Opportunities: greater demands on delivery services

Threats: exponentially growing competition

Networker is a networking platform (Janouš, 2016), that connects conferencing visitors in real time. They solve one of the main problems of the event, which is the lack of time for personal interviews and the exchange of contacts. If the participant pays 1,000 euros for the conference and 300 euros for ticket and travel, this problem becomes more pronounced. Providers will log in through their LinkedIn account or fill out the form after downloading the application. They enter the created event and can view a list of all the people who are on the site, send them a message or a business card. The application currently has 3000 downloads and is free. Networker earns revenue from event organizers.

Strengths: the first in Slovakia and the Czech Republic, a strong contact database for the company

Weaknesses: less intuitive system, complication of login

Opportunities: the transfer of major conferences to the CEE

Threats: a great deal of competition, the largest businesses offer a whole package of conference services

Woppa (Gašparík, 2017) is a platform that connects businesses with ambitious young people. Businesses wishing to fill new jobs, short-term brigades or internships and looking for ambitious students offer targeted advertising. It also hosts seminars, educational projects and webinars. It works with the Employers' Club and KPMG. So far, 100 companies and 1300 students from Slovakia and the Czech Republic have used it.

Strengths: a large database of students, personal contacts with businesses

Weaknesses: minimum added value, low innovation

Opportunities: the growth of ambitious and quality students

Threats: several similar projects (AIESEC), decreasing number of students

Remote assistant (2017) is a service that was originally created for people with worse eyesight and for the blind. Using video, voice, and localization systems should help users in real-time orientation in unknown spaces. With one button, the user can get in touch with their friends and ask them for advice and help. The company plans to draw revenues from state support, grants and endowment funds.

Strengths: quality processing of the application

Weaknesses: misidentification of the target group, internet necessity, low added value versus Skype / Viber / WhatsApp

Opportunities: purchase a platform by another company that will use the product for its business

Threats: -

Lionexpo (2014) is a platform that helps event organizers to provide more sophisticated and effective services to exhibitors as well as visitors. The project arose after the founders organized National Career Days for several years and found that things did not work as they should. The problem was a lot of administration, off-line data and a high price for businesses. They started to leave, because the cost of one fair in the hundreds to thousands of euros was high for them. The organizers did not innovate because they did not have the money or the know-how. The decline in the interest of businesses in these types of events is obvious. At this year's tourism fair in Prague, there were only a few travel agencies. Their marketing has moved to telephone and online sales.

The main goal of LionExpo is to help sell the organizer squarer meters. The company offers an integrated solution, which is the registration of the visitor and the exhibitors. Processes are simplified and the organizer can focus on their primary business. At the same time, he has a current overview of who sells in his premises and how many visitors have come. After the event, LionExpo is able to analyse these data and send a clear outline to the organizer.

The next goal of the company is to innovate the system so that the visitor responds to 4 basic questions a few days before the fair. LionExpo him prepare a list of stands that are most suitable for him. At the same time, exhibitors receive a list of 100 visitors who are relevant to them. They choose the most important and the company then arranges for them to meet directly during the event. At the same time, Lionexpo eliminates manual data processing and maximizes the efficiency of processes. The company has already collaborated with IBM, KPMG, Siemens, Microsoft, Lidl, Dell and Sheraton. Currently plans to expand to America, Germany and Asia.
Strengths: product still under development
Opportunities: development of exhibitions and fairs in CEE,
Threats: reduction of technology prices - organizers will make their own applications

TrashOut (2017) is environmental a project that aims to locate all illegal landfills around the world. It provides a solution for effective action against illegal landfills. Its goal is to help ordinary people to influence their environment and to easily engage in joint activities. This project also helps self-governments and local institutions to change the situation in their region. TrashOut is an application available for Android, iPhone and Windows Phone. The user installs it on the phone and reports it after finding the landfill. It can add a photo, specify its size, type, and mark a location via GPS. This will create a map that captures all illegal landfills in real time.

Users often just download the app and take a picture of landfill. The company wants them to be more proactive and monitor landfills on a regular basis. This would create the current global statistics. TrashOut has found that there is a correlation between corruption, the quality of education and the number of illegal landfills. These are the image of society. At the moment, a Swedish student cooperates with the startup (Sweden is 99% recyclable) looking for new correlations and verifying whether the country is improving education and reducing the number of landfills, reducing crime and increasing GDP. At the same time, the company lobbyed politicians for landfill to be the new economic indicator of the country.

The application already has 80,000 downloads in 14 languages. There are 18,000 landfills in 70 countries worldwide. Most of the registrations are from Slovakia and the Czech Republic, as the application was launched here first. Currently, Russia and Africa are very active. Trashout wants not only to point to landfills but also to create an information database where users find information about the nearest collection yard, battery bins, and recycling processes it plans to promote in short videos. The company employs 5 people on a half-time basis, after having found another investor, it should increase to 6 full-time employees.

Founder Jozef Vojdička has been sensitive to the problem of black landfills during his studies. When he travelled to Singapore, he saw a beautiful, clean landscape. Everything was recycled and the inhabitants had a strong environmental awareness. He then visited Finland, which has about the same population as Slovakia, but is much cleaner. After returning to Bratislava, he walked beside the inn, looked at a small dump, and thought that if they knew about it, they would have cleared it immediately. Sending them a mail or a letter would be complicated. He thought of using a smartphone that can also connect GPS coordinates to the photo.

Cleaning is organized by cities and local authorities, as well as by volunteers. The Green Patrol or a non-profit organization Let's Do it, which originated in Estonia and Slovenia in one day, managed to mobilize 10% of the population. People went out and cleaned their towns and villages.

During the Incorporation in Wayra CEE, the company launched its second startup, Venzo, based on TrashOut know-how. Helps businesses document manual activity and issues in the field. For example, a sticker of a billboard has to take the picture, stick to the computer, send a photo to the client and make a report. Venzo automates the entire process. One of the largest clients is the OLO waste collection business in Bratislava. When the driver in the field comes to a locked stand and some car blocks the entrance, he needs proof that he wants to, but he cannot load it. When a customer calls the OLO with a complaint, he gets a detailed report within a few seconds. The company currently has several customers in the Czech Republic and Slovakia and plans to expand to the UK and Germany.
Strengths: quality application processing, solves global problem, application is free
Weaknesses: number of passive disposable users, undefined revenue model
Opportunities: possible worldwide expansion, interest of ministries and government institutions
Threats:

Two startups, for personal reasons, failed to get involved in the incubation program and left Wayra. **Linxy** could not continue for personal and time reasons. Currently, the app can be downloaded on iOS. Makes it easier to get information when reading books and magazines. Just if a user points their iPhone to text and gets instant explanation and word definition. The user's language is English. **Excalibur** won the Deutsche Telekom competition and a support of € 500,000. Therefore, he decided to use Germany's offer. He succeeded in the competition of 443 registered ideas (eTrend, 2017) At a time when the whole world is paralyzed by the tumultuous confidence of a large number of passwords, pisces attacks on credit cards and hacked mailboxes, Excalibur has come up with unique encryption and password-enhancing technology, with advanced CRcOTP technology that has also taken businesses like AVG, Intel or Deutsche Telekom. This technology is trying to build on an existing Google pioneer with its Authenticator service and to move it further by creating a universal Cloud Authentication service. To use Excalibur, a mobile phone is also sufficient to serve as a hardware token. All you have to do is install Excalibur on your phone. Subsequently, the user combines each device (computer, gateway) with a web page where it scans the QR code through Excalibur. Whenever a mobile phone approaches your computer or gateway, the system automatically logs in. If they have resigned, they are automatically logged off. (Šandi, 2017)

By the end of February 2014, new startups could once again submit their application to Wayr. The second group selected a twelve-member jury composed of investors, sales representatives, ICT specialists and representatives of Telefónica. Wayra in April 2014 selected 10 projects out of 128 for its incubation program, of which 3 Slovak, 4 Czech, 2 Polish and one Bulgarian. (Klempová, 2017)

An application **LiveDispatcher** (Bednár, 2017) was created at the end of 2013. It is an application for small and medium-sized enterprises that have employees in the field and want to manage them more efficiently. With a combination of a web interface and a mobile application (iOS and Android), the system creates a calendar, map, and path link system with current locations. It connects to the system via a GPS signal and an Internet connection. The client on the screen sees the schedule of tasks, their current status and the position of field workers. The bonus is a break from bureaucracy because LiveDispatcher will automatically fill out the

necessary reports.

Initially, this should be a platform for logistics and forwarding businesses. In the spring of 2014, LiveDispatcher got into the Wayra CEE Incubator. After several weeks of incubation, he changed his business model and created an efficient **OrderLord** ordering platform for restaurants. The change was based on the fact that more than 20 million orders of food are registered per day from one million different restaurants around the world. The online ordering process is complicated from receiving the order itself through the preparation of the shipment, control over its shipment and the delivery equipment itself. Orderlord helps restaurant operators shorten delivery times, reduce costs and increase customer satisfaction. For clients, besides intuitive ordering, it also means that you can track your shipment and shorten your waiting time. In order to test the OrderLord, he was given the startup of an exclusive McDonald's Austrian partner who could not only try but also improve his system. Currently, the team of OrderLord is in New York, where global expansion should continue. (Mikula, 2017) In September 2014, the potential of founders and developers, as well as the annual growth of the online ordering market by 20%, convinced Neulogy Ventures to invest 200,000 euros in the company and further development.

Strengths: ithe intuitiveness and sophistication of the system, the experienced team

Weaknesses: no significant competitive advantage

Opportunities: growing online shopping, the need for efficient systems

Threats: rising competition - filling the market

Staffino is an application that addresses the problem of dissatisfied customers and creates feedback. They get direct managers of businesses, hotels, restaurants, shops and lots of other businesses. It does not create a social network in which negative or positive information is repeated. Connects the customer directly with the owner or manager. Staffino uses a foursquare database to gain geolocation of individual plants. These are displayed according to the distance from the current user's location. After choosing a particular bar or restaurant, you can criticize them. Initially, negative comments from all users were also suggested in the app. However, this idea was rejected after collecting several feedbacks. The Staffino team realized that the app they work for must do for their customer. And that's not the guest, but the owners and managers of restaurants, bars, shops and hotels. They can respond to complaints or indemnify them by providing a discount or bonus. In particular, the application should be a strong incentive for employees. These will be evaluated and rewarded based on feedback. (Šándor, 2017) The first six months of Staffino is free, then the service has to pay one of the programs, which ranges from 20 to 50 euros per month. (Venture beat, 2017)

Strengths: clear idea, sophisticated product, simplicity of the system

Weaknesses: high price, comprehensiveness system

Opportunities: applicability in other sectors, ideal for the creation of co-creation with customers

Threats: competition will create a complex system

Audiotrip (PL) is a global mobile GPS application that serves as an audio guide to cultural heritage. It combines classic audio guides with the latest mobile technology. The use of AudioTrip registration is necessary. The user then determines which trip he wants to attend. Most of them are charged, but some sample are free.

After selecting a trip, the user can see the photo, the length of the trip, listen to the audio file, and brief information about the author. When he decides to make a trip, he downloads it to his cell phone. At a specific location, you just plug in the headphones, a map with a route appears on the display, and an interpreting tour can begin. When zoomed in to a memorial or exhibit, an audio recording with specific information starts. The biggest advantage of AudioTrip is that it works with GPS navigation. After downloading to your mobile phone, the user does not need internet. Audiotrip offers the possibility to create a custom route, which can be used mainly by cultural centres, cities, hotels, and friends for fun. Users do not have to rely on financial and time-consuming guided tours. For tourists, AudioTrip is an excellent opportunity to promote the region and promote tourism in the region. (Kochanová, 2017)

Strengths: well-defined problem, quality solution, off-line mode

Weaknesses: a small audio tour database

Opportunities: lower travel costs (affordable hotels, air tickets) and the resulting growth of tourism, use for institutions, travel agencies

Threats: -

Lingout (SK) is a localization and translation application for developers. They have a difficult task on the table daily. One of them is the translation of their application into another language. They need to find translators, communicate with them, and manually enter text into code. It employs them and weakens their focus on work in development. Since 2012, there is a localization and translation platform for the application called Lingout. The programme helps track changes, view and comment on translations, all without limitation on the number of projects. For example, when you have texts in your source code, you need to move them to an external text file. Lingout can only identify the texts to be translated and those that appear on the mobile screen. At the same time, it can clean up an existing translation file from texts that are not already in the application. Automated translation, e.g. through Google translator is not at a level to match and makes sense for 100%. (Tomek, 2017) The price for this service is 9 euros a month, with a special starting price.

Strengths: quality complex solution, well-defined problem, professional team, low price

Weaknesses: -

Opportunities: almost no competition

Threats: -

Tabfoundry (CZ) allows businesses to use social networks more efficiently. It's a cloud and web application system that helps Facebook marketers sell more, get fans and empower customers. (Klempová, 2017)

One of the major marketing tools is social networking. "Primary is still holding Facebook with its space for sharing or commenting. The popular Facebook platform is, among other things, bookmarks, some separate pages that users create themselves. Most often there are various marketing actions, welcome videos, contact or order forms. Thanks to the Czech Tabfoundry launch, bookmark creation has been simplified to the most accessible and intuitive level.

Tabfoundry came to the world in May 2012 when he joined the StartupYard accelerator. This provided mentoring, space and interesting contacts. The public version of the page was launched at the beginning of 2015, and has continually improved, edited and simplified the product. The main engine of the platform thinking idea is Ladislav Hrbacek, who worked in a digital advertising agency. He was in daily contact with Facebook bookmarks. He realized he needed to edit these bookmarks according to his ideas. He had the advantage of being able to program, and so he and Peter Messner embarked on a gradual realization of the idea. After joining StartupYard, Michal Kvasnička also joined them.

The basic version is a free platform. The two paid versions are either Premium or Agency. In both, the user has access to premium support from the team. Tabfoundry's logo is shown in both the free and Premium versions. It's just that in the Premium version the logo is not a link and is located at the bottom. The number of Facebook pages whose bookmarks can be managed also differs from the price. In the free version, it is one, in the other two it can be up to ten. The most expensive version, Agency, also offers so-called corporate font types, which means that the type, size, and other details of that brand are automatically adjusted to the business logo standards, if necessary. The Premium Price is $ 9 and $ 39 Agency. The Tabfoundry platform has already been tested by companies such as Volvo, MTV, Nivea or Toshiba. (Tomek, 2017)

Strengths: intuitive sophisticated system

Weaknesses: no strong competitive advantage

Opportunities: growing online market

Threats: a great deal of competition

UpTAXI (CZ) creates an innovative relationship between marketing and taxi services that improves user experience and

creates a new sales channel with personalized ads. "UpTaxi decided to contribute to the upgrading of another problem, which is hurting taxi drivers. Their application will help thousands of them, because it saves them from charges that they would have to pay to the dispatcher, and the UpTaxi application will provide them with the same free items. The client can verify the reliability of individual taxi drivers in this way. Taxis are equipped with iPads that play ads and are coupled with discount coupons that can be exchanged by traders for specific merchants. In addition, taxi drivers can sell tickets for concerts, tickets and other online tickets. Through UpTaxi taxi drivers may also receive credit cards. Running on the "taxi app" wave means trying to distribute a fascinating application for passengers and driver completely free of charge for both parties, and the taxi route becomes more interesting. The vision of the business is to connect more than a hundred thousand taxi drivers in Europe.

Strengths: transparent app, ad revenue stream
Weaknesses: small taxi drivers' database, use only in several cities
Opportunities: reducing the number of passenger cars in large cities
Threats: strong competition - platform UBER, HopinTaxi

Telmedicin (PL) is a platform that delivers a breakthrough in accessing medical consultation by allowing patients to contact an expert anytime and anywhere using a webcam. It is about improving patient access to face-to-face consultation with a doctor or specialist anywhere, anytime. Just by registering on the site and then conducting a videoconference test to verify your connection. With the doctor, the candidate will agree on the date when he or she will be able to take full care of it. This way he is guaranteed to receive medical attention even in the evening and also saves the expense and travel time.

Strengths: predictive solution
Weaknesses: impossibility of physical examination (heart, pressure ...)
Opportunities: a growing number of patients, a full waiting room
Threats: video abuse, competition - Google doctor

SmartSense (CZ, now Geosense) is an asset management information system. It uses maps and sensors, brings geographic data in context and is also linked to the real estate cadastre. The Czech firm has decided to map what cartographers have failed to provide a comprehensive portfolio of services and products in spatial data management.If a person has a problem with the deployment of buildings on their land, the Czech startup knows the solution. GeoSense is one of the fastest-growing young technology companies in the Czech Republic and aims mainly at new innovations. The company was founded by Ladislav Čapek and Jan Zvoník in 2009. According to Delloite Fast 50, it is the fastest growing young technology company in the Czech Republic.

Strengths: transparent system, easy to use for municipality and population, possibility to draw directly to maps
Weaknesses: --
Opportunities: digitization of all information in municipalities
Threats: --

Ingen.io (Bulgaria) reveals hidden and valuable information from unstructured text and focuses on business users. Despite the technological advances today, no service has been able to retrieve information from an unstructured text. Ingen.IO can mimic the neurological processes of the human brain when analyzing such a text. From the context created, the candidate can get names of companies, names of people or products, although they are not directly mentioned but are part of a wider narrative.

Strengths: if successful, a very strong product will emerge
Weaknesses:
Opportunities: usability not only in companies but also in various institutions (police, etc.)
Threats: abuse of the system

Daty (CZ) creates the ultimate B2B information resource for entrepreneurs about their customers and competitors. It uses public databases and innovative data analysis tools. The company invented the product for all entrepreneurs who cannot keep up the competition and perceive any change around. It has created a system that tells the client how they are doing their competitors, what they are preparing, which trademark or website they have registered, and many others.

Strengths: quality product, strong product
Weaknesses: -
Opportunities: usability in each sector
Threats: -

The main objective of the research was to describe the business models of startups incubated in Wayra Academy, identify their strengths and weaknesses as well as the opportunities and threats of the market. Another goal was to make an estimate of their potential. Some of the startups have already succeeded in establishing themselves on the market and others are still in the experiment stage and their success is uncertain. Data were gathered from personal interviews directly from startup founders, conferences, presentations to investors, and online resources.

5. Discussion

The main aim of the research was to identify the factors leading to the success of incubated startups. The result has been to create an overview of the those startups, which were incubated and tried to be successful. We divided the main goal into testing **BigLauncher** precisely identified the problem that older people have when buying phones. They are small letters and numbers, unnecessarily many features and a complicated operating system. All this has been solved by using a simple interface that the user can install and can use immediately. The platform focuses on the basic features of the phone. Big Launcher is simple, inexpensive, high-quality and intuitive. The disadvantage is incompatibility with iOS and Windows Phone, as these operating systems do not allow these interfaces to be accessed. Android uses 800 million users, which represents a sufficiently large market and large growth of this business. After translating into multiple languages, the exponential increase in the number of users is expected in the coming months. The only threat is the creation of a proprietary operating system, which has long been announced by Samsung.

Datamolino is a system for optical detection and processing of invoices that the company wants to simplify accounting, reduce staff costs and eliminate error. In spite of the technology and the confidence that the startup has from its investors, especially in the form of large investments, the company will probably not grow exponentially in this form. The service is too expensive and its weakest place is that invoices leave outside the business and are stored on a cloud-based system. If Datamolino creates a platform that would be implemented directly into the customer system, success is possible. However, the business model that is now being built has no chance to grow and be profitable.

Mapilary a location service that helps businesses streamline processes, delivery of goods, which they ultimately reduce costs. At the same time, he can tell his clients exactly when their goods will be delivered. Similar solutions are bringing other businesses such OrderLord, damejidlo.cz, mrsiesta.cz, jidloted.cz and others. Although the Mapilary focuses on a completely different industry, the service is very similar. It is therefore important to develop so sophisticated and elaborate system, which differs from the competition and benefit. If it succeeds, it can be competitive even abroad and thus succeed in the global market.

One of the main goals of conferences is to search for new business contacts. Nevertheless, the organizers do not get enough effort and ideas, and in addition to standard business exchanges, no one has ever come up with any effective and innovative ideas. Aside from the startup **Networker** and its application, with which the conference participant can view it on your phone list of participating, contact potential clients and send them a card. Bizzabo's largest competitor offers more comprehensive and more sophisticated solutions, has experience with major international conferences and has been awarded $ 1.5 millions of investment. (Bizzabo Secures, 2017) There are more than 20 competing companies in the global industry offering the same product.

Networker has the real potential to become a profitable company, but only on the local CEE market.

Woppa connects two worlds, both business and student. In the nonprofit sector, it would be a fairly successful civic association, but if we evaluate this startup as an enterprise, it does not bring anything new and innovative. He does not seem to have a real chance to create a high-profitable business and to remain in the market for a long time. **Remote** assistant has a vaguely defined target group and does not have a revenue model. However, the application is well-sophisticated and its use would be profitable in a differently set business model. If the startup found the industry and defined its service differently, it could address a number of social or business issues. Under these circumstances, however, it has no hope of survival. **Lionexpo** helps event organizers to provide more sophisticated and effective services to exhibitors as well as visitors. This segment needs to be upgraded, otherwise it will disappear. Markets and exhibitions have great potential thanks to the creation of personal contacts. If a company succeeds in penetrating foreign markets with a comprehensive service, it can become very successful. **TrashOut** is one of the startups that can now be considered successful. Revenue may be obtained from government institutions and ministries of those countries where black landfills are considered a key social issue. However, an enterprise transformed in an incubator, has used its know-how and created **Venzeo**, which is already profitable. Changing the target group created a new product and gave an example to other startups who cannot find the revenue model.

Another example of a change in the business model during the incubation is the **LiveDispatcher**, which was primarily designed to coordinate and efficiently plan roadworks on the ground. After entering the Wayra changed its concept to the ordering system for restaurants called OrderLord. He wants to join the growing wave of online shopping and bring advanced technology to the restaurant. This market is beginning to be quite full in our small market. If the business develops and expands abroad, it faces a huge amount of competition. It is questionable whether it is able to fight and create great added value. Startup **Staffino** connects guests directly to the owner's or manager's gastronomic services to provide direct feedback. According to us, for standard restaurants, this service is retiring and does not provide a comprehensive solution, but only one part of it. Therefore, it does not succeed in the market for this business model. However, it could change its position, go to other sectors, and become a tool for product co-creation, feedback, and ultimately co-creation, especially in sectors where the manufacturer has no personal contact with the customer.

Using the available technologies, **Audiotrip** created a very clear, clean and necessary business model that solved the basic problem of many tourists in a simple way. Because it is also available off-line, it becomes available to every traveler even abroad. So far, it is scarcely expanded and the database consists of only a few trips, but it is only a matter of time when it will grow. Many cognitive routes will be created by people who want to make money and will be motivated to make their routes a good one. Audiotrip could primarily focus on developing its platform and did not have to create trips itself.

One of the companies that have a real chance to succeed globally and become one of the top technology companies is **Lingout**, which provides translations of applications into different languages. They are entered directly into the programming language, thus eliminating a significant concern for companies and can focus on developing their applications.

The development of social networks provides businesses with efficient and free-of-charge marketing, but managing multiple networks at the same time brings a time load to marketing companies. **Tabfoundry** helps streamline the management of all social networks by using one platform, making it easier to set up a strategy for their use. Competition is relatively high in this area. Startup success depends on whether a business can create a strong competitive advantage. **UpTAXI** solves the problem lies in implementation and payment of transport services while helping streamline logistics taxi drivers. There is a growing startup of HopinTaxi and a global UBER scale in Slovakia. Trends of phone orders will grow, and even taxi drivers will want to use it more so they do not have to pay dispatching monthly charges.

Telmedicin brings a breakthrough in access to medical consultation that allows patients to contact a specialist anytime and anywhere using a webcam. This eliminates long waiting times for a doctor. According to us, this service is now suitable for more solvent patients who can contact a non-stop doctor as needed. If a business in the future also includes devices that are easy to use for the patient, physicians can immediately get information about their physical condition. If the development is successful, an enterprise can become competitive in the global market. The question remains whether he will be able to compete with the Google Doctor that is currently on the market. **SmartSense** has created online geographic solutions for municipal self-government both in the Czech Republic and in the private sector. According to analysts, it is one of the most progressive technology companies in the Czech Republic. SmartSense is already successful and its global growth is highly likely. Equally innovative is **Ingen.io** that searches for hidden and valuable information from unstructured text. It can find any information about the subject being tracked and thus reduce its competitive advantage. If product development succeeds, it will be one of the most valued companies not only in Europe, but around the world. **Daty** creates a B2B information resource for business clientele. The company offers detailed monitoring of competition. Information is available from public data, but standard search engines cannot access it. Upon purchase of the service, the user receives a daily report of any movement of the competitor, registration of a new patent or trademark, new website, change of director or owners. He is able to find almost all the information that the client should be interested in.

Business models of startups described and analysed have many common features. They are depicted using the Canvas visualization tool, which divides the business model into nine parts, key partners, key processes, key resources, added value, customer relationships, channels, customer segments, cost structure, and revenue structure (Table 1). Provides a sufficiently precise and concise overview of the business operation. Startups minimize key partners only to those who help them finance or develop products, they are investors and mentors. All key processes of production and product development to marketing and sales trying to do themselves, eliminating the costs. Their key source is high-quality people with average expertise in the area, but with great personal engagement. They help to create a major product that is clearly scalable along with added value. Sales channels are mostly websites and applications, with personal contact being especially important for B2B solutions. Startup most invest in human resources that provide product development and online marketing that directly increases sales. Revenue is initially generated from investments, but some startups are already generating revenue.

6. Conclusion

The main goal of founding a startup is to discover new marketplaces and create high added value products. At the beginning, startups are low-cost projects mostly created by programmers and designers who want to create something unique and earn a lot. However, in more than 90% of cases, they fail. Three of five main problem deal with finance - either incorrect product pricing, poor cost estimates or lack of capital for further development. The second key issue is the lack of market need – result of inadequate product testing on the real market. The fifth biggest problem is the poor team that cannot solve the problems and cannot develop theright MVP or business model. Examined startups (18 startups) can be divided into four groups. The first group includes businesses that will be highly successful in the global market for a long time, such as BigLauncher, TrashOut, Audiotrip, and Daty. They have great growth potential, a high-quality product, an experienced team and a good solution to a well-defined problem. Lionexpo, Venzeo, Lingout, UPTaxi and Smartsense are included in the second group of long-term successful businesses. They are expected to grow steadily, but they will not be extremely high. If

businesses continue to develop their products, they can be profitable in the long run. Undertakings in the third group OrderLord, Mapilary and Staffin is proposed to change the business model, which would use an existing one technology and know-how, but it is focused on a different target group or to solve another problem. The latest group includes Datamolino, Networker, Woppa and Tabfoundry, which will not keep up with the current business model on the market for a long time due to stronger competition or incorrectly set up processes. The two companies Telmedicin and Ingen.io are still developing their product and their potential cannot be estimated.

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OPPORTUNITIES TO ENHANCE ENERGY EFFICIENCY AND EVALUATION OF ENERGY PROJECTS IN INDUSTRIAL ENTERPRISES

Assistant Prof. Valeva K. PhD.[1], Associate Prof. Alexieva-Nikolova V. PhD.[2]
Business Faculty – University of Food Technology -Plovdiv, Bulgaria, tomika_888@yahoo.com [1]
Business Faculty – University of Food Technology -Plovdiv, Bulgaria, , valentina_nikolova@abv.bg [2]

Abstract: *Efficient use of energy means meeting the necessary needs, without compromising the level of comfort and safety, effectively using energy resources that achieve a direct saving of resources and money. Effective use of energy has a direct impact on reducing energy costs in enterprises, thus increasing their competitiveness. The purpose of this report is to investigate the opportunities for energy efficiency improvement and evaluation of energy projects in industrial enterprises. The results show an increase in the production of RES from all types of power plants except HPP. Nevertheless, hydropower retains the largest share in the structure of RES production. At the same time, there is a decrease in the average cost to society of all types of RES, except for biomass. Europe faces a number of energy problems including: increasing dependence on imports, insufficient diversification, high and volatile energy prices, rising global energy demand, security risks affecting producer and transit states, increasing threats climate change, slow progress in the area of energy efficiency, challenges related to the use of an increasing share of renewable energy sources, and need of greater transparency, further integration and interconnection of energy markets.*

Keywords: ENERGY EVALUATION, ENERGY EFFICIENCY, ENERGY PROJECT

1. Introduction

Energy efficiency related to the amount of product that is produced in a given process per unit of energy. It is defined as a sum of actions to optimize/reduce the energy consumed, while maintaining the level of services offered. Efficient use of energy does not mean imposing deprivation or restrictions on the satisfaction of production or personal needs. Efficient use of energy means meeting the necessary needs, without compromising the level of comfort and safety, effectively using energy resources that achieve a direct saving of resources and money. Effective use of energy has a direct impact on reducing energy costs in industrial enterprises, thus increasing their competitiveness [1],[2],[8]. In addition, businesses gain a competitive advantage in terms of that: decreases dependence on expensive and imported fuels; improves quality of life; helps protect the environment by reducing greenhouse gas emissions; creates new jobs [3],[4],[7]. Under the Lisbon Treaty (2015), the five main objectives of the EU's energy policy are:

- ensuring the functioning of the internal energy market and the interconnection of energy networks;
- ensuring the security of energy supply in the Union;
- promoting energy efficiency and energy savings;
- promoting the development of new and renewable forms of energy in order to better align and integrate climate change objectives into the new market structure;
- promoting research, innovation and competitiveness.

The current energy program is guided by the integrated integrated climate and energy policy adopted by the European Council on 24 October 2014, which sets itself the following objectives:

For the period up to 2020 - to reduce greenhouse gas emissions by at least 20% compared to 1990 levels; - increasing the share of energy from renewable sources in energy consumption to 20%; - Increasing energy efficiency by 20%.

By 2030, it is agreed: - to reduce greenhouse gas emissions by at least 40% compared to 1990 levels; - up to 27% of the share of energy from renewable sources in energy consumption; - to increase energy efficiency by 27% to reach a 30% level; - development to achieve at least 15% interconnection in terms of electricity.In practice, energy managers are also faced with the question of which of the possible energy efficiency projects to choose. One of the goals of saving energy is to achieve financial savings. For this reason, the assessment of energy efficiency projects is also done on the basis of financial indicators and not only technically [5],[7],[8]. The main objectives of the financial assessment of energy efficiency projects are: to determine whether the project is profitable or not; to make it possible to compare and prioritize different projects; to provide information to a bank or other funding institution as to whether the financial performance of the project meets the funding requirements of such projects.

The purpose of this report is to investigate the opportunities for energy efficiency improvement and evaluation of energy projects in Bulgarian industrial enterprises.

2. Exploration

The current energy program is guided by the integrated climate and energy policy adopted by the European Council on 24 October 2014, which sets itself the following objectives:

- For the period up to 2020:

- to reduce greenhouse gas emissions by at least 20% compared to 1990 levels;
- increasing the share of energy from renewable sources in energy consumption to 20%;
- increasing energy efficiency by 20%.

- For the period up to 2030:

- to reduce greenhouse gas emissions by at least 40% compared to 1990 levels;
- up to 27% of the share of energy from renewable sources in energy consumption;
- to increase energy efficiency by 27% to reach a 30% level;
- development to achieve at least 15% interconnection in terms of electricity.

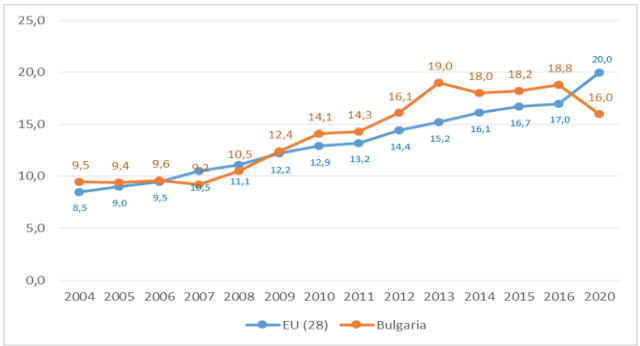


Fig. 1. *Share of renewable energy in gross final energy consumption.*

According to latest Eurostat and NSI data, progress has been made with regard to the three objectives set. Regarding renewable energy, the data over a 12-year period (2004-2016) shows that the share of renewable energy in final energy consumption in both EU-

28 and our country has doubled (See Fig. 1). Total for the Union, from 8.5% in 2004 to 17% of gross final energy consumption. For the same period, our country also recorded almost double growth of 9.3% (9.5 in 2004 - to 18.8 in 2016). The dynamics of the development of the share of RES in gross final energy consumption is presented in Fig. 1. The results show that the target of a 20% share of renewable energy by 2020 for the Union as a whole is fully achievable.

Renewable energy sources (RES) are inexhaustible natural sources of energy. These include solar and wind energy, marine and hydroelectric energy, geothermal energy and bioenergy. In Fig. 2 shows the main types of energy from renewable sources, the respective technologies and their usual applications. In general, the sectors of application of RES are electricity, heating and cooling, and the transport sector.

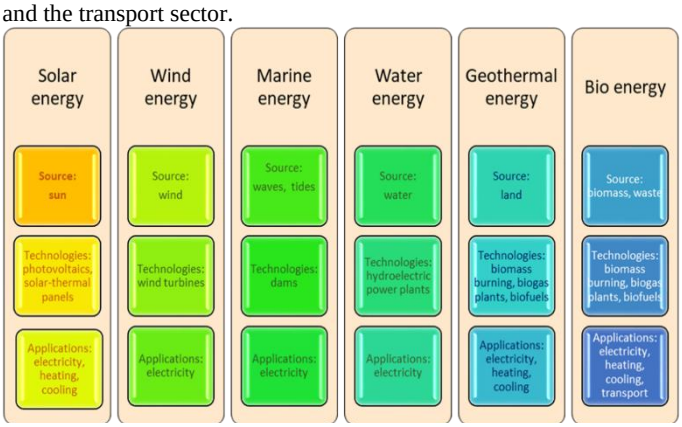


***Fig.2** Renewable energy sources*

According to latest Eurostat and NSI data [1],[3],[4] the distribution of final consumption of renewable energy in the EU and Bulgaria by sector by 2017 is presented below. The largest share of RES consumption in the Union has heating and cooling. (Fig. 3), it accounts for only 30% of total renewable energy consumption in our country (Fig. 4). The share of electricity used in the Union is 42%, while in our country it is 63%. Approximately the same application of bioenergy in the transport sector. 8% in total in the Union and 7% in Bulgaria.

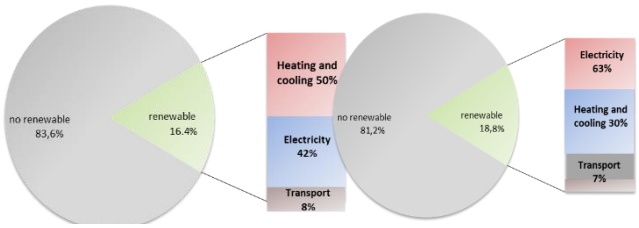


***Fig. 3.** RES in EU-28, 2017*

***Fig. 4.** RES in Bulgaria by sectors, 2017*

In graphical form is presented a comparison of key indicators of the leading production technologies for renewable energy. The structure of the annual gross production of energy from RES and the weighted average expenditure for the Bulgarian society by type of renewable source for 2014 and 2017 are presented on the Fig. 5 & Fig.6.

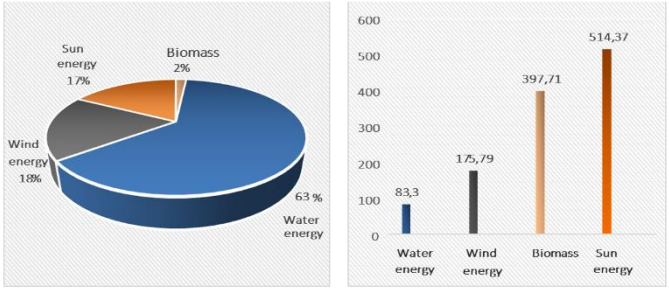


***Fig. 5.** Share of Renewable Energy Production Technologies- 2014 in % and average cost to society, BGN / MWh.*

The data show an increase in the production of RES from all types of power plants except hydroelectric power plants (HPP). Nevertheless, hydropower retains the largest share in the structure of RES production. At the same time, there is a decrease in the average cost to society of all types of RES, except for biomass.

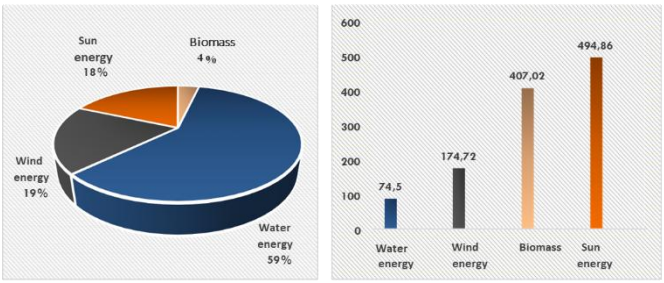


***Fig. 6.** Share of Renewable Energy Production Technologies -2017 in % and average cost to society, BGN / MWh.*

It is clear from the graphical data that hydroelectric power plants represent the largest share of electricity generation from renewable energy sources, while the weighted average water price is the lowest in relation to other electricity producers.

Advantages of hydropower plants are as follow: HPPs are the world's oldest, most sustainable and reliable power producer; do not emit greenhouse gases and do not produce toxic waste; the cheapest producer of renewable energy; HPPs are the most efficient of all other renewable technologies, reaching their maximum power within 30 minutes; the main regulating and balancing capacities in the power system in Bulgaria are the large hydropower plants;regulation of natural river runoff for certain water and flood protection; ensure good ecological status of the water basins through the treatment of rivers; the water basins are used for irrigation and water supply; have low operating and maintenance costs; their life cycle is very long.

- water energy can be used under variable demand conditions.

Renewable energy remains a key element of the EU's energy policy. The conservation and use of natural energy sources is a fundamental problem set out in the Union's strategies. The role the EU places on RES is expressed in:

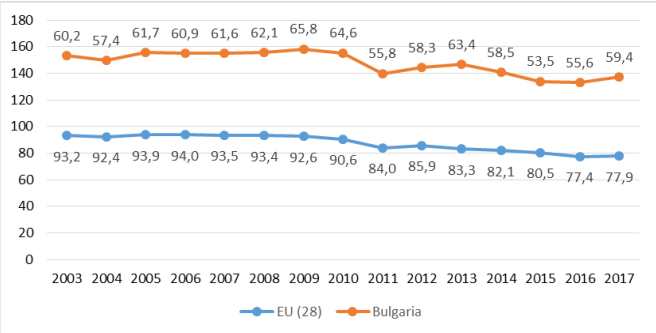
- ensure energy security in the Union. As an inexhaustible local energy source, they contribute to a reduction in the import of fossil fuels, which in 2015 is approximately 16 billion euros, and in 2030 is expected to reach 58 billion euros.
- easy integration into the energy market. Despite the initial high investment for renewable energy installations, there is no long-term cost of fuel and waste storage, which leads to a reduction in the cost of energy production;
- contribute to increasing energy efficiency by reducing energy costs
- reduce greenhouse gas emissions and air pollution. In 2015, as a result of RES, greenhouse gas emissions decreased by 436 million tons. compared to 2005 (comparable to Italy's emissions) of 436 million tonnes of CO^2 equivalent compared to the 2005 baseline (Source: EEA)
- renewable energy leads to economic growth and creates jobs for European citizens.
- developing new industry, technology and know-how;
- they save money due to the lack of the need to buy CO^2 emissions.

As regards greenhouse gas emissions, progress has also been made. Total greenhouse gas emissions in the Union declined by almost 16.42% over the period 2003-2017. Under this indicator, Bulgaria's data show a very small contribution, falling below 1% or 0.87% (Fig. 7).

According to the EU Energy Commission report from 2017, progress has also been reported in the field of energy efficiency. The term "energy efficiency" is defined as - the ratio between the output quantity, service, commodity or energy output and the energy input, the less the energy input to produce the same output, the higher the energy efficiency. The amount of energy needed to

produce a unit of economic output is a measure of energy intensity. Data analysis shows that although there are indications for a decrease in this indicator in our country, the energy intensity still remains at levels higher than the EU average. This is related both to the specific sectoral structure of the economy and the high share of energy intensive industries, as well as to the low energy efficiency in some sectors.

Bulgarian industrial enterprises are among the consumers with the highest share of energy consumption, followed by households and services. Under the Energy Efficiency Act, which reflects the commitments under EU Directive 2012/27/27/EU, all industrial plants with annual energy consumption exceeding 3000 MWh and



public buildings with an area of over 250 m² are obliged to carry out energy audits; the validity of the energy audit of industrial enterprises is 5 years.

Fig.7.*Greenhouse gas (GHG) emissions dynamics (2003-2017)*

The Energy Efficiency Survey of Industrial Enterprises aims at identifying the specific opportunities for reducing energy consumption and recommending measures to increase energy efficiency [4],[5],[6]. This will lead to:

- reduction of costs of energy consumption;
- lower cost of production;
- improves the competitiveness of the enterprise or industrial system;
- certification of the enterprise;
- improving his / her image and
- the opportunity to access public procurement and auctions.

This engages industrial enterprises to: manage energy efficiency by:

1. Prepare analyzes of the total and specific consumption of fuels and energy at least once a year;
2. Prepare programs for optimizing the efficiency of energy consumption;
3. Implement annually the energy efficiency plans and programs that are in line with the reports issued by the audits carried out;
4. Implement the energy saving measures provided in the plans and programs;
5. The owner of each industrial system shall designate at least one employee whose responsibilities include the responsibilities related to the management of energy efficiency.

The implementation of these obligations requires the development of plans and programs for their implementation, increasing energy efficiency, saving energy and correspondingly reducing the cost of its consumption.

2.1. Opportunities to increase energy efficiency in the industrial enterprises

2.1.1. Implementation of an energy management system.

It applies a system approach at all stages - from purchasing and conversion to energy use in an enterprise. In 2009 a European standard EN 16001: 2009 was introduced and in 2011 an international standard for such systems BDS EN ISO 50001: 2011 "Energy Management Systems, which set the minimum requirements for the implementation of CEM. The CEM standard is flexible enough and can be implemented even in small companies that do not have certified management systems but have the will and ambition to apply a systematic approach to energy management.

Globally, complex platforms are being developed to monitor, analyze, identify measures to increase energy efficiency in enterprises called energy management systems. These systems encompass energy flows in an industrial system by offering generic or specialized solutions, monitoring key indicators and may have additional functions depending on system goals and sectoral specifics [3],[5],[7],[8].

2.1.2. Implementation of technical solutions that can be applied to increase energy efficiency in industrial enterprises, regardless of their size.

They save energy and reduce the cost of consumption:

➢ *Reducing the consumption of electricity by optimizing the operation of an electricity supply system of the enterprise by*:

• choosing the optimal supply voltage of the individual technological stages and the production plant as a whole;
• increasing the quality of electricity;
• compensation of reactive loads in the system;
• maintaining the optimal number of working power transformers for the particular application.

➢ *Choosing the most efficient tariff for the payment of electricity*. Opportunities to reduce electricity costs are:

• by managing the load schedule. Industrial plants, due to the large amounts of electricity they consume, measure their electricity consumption mostly with three-tariff electricity meters. In order to reduce the value the company pays for electricity, it is necessary to precisely calculate the peak, day and night electricity consumption for the month. The ultimate goal is to manage the freight schedule so that the most energy-intensive activities concentrate in times of cheapest electricity.
• achieving compliance between regulated and actually used power. The goal is, without limiting energy consumption, to save the allowances it pays each month, depending on the deviation between the prescription and the power factor achieved.

➢ *Construction of electrical consumption control systems.*

The construction of systems for remote reading and control of electrometers is a basic tool for developing and implementing programs for optimizing the consumption of electric energy. They automate the process of reading current consumption, provide information on the quality of electrical power and reliability in its delivery, analyze and monitor voltage and current. Thus, all collected, processed and archived information is provided to users in various graphical and tabular reports.

2.1.3. Investments in new techniques and technologies to reduce energy consumption and save energy costs.

Table 1: *Terms of action of commonly used energy saving measures/ projects in industrial enterprises.*

The choice of an investment solution depends most often on the technical and economic life of the projects in which investments are invested. The technical life is equal to the length of time that the equipment for a given measure can be exploited before scrapping. There is presented the technical life of projects that are most often applied in industrial enterprises in the Table 1.

2.2. Energy projects evaluation in the industrial enterprises

In practice, energy managers are also faced with the question of which of the possible energy efficiency projects to choose. One of the goals of saving energy is to achieve financial savings. For this reason, the assessment of energy efficiency projects is also done on the basis of financial indicators and not only technically. The main objectives of the financial assessment of energy efficiency projects are: to determine whether the project is profitable or not; to make it possible to compare and prioritize different projects; to provide information to a bank or other funding institution as to whether the financial performance of the project meets the funding requirements of such projects.

- **Net annual savings (B)**

In order to calculate the financial indicators necessary for the economic justification of the projects, the following data should be available: I_0 - investment costs related to the project; S - net annual savings in natural terms; E - the prices of the energy sources for the project period; n - the technical / economic life of the project / project; nr rate and b - inflation rate (See 1.1).

Investment costs (I_0) associated with the project are all costs that need to be incurred for: designing; capital costs - related to the purchase, delivery, installation and commissioning of the equipment.

Annual savings (S) are the net savings for each year as a result of the capital and other costs incurred in BGN. They are usually the result of lower fuel and electricity consumption, but they can also come from reduced operating costs.

$$B = \sum_{i=0}^{n}(S_i E_i - \Delta O\&M) \quad (1.1)$$

Where:

B - net annual savings, BGN / year;

S - annual energy savings, kWh / year;

E - energy price, BGN / kWh;

O & M - changes in operating and maintenance costs (+ or -) (spare materials, maintenance work, etc.), BGN / year.

The economic life is the period for which the measure or the project brings profit as set out in the investment proposal. Economic life needs to be used for economic justification. A set of financial indicators is used for this purpose:

- **Payout Time (PB) -** the best known and simple way to evaluate an investment is through the payback period. With equal savings over the years of the project, it is easily calculated using the formula:

$$P = \frac{I_o}{B} \quad (1.2)$$

Where:

I0 - the costs associated with the project;

In - net annual savings;

An advantage is the easy calculation, and a disadvantage - its relative inaccuracy, as it does not take into account the cash flows after the return period and does not take into account the value of money over time.

- **Net Present Value (NPV) –** because of inflation with the same amount of money today, it can be bought more than one or two years.

Respectively, savings that will be generated in a few years have a lower current value. Normally, projects start with an initial investment, which is done in the so-called "Zero year of the project"[6],[7],[8]. The project runs (generates savings but may also have additional operating costs) from the first to the nth year of economic life. The purpose of the NPV e show how much will remain after the discounted net cash flow for the duration of the project minus the initial investment made in the "zero year". The project is profitable if NPV> 0.

Components	Duration of the measures [year]
Insulation: building envelope; facade insulation	25
Glazing: glazing with good insulation properties	30
Combustion heaters with an efficiency exceeding 30 kW	25
Waste heat recovery systems: installation of heat recovery and circulation systems (Services)	20
Energy efficient lighting and starter systems	12
Combined Heat and Power Production	8
Waste heat recovery (Industry)	15
Energy-efficient compressed air systems: using new energy-efficient compressors or increasing the efficiency of existing	15
Energy efficient electric motors and smooth speed drives	10
Energy Efficient Pumping Systems in Industrial Processes	15
Energy management and monitoring (after a period, the measure must be reassessed)	2

Typically, in energy efficiency projects, net economies are the same in their economic life years, B1 = B2 = B3 = ... = Bn. In this case, the net present value is calculated using the following formula:

$$\mathbf{NPV} = \mathbf{B}\frac{\mathbf{1-(1+r)^{-n}}}{\mathbf{r}} - \mathbf{I_0} \quad (1.3)$$

- **Net Present Value (NPVQ) -** the Net Present Value (NPVQ) is the ratio between the net present value and the total amount of the investment :

$$\mathrm{NPVQ} = \frac{\mathrm{NPV}}{\mathrm{I_0}} \quad (1.4)$$

The higher NPVQ net present value indicates a more cost-effective project. NPVQ can be used for internal company ranking of projects by priority.

- **Return Period (RO) -**the payback period is the time it takes to return the investment, taking into account the real interest rate. This means the time required to fulfill the condition NPV = 0.

$$\mathbf{NPV} = \mathbf{B}\frac{\mathbf{1-(1+r)^{-n}}}{\mathbf{r}} - \mathbf{I_0} = 0 \quad (1.5)$$

The solution of this equation can be done either by iterations or by calculating the real interest rate (r) and the annuity coefficient (f) and using an annuity table. The annuity coefficient is calculated using the following formula:

$$\mathbf{f} = \frac{\mathbf{B}}{\mathbf{I_0}} = \frac{\mathbf{r}}{\mathbf{1-(1+r)^{-n}}} \quad (1.6)$$

- **Internal Rate of Return (IRR) -** the IRR is the discount rate at which NPV = 0, or otherwise the IRR is the discount rate at which the discounted net proceeds of the project are equal to the initial investment.

The IRR is determined by iterations based on a change in the discount rate. It can also be determined graphically or by using an annuity coefficients. Projects with a higher IRR are better. For

example, if a loan is taken at 12% interest, an IRR of 16% would allow the loan to be covered and profitable

In addition to the listed financial indicators, there are a number of others. However, it is essential for everyone to have their calculation data credible. The other crucial moment is what is expected from the project - whether it's a quick return or a big savings figure. In the first case, the measures with the highest IRR should be selected, and the latter with the highest NPV measures.

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ФОРМИРОВАНИЕ ПОЛИТИКИ ЭКОНОМИЧЕСКОЙ БЕЗОПАСНОСТИ ГОСУДАРСТВА В УСЛОВИЯХ ГЛОБАЛИЗАЦИИ

GOVERNMENT ECONOMIC SECURITY POLICY FORMATION IN CONDITIONS OF GLOBALIZATION

Postgraduate Ukraintsev V

Faculty of Economics and Law, Odessa National Mechnikov's University, Odessa. Ukraine.

vladukrconvers@gmail.com

Abstract: *The article describes the definition approaches, principles and other countries experience in the economic security sector.*

KEYWORDS: ECONOMIC SECURITY, GLOBALIZATION, SECURITY POLICY, NATIONAL SECURITY.

1. Введение

Развитие и становление основ рыночной системы в Украине изменило среду их взаимодействия с государственными институтами, что привело к изменениям социально-экономических факторов, которые частично утратили свою функциональность или были заменены другими факторами. В таких условиях возникает необходимость совершенствования системы управления предприятиями путем усиления уровня безопасности их деятельности.

2. Предпосылки и средства для решения проблемы

В Украине относительно недавно начали изучать вопросы категории экономической безопасности и ее компонентов, что связано с недавним формированием государственности и формированием экономических интересов страны.

Безопасность – состояние, когда защищены жизненно важные интересы личности, общества, государства от внутренних и внешних угроз, либо способность предмета, явления или процесса сохранятся при разрушающих воздействиях.

Исходя из этого определения, безопасность является основой обеспечения базовых ценностей. Именно поэтому можно рассматривать безопасность как главное условие для существования государства, общества и индивида.

Необходимость обеспечения экономической безопасности обусловлена процессами, которые происходят в национальной экономике, глобальной экономике и в обществе в целом. Противоречие интеграционных тенденций становится особенно значимым при рассмотрении проблемы экономической безопасности страны как основы обеспечения ее суверенности, конкурентоспособности и возможности внедрения страны в систему мировой экономики.

Определение безопасности указано в Законе Украины «Про основы национальной безопасности Украины», где указано, что национальная безопасность – это защищенность жизненно важных интересов человека, гражданина, общества и государства, с помощью которой обеспечивается устойчивое развитие общества, своевременное выявление, упреждение и нейтрализация реальных и потенциальных угроз национальным интересам. [1]

Нужно отметить, что большая часть структурных элементов национальной безопасности имеет экономическое основание, из чего следует, что ключевым элементов национальной безопасности является экономическая безопасность.

3. Решение рассматриваемой проблемы

Все составляющие национальной безопасности взаимосвязаны и не могут существовать друг без друга.

Демографическая безопасность определенно зависит от уровня реальных доходов, для обеспечения военной безопасности необходимо наличие экономического и научно-технического развития. Так же, для обеспечения экономической безопасности необходим достаточный уровень трудовых ресурсов, которые напрямую зависят от демографической безопасности. Экономическая безопасность является материальной основой для обеспечения всех видов национальной безопасности.

Баланс экономических интересов, которые дают возможность субъекту сберечь его состояние в определенных условиях раскрывается через категорию экономической безопасности государства.

Определение баланса интересов многоуровневой системы позволит решить проблемы экономической безопасности.

В глобальном смысле экономическая безопасность государства – это характеристика, суть которой заключается в нормальном функционировании экономической системы в целом, возможности нормальной работы внутренней экономической системы и возможности внедрения в мировую экономическую систему.

Была разработана концепция экономической безопасности Украины, в которой экономическая безопасность определяется как возможность национальной экономики обеспечить свое независимое развитие и стабильность институтов общества, а также оборонный потенциал страны в случае неблагоприятных условий развития событий и возможности страны защищать национальные интересы от внутренних и внешних угроз.

В концепции разработанной в 1998 году определили основные угрозы национальной безопасности Украины, рассмотрели вопросы безопасности реального и финансового секторов и приведены интегральные показатели экономической безопасности. [2]

Основными элементами экономической безопасности являются: субъекты, объекты, риски и угрозы. Субъекты могут влиять, контролировать и противодействовать рискам и угрозам. Именно эти элементы в своей совокупности дают возможность обеспечить устойчивое экономическое развитие государства. Основные элементы экономической безопасности представлены на Рис.1.

Рис. 1. Основные элементы экономической безопасности

Экономическую безопасность определяют как состояние и тенденцию развития защищенности жизненно необходимых интересов общества от внутренних и внешних угроз, а так же результат социальной деятельности по обеспечению безопасности. Так же трактуют экономическую безопасность, как совокупность условий и факторов, которые обеспечивают независимость национальной экономики, ее стабильность и стойкость, возможность к постоянному самосовершенствованию. [3]

Все определения экономической безопасности рассматривают отдельные части этого многофункционального и многоуровневого явления.

Поскольку экономика является необходимой стороной деятельности общества, государства и личности, то базисом национальной безопасности будет экономическая безопасность. Экономическая безопасность формирует условия для обеспечения превентивных мер и мер обеспечения защитно-оборонного комплекса и так же является основой развития производства и рыночных отношений, обмена товарами и услугами. Когда речь идет о внешних отношениях, главным фактором является военная безопасность, для внутренних – социальная, для внешнего окружения – экологическая безопасность. Определяющим базисом всех составляющих национальной безопасности является социально-экономический механизм, от которого зависит уровень благополучия населения. Структура национальной безопасности изображена на Рис.2.

Исходя из этого, экономическую безопасность можно рассматривать как совокупность взаимосвязанных систем безопасности, которые отображают функционирование отдельных блоков экономической системы государства. Финансовая безопасность становится основным экономическим гарантом стабильности, обеспечивая необходимыми ресурсами производственную сферу.

Рис.2. Структура национальной безопасности

Экономическая безопасность государства не может развиваться без учета инвестиционного фактора, ведь именно он дает возможность приобретать новые формы, виды и способы функционирования путем финансирования тех областей экономики, которые являются наиболее привлекательными в глобальном смысле. Таким образом, обеспечивая инвестиционную безопасность необходимо создавать наиболее благоприятные законодательные, финансовые, социальные и др. условия со стороны государства для улучшения инвестиционной привлекательности государства.

Особое место в обеспечении национальной безопасности занимает внешнеэкономическая сторона, учитывая увеличивающийся уровень зависимости хозяйственного комплекса страны он внешней среды. [4]

Зависимость национальной безопасности от внешних факторов сохраняется при любых обстоятельствах, однако уровень зависимости и характер может быть разным. Сохранение необходимого баланса между этой зависимостью экономики и являет собой основную проблему экономической безопасности государства.

4. Результаты и дискуссия

Необходимо признать, что на сегодняшний день нету единого понимания сути определения «экономической безопасности» как в Украине, так и за рубежом. Среди украинских исследований можно выделить более десятка различных определений. Причиной разногласия можно назвать недостаточную разработанность теории экономической безопасности, методологии ее изучения и обеспечения.

Объяснение сущностных особенностей и конкретных характеристик экономической безопасности дает возможность выделить следующие принципе обеспечения национальной безопасности:

- Законность, определение баланса интересов общества и государства;
- Взаимная ответственность общества и государства для обеспечения безопасности;
- Взаимосвязь национальной и международной безопасности

Анализ основных подходов к определению экономической безопасности дает возможность сделать вывод о необходимости дальнейших теоретических разработках в данной сфере.

Проблема становится более актуальной, когда обнаруживается, что нету конкретного законодательного определения экономической безопасности, в связи с чем рождается неопределенность в действиях управленческого аппарата государства и приводит к проблемам формирования программ и систем развития экономической безопасности в стране и ее регионах.

Глобализация проявляется в формировании единого экономического пространства путем интеграции национальных экономик, созданием новой системы распределения труда и все больше уделяется внимание защите национальных экономических интересов, которую можно обеспечить только рациональными средствами.

Можно определить следующие принципы исследования экономической безопасности:

- постоянность (Принцип постоянности предполагает, что экономическая безопасность анализируется постоянно на основе соответствующих периодических выводов);

- комплексность (анализ экономической безопасности рассматривает все виды и формы производственных отношений);

- системность (принцип предполагает подчинение решений локальных заданий решениям проблем более обширного уровня для всей системы). [5]

Реализация интересов и создание возможностей для выхода на новый уровень развития возможно только путем обеспечения безопасности, а именно создания и сбережения субъектом условий его существования.

Особенно сложно спрогнозировать будущие пути решения основных проблем, которые стоят перед обществом, в ходе трансформации экономики страны, когда еще не определен окончательный выбор наиболее благоприятной модели развития экономики. До сих пор в Украине не произошло перелома в проведении радикальных реформ. Большая часть промышленных предприятий страны работают убыточно или прекратили свое существование не имея оборотных средств и капиталовложений. На рынке труда увеличивается уровень безработицы и параллельно с этим растет уровень задолженности зар. платы со стороны государства.

Для внедрения Украины в процессы глобальной экономики необходимо определить долгосрочную модель рыночной экономики, которая учитывает её специфику. Такая модель должна адаптироваться к уже сформированным в развитых странах тенденциям и механизмам регулирования экономического развития. Определенные формы реализации модели будут регулярно изменятся, при том, что основная структура и ориентация модели будет оставаться прежней.

Украина застряла на старте реформ, так и не определив четкой модели рыночной экономики. Необходимо сосредоточится на подготовке наиболее подходящей национальной программы экономического развития и стабилизации в целях обеспечения экономической безопасности и устойчивого развития.

В условиях процессов глобализации важными элементами украинской программы развития рыночной экономики должны стать:

- развитие экономической активности отдельных индивидов, ориентированных на заработок максимальной прибыли в полезных для общества сферах деятельности;
- обеспечение максимально эффективного распределения ресурсов с параллельным обеспечением страховки от влияния на процесс сторонних интересов;
- распространение в обществе идеи необходимости в наведения порядка в сферах хозяйствования для достижения баланса общих и индивидуальных интересов
- обеспечение наиболее благоприятных условий для определения каждым индивидом его полезности и общественной активности;
- обеспечение интеграции государственных и индивидуальных интересов через социальные и экономические инструменты.

В основе разработки новой концепции национальной безопасности Украины должен лежать геоэкономический подход. Оставаясь в рамках поставщика сырья и полуфабрикатов национальная экономика с каждым годом все больше изматывается, отдавая свое национальное богатство через внешнюю торговлю.

В основе развития любого государства лежит реализация национальных, коллективных и собственных интересов, поэтому проблема обеспечения экономической безопасности касается всей социально-экономической системы. Существует определенная связь между интересами государства, регионами, хозяйствующими субъектами и индивидами, что должно учитываться при разработке и проведении государственной политики с целью согласования этих интересов для сохранения целостности государства и обеспечения необходимого уровня экономического развития.

Заключение

Анализ путей решения проблем экономической безопасности в Европе и США показывает, что наиболее развитые страны выстраивают стратегию экономической безопасности на основе получения экономического преимущества путем влияния на другие страны, где используются политические, экономические и военные

рычаги воздействия. Экономическая безопасность в странах Европы обеспечивалась путем радикальных реформ, тесных интеграций в мировую и Европейскую системы безопасности и присоединение к экономическим союзам. [6]

5. Выводы исследования

Текущий этап развития экономической безопасности характеризуется усилением процессов глобализации, высоким уровнем нестабильности влияния отдельных факторов, эффективным методом обеспечения безопасности при которых будет адаптация к постоянно изменяющейся внешней среде.

Для Украины, как страны находящейся в зоне системного кризиса, наиболее оптимальная модель обеспечения экономической безопасности будет базироваться на стабильности в сферах хозяйствования, в которых возможно получить максимальную социально-экономичную эффективность, что позволит создать благоприятные условия для будущих инновационных проектов.

Опыт решения проблем экономической безопасности в развитых странах указывает на необходимость совершенствования обеспечения экономической безопасности во внешнеэкономической сфере страны. При формировании внешней и внутренней политики государства необходимо учитывать приоритетность обеспечения национальных экономических интересов и использование позитивных признаков глобализации.

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САМООРГАНИЗАЦИЯ КАК СОВРЕМЕННЫЙ ЭТАП УПРАВЛЕНИЯ

SELF-ORGANIZATION AS CONTEMPORARY STAGE OF MANAGEMENT

A.S. Krygyn, D.S. Krygyn - PhD students of Law Faculty of Odessa National Mechnikov's University, Odessa. Ukraine.
Atn2@meta.uaxc

Abstract: *The main issues are considered in this topic:. Analize of new methodology self-organization as contemporary stage of management*
Keywords: MODERN MANAGEMENT, SELF-ORGANIZATION, MODELLING, HARMONIOUS DEVELOPMENT MACROECONOMIC PROCESSES

1. Введение

Процесс экономического развития современного общества, геополитическая ситуация в мире в целом отличаются сегодня от прошлых времен прежде всего масштабностью действия. Экстенсивное наращивание территорий и ресурсов для освоения, и отступления в случае неудач, исчерпано.

Проблемы системного качества управления сегодня остаются едва ли не самым важным направлением, где скрещиваются интересы больших групп людей. Качество сегодня востребовано как главный императив жизни и движитель общественного развития, что подтвердил Конгресс, проведенный Европейской организацией качества

Самоорганизация в менеджменте — это одновременно и новая наука, и новая парадигма познания, и новое мировоззрение целостности, управления и самоуправлении. В центре ее внимания: процессы самоорганизации; фазовые смены состояний сложных систем; инварианты и вариации и другие закономерности становления новых качеств..

Очевидно, что все объекты живой природы обладают свойствами самоорганизации и самогармонизации.

2. Предпосылки и средства для решения проблемы

Эволюция системы управления предполагает исследование, проектирование, диагностика состояний и прогноз развития сложных систем на основе инвариантов самоорганизации — обобщённых золотых сечений является уникальным методом, не сравнимым ни с каким другим. При проведении такого исследования необходим строгий контроль в сборе статистического материала. Аспект «интегральный измеритель фазовых состояний систем — узловая линия меры» также представляет собой своего рода обобщенный «методологический компаратор» поскольку применим при проектировании и анализе систем различного происхождения, как экономической, так и социальной природы

.Несовершенство современной системы управления доказывается высоким уровнем тенизации экономики как традиционной, так и виртуальной - виртуальная составляющая системы также находится в условиях риска тенизации. , например, украинский рынок интернет-торговли находится в стадии активного развития. Отсутствие алгоритма проектирования виртуального рынка как самоорганизующейся системы и несовершенство законодательного окружения также способствует тенизации деятельности в виртуальном экономическом пространстве.

3. Решение рассматриваемой проблемы

Диагностика уровня самоорганизации предполагает энтропийное тестирование систем и расчёт в качестве интегрального показателя относительнойц информационной энтропии. Энтропия зависит от температуры, давления и распределения составляющих систему структурных включений. При постоянстве первых двух, будучи исчисленными в относительной форме, структурные составляющие системы предстают в виде удельных весов, частот или вероятностей. Соответственно, энтропия становится выразителем количества информации, связанной в распределении компонентов системы. Нормированная на единицу, т.е. будучи отнесена к своему максимальному значению, она в данном случае принимает вид:

$$\overline{H} = -\frac{1}{\log n}\sum_{i=1}^{n} p_i \log p_i \ ,$$

где n – число компонентов системы. Будучи мерой хаоса, структурного разнообразия, максимум которого достигается при $\overline{H}$ = 1 – в состоянии равновесия системы (т.е. при равенстве весов p_i ее структурных компонентов), она дополнительна к мере организации, порядка, единообразия R и удовлетворяет вместе с нею закону сохранения:

$$\overline{H} + R = 1.$$

По теореме Пригожина, за пределами равновесия системы энтропия способна достигать минимума производства (приращения), а ее антипод R – максимума: $\frac{d}{dt}(\frac{1}{\overline{H}}\frac{d\overline{H}}{dt}) = 0$ и соответственно $\frac{d}{dt}(\frac{1}{R}\frac{dR}{dt}) = 0$. Согласно условию кратности относительных мер, $\frac{1}{R}\frac{dR}{dt} = k\frac{1}{\overline{H}}\frac{d\overline{H}}{dt}$, т.е. $R = \overline{H}^{\,k}$, что в сочетании с законом сохранения дает генератор узлов меры $\overline{H}$: $\overline{H}^{\,k} + \overline{H} - 1 = 0$. Это то же уравнение, что и выше, но уже для интегральной меры $\overline{H}$, как средней по статистическому ансамблю вероятностей, способной выражать и уровень внутриструктурного разнообразия, и «градус» внутрисистемного хаоса. Согласно же принципу Циглера, за пределами равновесия системы производство энтропии в ней максимизируется. Аттракторами и репеллерами неравновесных состояний системы являются узлы антиузлы – характеристики состояний, обретаемых любой из систем безотносительно к их масштабу и конкретной реальной специфике в процессе самоорганизации [3].

4. *Результаты и дискуссия*

.Интегральной характеристикой сложноорганизованной системы может служить коллективная переменная, играющая роль параметра порядка. Таковой может быть любая из известных видов средних; информационная энергия Ониценку $E = p_1^2 + p_2^2 + \cdots + p_n^2$; мера хаоса (разнообразия), в качестве которой выступает относительная энтропия $\hat{H}$, и ее антипод избыточность R (мера организации, структурного единообразия), удовлетворяющие закону сохранения: $\hat{H}$ + R =1, где

$$\hat{H} = -\frac{1}{\log n}\sum_{i=1}^{n} p_i \log p_i$$ и

$$R = \frac{1}{\log n}\sum_{i=1}^{n} p_i \log(np_i),$$ n – число структурных компонентов системы (“частей” целого, страт, групп, субъединиц).

Информационная энтропия, исчисляемая на ограниченном разнообразии тех или иных структур индифферентна и инвариантна по отношению к собственно физическим показателям температуры, давления и других и применима там, где они, как уже было сказано, константны. Но, вместе с тем, все научные положения и принципы, выведенные для термодинамической энтропии, истинны и в данном случае. Это касается, например, и принципа Пригожина: за пределами равновесия производство энтропии достигает минимума [3].

Производство (приращение) энтропии H есть ее производная по времени: dH/dt. Взвешивая H, т.е. относя к ее максимуму, $\hat{H}$ = H/log n, и соотнося $\hat{H}$ с ее текущим значением, находим: принцип Пригожина гарантирует максимум производства организации:

$$\frac{d}{dt}\left(\frac{1}{\hat{H}}\frac{d\hat{H}}{dt}\right) = 0, \quad \text{или} \quad \frac{d^2\hat{H}}{dt^2} \geq 0, \quad \frac{d^2R}{dt^2} \leq 0.$$ Из кратности мер $\left(\frac{1}{R}\frac{dR}{dt} = k\frac{1}{\hat{H}}\frac{d\hat{H}}{dt}\right)$ производства энтропии и производства организации следует: $\hat{H}^k + \hat{H} - 1 = 0.$ Это гарантирует теорема Лебега: если на одном и том же множестве заданы две меры, то одна из них всегда кратна другой [3, с.155]. Таков же и основной принцип измерения величин: измеряемое U выражается через эталонную единицу Q, кратное увеличение которой его полностью исчерпывает [2, с.19]: U = k Q. Корни вышеприведенного уравнения – это узловые значения относительной информационной энтропии, интегральной меры состояний систем. При натуральных k узлы меры $\hat{H}$ таковы: 0,500 (k = 1); 0,618... (k = 2); 0,682... (k = 3); 0,725... (k = 4); ... Их называют обобщенными золотыми сечениями (ОЗС). Значениям k, наиболее удаленным от целочисленных, т.е. полуцелым, соответствуют антиузлы, пучности, точки безмерия и дисгармонии систем: 0,570... (k = 3/2); 0,654... (k =5/2); 0,705... (k = 7/2);... Близость $\hat{H}$ к числам первого либо второго ряда говорит о системном качестве выражаемого ею структурированного целого – о стационарности, устойчивости его неравновесных состояний – либо об отсутствии такового. Это проливает свет на природу нормы и адекватные ей структурные пропорции гармонично организованных систем 1; 2]..

Заключение

Соврершенствование системы управления на основе исследования, проектирования, диагностики состояний и прогноза развития сложных систем на основе инвариантов самоорганизации — обобщённых золотых сечений является уникальным методом, не сравнимым ни с каким другим. При проведении такого исследования необходим строгий контроль в сборе статистического материала. Аспект «интегральный измеритель фазовых состояний систем — узловая линия меры» также представляет собой своего рода обобщенный «методологический компаратор» поскольку применим при проектировании и анализе систем различного происхождения, как экономической, так и социальной природы.

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ПЛАНИРОВАНИЕ КАК НЕОБХОДИМЫЙ ИНСТРУМЕНТ В СИСТЕМЕ ОБРАЗОВАНИЯ

PLANNING AS A NECESSARY TOOL WITHIN THE EDUCATION SYSTEM

Senior Lecturer, Kirilina M. Economics – Law Faculty of Odessa National Mechnikov's University, Odessa. Ukraine.
kirilina1@ukr.net

Abstract: *The main issues are considered in this topic: C*onsideration of the problems of the effectiveness of the education system through the prism of management tools.
Keywords: *PLANNING, EFFICIENCY, COMPETITIVENESS, INSTITUTIONS OF HIGHER EDUCATION, LABOR MARKET, EDUCATIONAL MARKET.*

1. Введение

Планирование присуще всем сферам жизни общества, но особенно актуальным оно является для сложных иерархически структурированных систем, обеспечивающих различную экономическую деятельность.

Современное предприятие является сверхсложной открытой социально-технической системой, связанной специфическими отношениями с окружающей средой. Назначение планирования как функции управления состоит в стремлении заблаговременно учесть по возможности все внутренние и внешние факторы, обеспечивающие благоприятные условия для нормального функционирования и развития предприятий. Оно предусматривает разработку комплекса мероприятий, определяющих последовательность достижения конкретных целей с учетом возможностей наиболее эффективного использования ресурсов каждым производственным подразделением и всей организацией.

В условиях рыночной системы хозяйствования ни одно предприятие не может работать прибыльно без тщательно проработанного плана. Опыт организации предприятий свидетельствует, что планирование их деятельности приобретает все большее значение в условиях быстрых изменений в среде функционирования. Чем более динамичным и неопределенным становится среда деятельности, тем больше порядка должно быть на самом предприятии, тем больше внимания следует уделять разработке стратегий и оперативных действий для их реализации. Отсутствие четкого плана является неоспоримым свидетельством неудовлетворительного управления предприятием. Успех предпринимательского проекта, независимо от его масштабов, сферы деятельности, формы организации бизнеса, невозможно без четкого представления о перспективах, деятельности, без проработки надежных ориентиров и реального плана предприятия. Как показывает зарубежный опыт университетского образования, существует целесообразность и эффективность экономических подходов к управлению деятельностью ЗВО. Современные преобразования в развитии экономики и государства Украины, глобальные процессы вывели современные университеты с академической и фундаментальной сферы подготовки специалистов к пространству рыночных отношений и должны заставить понять руководство ЗВО, что наступили времена жесткой конкуренции на рынке образовательных услуг, которые , в свою очередь, должны соответствовать стандартам качества, требованиям трансграничного взаимодействия и удовлетворять потребности современного общества, государства, экономики.

2. Предпосылки и средства для решения проблемы

Заведения высшего образования, как составляющие системы образования, выполняют важную экономическую функцию в обществе и государстве по обеспечению населения образовательными услугами, а экономическую систему страны - квалифицированными кадрами. Именно рынок определяет, что необходимо обществу, решает для кого производятся и каким образом распределяются услуги. Образовательные услуги не являются исключением, поэтому, учитывая, что заведения высшего образования функционируют в условиях рыночных отношений, конкурентной среды и стремительного развития научно-технического прогресса, следует пересмотреть стратегические ориентиры и подходы к управлению деятельностью образовательных учреждений. В этих условиях возникает потребность в разработке принципиально иных концептуальных основ управления учреждением, как субъектом рынка образовательных услуг. Без четко определенных ориентиров, направлений ни одно заведение высшего образования не сможет успешно выжить в конкурентной среде.

Управление в таких условиях должно базироваться на использовании методов управленческого планирования и прогнозирования.

Исследованием деятельности заведений высшего образования и обеспечения их конкурентоспособности на рынке образовательных услуг занималось много как отечественных, так и зарубежных ученых. Их исследования в большинстве своем направлены на освещение проблем качества и соответствия полученных компетенций выпускников запросам рынка труда. Однако, проблема конкурентоспособности и эффективности самой системы образования, и. в частности, заведений высшего образования, с точки зрения разработки и совершенствования методики прогнозирования и планирования объемов подготовки специалистов ЗВО требует дальнейшего исследования.

3. Решение рассматриваемой проблемы

Анализ количественных показателей деятельности заведений высшего образования в Украине позволяет утверждать, что сегодня система образования переживает управленческий кризис, причиной которой является несоответствие существующей системы управления новым условиям хозяйствования. [1].

Одним из рейтингов, который исследует высшее образование страны в целом является Рейтинг национальных систем высшего образования (U21 Ranking of National Higher Education Systems). Это глобальное исследование и сопровождающий его рейтинг, измеряющий достижения стран мира в сфере высшего образования по версии международной сети университетов Universitas 21 [2].

Рейтинг рассчитывается по методике Института прикладных экономических и социальных исследований Университета Мельбурна (Австралия) и оценивает национальные системы высшего образования по 24 основным показателям, объединенным в четыре группы:

– ресурсы (инвестиции со стороны частного и государственного секторов),25%;

– результаты (научные исследования, научные публикации, соответствие высшего образования потребностям национального рынка труда, включая дальнейшее трудоустройство выпускников учебных заведений) - 40%;

– связи (уровень международного сотрудничества, демонстрирующий степень открытости или замкнутости системы высшего образования) - 10%;

– среду (государственная политика и регулирование, возможности получения образования) - 25%.

Рейтинг национальных систем высшего образования охватывает 50 стран. Первую строчку рейтинга занимает США с индексом в 100 баллов, за ними следуют страны, имеющие индекс более чем на 20 баллов ниже. Украина в данном списке занимает места в последней десятке, хотя в 2017 году она поднялась в рейтинге с 42 позиции на 36 и индекс изменился с 42,1 баллов на 47,7 баллов. Это свидетельствует о несовершенстве и незавершенности системы высшего образования в стране в целом, что в значительной мере влияет как на конкурентоспособность страны на мировой арене, так и на эффективность и конкурентоспособность ее заведений высшего образования.

Результатом эффективной организации деятельности заведений высшего образования, его конкурентоспособности является конкурентоспособность его выпускников, то есть молодых специалистов на рынке труда. В настоящее время существует такая тенденция, что молодые специалисты в результате поиска работы устраивается не по полученной специальности, а там, где в настоящее время есть вакансия. Это не только снижает возможность реализации выпускников и их конкурентоспособность в целом, но и снижает эффективность и конкурентоспособность высшего образования и экономики страны. В то же время, это не только причина снижения производительности и конкурентоспособности, а и ответ на структурный дисбаланс между рынком труда и рынком образовательных услуг [4, с. 289-304]. Система высшего образования - это тот механизм, который должен эффективно готовить конкурентоспособные кадры, которые будут востребованы на рынке труда и ускорять его развитие. Но в настоящее время наблюдается то, что она не способна быстро реагировать на изменения спроса на кадры, которые готовит, это приводит к снижению их профессионально-качественных характеристик, ощущается нехватка внимания к развитию личностных качеств выпускников, которые должны обеспечивать адаптацию молодых специалистов с потребностями работодателей. Это, в свою очередь, провоцирует появление на рынке труда циклов, состоящих из периодов «перепроизводства» и дефицита. Первоочередной причиной данной проблемы является отсутствие методологии планирования и прогнозирования количества абитуриентов.

В настоящее время система управления заведениями высшего образования как субъектом рыночных отношений не сложилась как специфическая деятельность, которая должна характеризоваться своей структурой, механизмами и процессами. Созданные в других условиях заведения высшего образования были сориентированы на достижение экономического результата путем наилучшего удовлетворения потребительского спроса и достижения минимального уровня расходов. Они были нацелены прежде всего на выполнение государственных планов. Если в стабильной плановой экономике эти факторы не играли значительной роли, то в условиях рыночных отношений они резко ухудшили положение системы образования [4].Баланс трудовых ресурсов СССР был частью баланса всего народного хозяйства страны и базировался на принципах полной занятости и представлял систему показателей, отражающих различные аспекты использования трудовых ресурсов: численность и качественный состав по возрасту, полу, социальными группами, отраслями народного хозяйства, видам занятости и профессиям [5]. В условиях государственной плановой экономики объемы подготовки специалистов с высшим образованием определялись по задачами государственного плана социально-экономического развития страны. На сегодняшний день эта система не функционирует, и не является релевантной в связи с переходом от плановой экономики к рыночной. На сегодня в Украине отсутствует системный подход к планированию и прогнозированию потребностей экономики и общества в квалифицированных специалистах с учетом изменений в структуре национальной экономики.

4. Результаты и дискуссии

Главными проблемами, которые приводят к ситуации, сложившейся в экономике, является недостаточный уровень прогнозирования, планирования и координации действий учреждений, связанных с воспроизведением и использованием трудовых ресурсов; не сформированный рыночный механизм оценки качества общеобразовательной и профессиональной подготовки специалистов.

С одной стороны, должен быть орган, который смог бы поддерживать связь рынка образовательных услуг и рынка труда; с другой стороны, должен быть существующий механизм, который смог бы обеспечить рациональное функционирование всей системы, элементы которой должны быть взаимосвязаны. Важно избегать создания разрыва между рынками труда и образовательных услуг еще на этапе планирования деятельности. Сегодня система образования строится на том, что исходя из определенных показателей, государство создает определенный уровень государственного заказа на отдельные специальности, которые на его взгляд необходимы для экономики, и исходя из этих же показателей создается лицензионный объем на подготовку специалистов в той или иной области. Все это не отражает реальной картины потребностей рынка. Зачастую даже противоречит ей. Так как в организации своей деятельности заведения высшего образования опираются на государственную политику в этой сфере, то регулирование должно начинаться именно на уровне государственного планирования. В то же время, постепенные преобразования и повышение роли взаимодействия рынка образовательных услуг и рынка труда начинают отображаться в образовательной политике, ориентироваться на потребности рыночной экономики и искать пути урегулирования неуравновешенности в ее структуре. Но здесь возникает проблема в том, что эти преобразования происходят в настоящее время с учетом данной ситуации на рынке, никак не координируясь с учетом прогнозов на будущее. Понятно, что и структура спроса и предложения на рынке труда, является сегодня результатом образовательной политики в прошлом. Для подготовки специалистов, необходимых рынку сегодня, в высшем образовании это будет занимать 6 лет. Ведь в настоящее время обучение по уровню «бакалавр» занимает 4 года и по уровню «магистр» - 1,5 года. За этот период уже произойдут изменения в качественном и количественном составе рынка труда, что может привести к усилению дисбаланса на нем.При планировании нужно помнить о временном факторе, который приводит к задержке в реализации изменений и урегулировании диспропорций. На сегодняшний день не существует механизма обеспечения планирования подготовки специалистов для рынка труда. Подготовка специалистов осуществляется по тем направлениям, которые стимулируются государственной политикой, что приводит к разрыву в желаемых и реальных результатах. Планирование нужно внедрять еще на этапе привлечения к обучению в

учебных заведениях абитуриентов. Оно должно базироваться на принципах качественного образования, соответствовать потребностям и требованиям современного мира, реагировать на изменения рыночной среды и удовлетворять потребности субъектов отношений, возникающих в процессе деятельности. Важным влиянием на взаимодействие в организации изменений должен быть системный подход. Он должен привлекать к взаимодействию всех элементов системы: компетентные государственные органы, органы местной власти, учреждения высшего образования, студентов и выпускников, работодателей.

5. Заключение

В отечественной практике повышение эффективности и конкурентоспособности заведений высшего образования определяется не качеством их выпускников, уровню престижности их трудоустройства, а наличием и соответствием лицензированным требованиям. Конкурентоспособность заведений высшего образования возможно достичь только в условиях баланса спроса и предложения образовательных услуг, что возможно лишь при наличии методологической базы прогнозирования и планирования лицензированных объемов. Отслеживая конкурентоспособность заведений высшего образования, нужно рассматривать трудоустройство выпускников как составляющую качества образования и конкурентоспособности. Этот показатель, как правило, должен коррелировать с показателями рынка труда и основываться на достоверных моделях прогнозирования и планирования.

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INTERNATIONAL COMPARISON OF UNIVERSITY EDUCATION QUALITY ON THE BASE OF MODELING VALUE INDEX

Prof. Alieksieiev I. D.Sc., Assoc. Prof. Mazur A. PhD, Assoc. Prof. Alieksieiev V. PhD

Lviv Polytechnic National University, Lviv, Ukraine

Ihor.V.Alieksieiev@lpnu.ua, http://orcid.org/0000-0001-6618-3100
Andriana.V.Mazur@lpnu.ua, https://orcid.org/0000-0002-5985-5674
Vladyslav.I.Alieksieiev@lpnu.ua, http://orcid.org/0000-0003-0712-0120

Abstract: The article is dedicated to studying and comparing the indicators used to evaluate the educational activities quality of universities from various countries. In particular, the indicators of tuition fees, and expenses for the separate indices of inputs for educational activities are being investigated. The ratio of universities tuition fees to incomes of the educational services consumers is being simulated.

KEYWORDS: INDUSTRY 4.0, THE MINIMUM WAGE INDEX, THE REAL WAGE INDEX, THE ANNUAL TUITION FEES, THE RATIO OF TUITION FEES TO WAGES

1. Introduction

The investigation of universities activities, and in particular the education quality, has many dimensions [1-3]. Training programs and plans are being examined. Also, the researches of the educational services marketing are interesting [4]. There are realized special studies regarding the education quality [5]. Entrants, who are selecting the educational institution in order to obtain the university education, are particularly interested in the results of researches related to the education quality in universities of different countries [6-11]. When comparing the education at universities across countries, such aspects are separated as the university's image for providing further employment [12-13], as well as educational opportunities at the lowest cost [14-15]. A separate point must be made about studying the universities ratings, where the result of researches with wide spectrum are being consolidated [16]. There are a lot of ratings that somehow reflect the educational and scientific activities of universities. But the key goal of these rating systems is to substantiate the advantages of some universities over the others. In other words, ratings are being used for the further marketing conclusions that are addressed to the potential entrants. However, the universities goals are rather aimed at applicants of post-graduate course and potential research workers. This very contingent is already versed in rating activities. And more importantly, the future post-graduate students can bring new ideas into investigates, which the holder of master's degree is better informed in than the applicant of bachelor's degree. Consequently, both the ratings, which are the synthesized investigation results, and the researches across the separate factors of universities educational activities, in large amount, are pointed to persuading the potential consumers of education services in activities advantages of the certain higher educational establishments. In order to compare the educational activities of universities, they use various indicators. Instead of this, to convince the applicants for the bachelor's degree, that is, graduates from schools, gymnasiums, lyceums, as well as their parents, they use such concepts as "cheap education", "bad education" [17]. In this case, in particular, it is commonly believed that educational services are better in those universities where the price for educational services is higher. Comparison in such cases is carried out directly, for example, in the Euro currency or in US dollars.

This research is dedicated to discussing the problem of comparing the education quality by evaluating the educational services value and the abilities of consumers to pay these services cost. The implementation of "INDUSTRY 4.0" in Ukraine is possible only in the conditions of the wide staffing base existence. With this aim, it is a necessity to train the workforce in Ukrainian universities. The latter requires understanding of the fact that the value of education service needs to be evaluated not only within the direct comparison and transfer the education services cost from hryvnias to Euro or US dollars at the exchange rate. It is worth understanding that the value of education services, like the cost of other services and goods, should be always compared with the income of potential consumers in every country. We are not objecting the importance of training national staff at the foreign universities. Similarly, we support the idea and practice of academic mobility. In this context, it is necessary to develop and enhance training of specialists in Ukrainian universities. And this requires the correct approach to evaluating and developing ratings of the domestic universities, as well as comparing the result of their activities with the foreign ones.

2. Prerequisites and Instruments for Solving the Problem

Education services are an important component of the activities of all the educational establishments and all levels of accreditation. However, for universities that are ought to work not only under the state order, but also in terms of payment of such services by individual persons and legal entities, the question of covering costs, related to education services provision, is extremely important. Recently, the mentioned problem has become particularly acute. There arises the need to increase the remuneration of teachers and the auxiliary personnel. The tariffs for public services are being raised. The facts, mentioned above, requires ever-increasing amount of expenditures from universities. But an income of individual persons interested in receiving the education services, and so obliged to pay for them, is growing much slower.

Let us present data on expenditures. The prime example of changing the wage costs is a dynamic of minimum wages (Table 1), related to all the citizens of Ukraine. We have adopted the changes in the minimum wages exactly because they are similar for all territories of Ukraine. At the same time, the amount of the average wages is different in various regions.

Table 1: *Changes in the amount of the monthly minimum wages during 2014-2018 **

The date, on which the minimum wages is shown	The amount of minimum wages, UAH	Index** of minimum wages, %
01/01/2014	1218.00	
01/01/2015	1218.00	100.00
01/01/2016	1378.00	113.14
01/01/2017	3200.00	232.22
01/01/2018	3723.00	116.34
Draft at 01/01/2019	4173.00	112.09

Notes:

* according to [18]

**the minimum wages index is shown as ratio to the previous period, represented in a table.

Data from Table 1 indicates obviously of insignificant changes related to the minimum wages increase. It is well-known that the jump of the minimum wages amount in 2017 only slightly smoothed things over. This situation was that there appeared a

significant gap among the dynamic of prices and tariffs and the dynamic of a subsistence level, the minimum wages dynamic.

One more important factor, although not the largest by the absolute value, is changes in electricity tariffs (Table 2). We have taken electricity tariffs for dormitories, since they coincide with the tariffs for the population, among which there are also consumers of educational services. Here it is important to understand that in addition to higher education institutions (HEIs), which conduct calculations with power engineers, the same calculations are carried out by families of students - direct recipients of educational services, among which there are many residents of dormitories. That is, the family, on the one hand, pays for electricity in its premises, and on the other hand, it pays for electricity in the dormitory where its student lives. In other words, the expenses of a family while teaching her child at the university are increasing.

Table 2: *Changes in electricity tariffs for dormitories and population during 2014-2018**

The date, on which tariff payments are shown	The amount of tariff payment, UAH kopecks/kWh.	Index** of the tariff payments amount, %
06/01/2014	30.84	
04/01/2015	36.6	118.68
09/01/2015.	45.6	124.59
03/01/2016	57.0	125.00
09/01/2016	71.4	125.26
03/01/2017	90.0	126.05

Notes:

* according to [18]

**the electricity tariff payments amount index is shown as ratio to the previous period, represented in a table.

The dynamic of electricity tariff payments indicates its steady growth. This requires the universities to increase permanently their costs. Electricity is spent not only for lightening the classrooms and spaces in campus and dormitories, since it is also necessary for conducting laboratory exercises and research, develop prototypes of materials, instruments, machines and mechanisms developed by scientists at universities.

It is interesting to compare the data obtained regarding changes in minimum wages with the real wage index within the studied periods (Table 3).

Table 3: *The comparison of changes in minimum and real wages during 2014-2018 **

The date, on which the minimum wages is shown	Index of the minimum wages, shown as ratio to the previous period (represented in a table), %	Index of the real wages per year, %
01/01/2014		86.5
01/01/2015	100.00	90.1
01/01/2016	113.14	106.5
01/01/2017	232.22	118.9
01/01/2018	116.34	100.8 (Forecast)
Draft at 01/01/2019	112.09	

Notes:

* according to [18]

As we can see from Table 3, the minimum wage index differs significantly from the real wage index, which indicates an increase in the value of the minimum wage against the background of a slight increase in real wages. As is known, it is real wages that give an idea of the purchasing power of the population, among which there are educational services consumers. And if the minimum incomes of people grow by even more than 2 times, as shown for 2017, then real incomes grew only 1.1 times. Is this 10-percent growth enough to cover the cost of paying for educational services? To answer this question, it is worthwhile to analyze only for some examples the amount of tuition fees at universities in Ukraine (Table 4).

Table 4: *The annual tuition fees for economic specialties at universities in Ukraine **

Universities of Ukraine	Annual tuition fee, thousand UAH / per year, 2018
1) Oles Honchar DNU	12.700
2) Taras Shevchenko NUK	33.430
3) KNEU	24.500
4) KNUTE	15.730
5) IFNUL	14.115
6) LPNU	9.000
7) ONU	15.028
8) ONEU	13.050
9) KhNEU them. S. Kuznets	16.400

Notes:

*According to data of the following universities:

1) Oles Honchar Dnipro National University
2) Taras Shevchenko National University of Kyiv
3) Kyiv National Economic University named after Vadym Hetman
4) Kyiv National University of Trade and Economics
5) Ivan Franko National University of Lviv
6) Lviv Polytechnic National University
7) Odessa I.I. Mechnikov National University
8) Odessa National Economic University
9) Simon Kuznets Kharkiv National University of Economics

The data from Table 4 show that university tuition fee on economic specialties, which in recent years have been one of the most popular among applicants, exceeds the minimum wage. Of course, this should not be considered as some kind of complete anomaly. However, the situation when the annual minimum wage is equal to the annual tuition fees indicates a difficult environment for providing university education to children from low-income families. In Ukraine, individual examples are well-known, when not only good specialists with a university education, but also eminent scientists came out of low-income families.

3. Solution of the Examined Problem

In order to solve the examined problem, it is necessary to simulate the corresponding indicator (Ex_{min}^{ed}). It is inadvisable to rely, for comparison, on determining only the value of educational services. We propose to compare the costs for education (Pr_{year}^{ed}) with an income of citizens, which are the potential consumers of education services. In particular, let us take the minimum wages (Wg_{min}^{per}) as an income indicator in this research. Then, the proposed indicator will look as follows:

$$Ex_{min}^{ed} = \frac{Pr_{year}^{ed}}{Wg_{min}^{per}},$$

Ex_{min}^{ed} – expenditure for education with minimum wages, point;
Pr_{year}^{ed} – price for education per year, **€;**
Wg_{min}^{per} – minimum personal wages per year, **€.**

Thus, to determine the proposed indicator, the one should perform the following calculation algorithm.

First, we define the costs of educational services and income of Ukrainians. For comparability of such indicators, a single value should be taken for the whole country. This value is the minimum wage.

Secondly, we determine the costs of educational services and revenues for the countries, which we are comparing with, in particular for Bulgaria and Austria.

Thirdly, we compare calculated indicators for Ukraine with those of Bulgaria and Austria.

Table 5: *University tuition fees by the example of specialties in economics and management*

Country	Average annual tuition fee, UAH	Average annual amount of wages, UAH**	Ratio of the tuition fees to wages, %
Ukraine			
Lviv Region	9000.0*	78024.00	11.53
National University of "Kyiv-Mohyla Academy"	27000.00*	132876.00	20.32

Notes:

*Average annual tuition fee for the bachelor's level. For Lviv region, the equivalent in Euros is 300,00 **€. For the** National University of "Kyiv-Mohyla Academy", the equivalent in Euros accounts for **900,00 €.**

**Average annual wages (gross, before the tax payment) in Ukraine is taken according to the Ukrstat statistical data for August 2017: Lviv region – 6502.00 UAH per month; Kyiv – 11073.00 00 UAH per month.

Determining the average annual tuition fee for Austria requires a study of tuition fee for a certain number of leading Austrian universities. In general, it is worth noting that education in public educational establishments is free both for Austrians and for foreigners. However, students are required to pay a semester fee. This contribution may be of varying sizes in different universities.

At the Technical University of Wien (WTU) students pay the semester contribution that is equal to 726,72 € per a half-year. At the Wien University (WU) Ukrainian students are ought to pay 382,06 € per half-year as the semester fee. At Wien Economic University (WEU) students contribute 726,72 € as a semester fee. The tuition fee at University of Applied Sciences Wiener Neustadt is 363,36 € per half-year, and the student trade-union contribution is estimated at 19,20 € / semester. Talking about the University of Applied Sciences of Kärnten, students pay 363,36 € as a semester fee. At University of Klagenfurt (UKlf) students pay the semester fee equal to 726,0 € per half-year. Lauder Business School, which is private, provides free education, although students are ought to pay the semester fee in the amount of 726,72 € per half-year. Students at Johannes Kepler University Linz are obliged to pay the semester fee equal to 363,36 € / semester.

The results of such a study, recalculated per average annual value, are generalized and presented at Table 6.

Table 6: *Tuition fees at universities of Austria, by the example of specialties in economics and management*

Country	Average annual tuition fee*, Euros **€**	Number of students, people
Austria		
Technical University of Wien. WTU	1453.44	20000
Wien University WU	764.12	79300 (bachelors)
Wien Economic University. WEU	1453.44	23000
University of Applied Sciences Wiener Neustadt	726.72	3600
University of Applied Sciences of Kärnten	726.72	2000
University of Klagenfurt UKlf	1452.00	10000
Lauder Business School BUW	1453.44	310
Johannes Kepler University Linz JKU	726.72	18036

Notes:

*Average annual tuition fee for the bachelor, according to data of the Austrian universities

In addition, Table 6 represents data on the number of students in certain universities for the further determination of average pay rates. Data on the students' number is taken from the official websites of universities and Wikipedia. Of course, these data are approximate and may not fully correspond to the number of students on a specific date. Instead, it should be mentioned that the number of students is always a variable value. This is due to the constant migration of students, which is explained by their academic mobility, exclusions because of the academic failure and other factors.

The calculation of the average annual tuition fees for Austria will be obtained by means of weighted average value, where the weighting factor is the number of students at the university.

1) First, we determine the total amount, paid by students, as the sum of multiplies of tuition fee at a particular university and the number of students at that university:

1453.44 x 20000 + 764.12 x 79300 + 1453.44 x 23000 + 726.72 x 3600 + 726.72 x 2000 + 1452.00 x 10000 + 1453.44 x 310 + 726.72 x 18036 = 29 068 800.00 + 60 594 716.00 + 33 429 120.00 + 2 616 192.00 + 1 453 440.00 + 14 520 000.00 + 450 566.40 + 13 105 318.32 = 89 663 516.00 + 36 045 312.00 + 15 973 440.00 + 13 555 884.7 = 125 708 828.00 + 29 529 324.7.00 = **155 238 153.00€**

2) Now we determine the total number of students studying in all the examined universities in Austria:

20000 + 79300 + 23000 + 3600 + 2000 + 10000 + 310 + 18036 = **156246 students**

3) We define the average annual amount of tuition fees when dividing "the general amount paid by the students per year for the education services delivery" by "the number of students that are studying at all researched Austrian universities":

155 238 153.00: **156246 = 993.55 €/year**

4) To compare with the tuition fees in Ukraine, let us determine the equivalent amount in hryvnias under the certain exchange rate of Euro to UAH. The amount of **993,55 €/ per year under the exchange rate of 31,1**(https://minfin.com.ua/ua/currency/eur/) hryvnias per year, is an equivalent to **30 899,405** ₴ per year (UAH/year).

Now we will carry out similar calculations for universities in Bulgaria. Data on tuition fees on the specialties of economics and management in some of the leading universities in Bulgaria are shown in Table 7.

Table 7: *Tuition fees at universities of Bulgaria, by the example of specialties in economics and management*

Country	Average annual tuition fee*, Euros **€**	Number of students, people
Bulgaria		
Sofia University "St. Kliment Ohridski"	3450.00	14000
Technical University of Sofia	3000.00	1100
Technical University of Varna	2500.00	7000
University of economics - Varna	2500.00	11000
Varna Free University	3000.00	10000
Plovdiv University "Paisii Hilendarski"	3000.00	1300
Burgas Free University	3000.00	7500

Notes:

* Average annual tuition fee for the bachelor's level, according to data of the Bulgarian universities

Calculation of the average annual tuition fees for Bulgaria will be held similarly as for Austrian universities, through the weighted average, where the weighting factor is the number of students at the university.

1. First, we determine the total amount, paid by students, as the sum of multiplies of tuition fee at a particular university and the number of students at that university:

3450.00 x 14000 + 3000.00x 11000 + 2500.00 x 7000 + 2500.00 x 11000 + 3000.00 x 10000 + 3000.00 x 1300 + 3000.00 x 7500 = 48 300 000.00 + 33 000 000.00 + 17 500 000.00 + 27 500 000.00 + 30 000 000.00 + 3 900 000.00 + 22 500 000.00 = 81300000.00 + 45000000.00 + 33900000.00 + 22500000.00 = 126300000.00 + 56400000.00 = **182 700 000.00 €**

2. Now we determine the total number of students studying in all the examined universities in Austria researched:

14000 + 11000 + 7000 + 11000 + 10000 + 1300 + 7500 = **61800** students

3. We define the average annual amount of tuition fees when dividing "the general amount paid by the students per year for the education services delivery" by "the number of students that are studying at all researched Bulgarian universities":

182 700 000.00 : 61800 = 2956.31 € per year

4. To compare with the tuition fees in Ukraine, let us determine the equivalent amount in hryvnias under the certain exchange rate of Euro to UAH. The amount of **2956,31 € per year under the exchange rate of 31,1(** https://minfin.com.ua/ua/currency/eur/) hryvnias per year, is an equivalent to **91 941,241** ₴ per year (UAH/year).

Let us determine the minimum wages calculated per year for each of the countries.

Table 8: *Minimum wages within the researched countries, calculated per month and per year, respectively*

Country, monetary units	Minimum (gross) wages per month / per year	Date (period), at which the amount of wages has been determined, and the literary source
Austria, **€ (Euros)**	1500.00 / 18000.00	July 2018 [19]
Bulgaria, **€ (Euros)**	260.00 / 3120.00	2018 [20]
Ukraine, ₴ (UAH)	3723.00 / 44676.00	May 2018 [18]

Let us determine the average annual tuition fees for each country (Table 9). As the data from Table 9 shows, the lowest annual amount of tuition fee is in Ukraine. This is explained by the national ratios of prices and tariffs with Ukrainian income. Slightly more sum is characteristic for universities of Austria. However, the state policy of financial support for universities makes the costs for consumers of educational services quite small. The most expensive from the three countries studied is the education at universities in Bulgaria and it can also be explained by the national policy of education financing. But a direct comparison of the education cost in universities of the compared countries is, in our opinion, not objective enough. After all, such a direct comparison does not consider the solvency of potential consumers of educational services.

Table 9*: Comparison of the annual tuition fees in Austria, Bulgaria and Ukraine* *

Countries	Annual tuition fees	
	Euros	UAH
Austria	993.55	30 899.405
Bulgaria	2956.31	91 941.241
Ukraine: Lviv region	300.0	9000.00
National University of "Kyiv-Mohyla Academy"	900.00	27000.00

Notes:

*Calculated by the authors

To overcome this drawback, we will simulate an indicator that should take into account not only the educational services costs, but also the solvency of entrants and their families. We propose to determine solvency as the value of wages. At the same time, we consider it expedient to choose the minimum wage when determining the proposed indicator for international comparisons. Let us determine the values of the simulated and proposed by us indicator of the ratio of the tuition fee and the minimum wage as a possible characteristic for the cross-country comparison of universities by value indicators.

Table 10: *Tuition fees at universities in comparison with the annual minimum wages amount**

Countries, monetary units (gross, before taxes)	Average annual tuition fee **	Minimum wages within the country in 2017, monetary units	Ratio of the tuition fees and wages, %
Austria, Euros	993.55	18000.00	5.52
Bulgaria, Euros	2956.31	3120.00	94.75
Ukraine, Lviv region, UAH	9000.0	44676.00***	20.15
Ukraine, Kyiv-Mohyla Academy, UAH	27000.00	44676.00***	60.44

Notes:

*Calculated buy the authors

** Average annual tuition fee for the bachelor's level

***Average annual amount of wages (gross) in Ukraine was taken according to the Ukrstat statistical data on August 2017.

It follows from the calculations that, despite significant differences in absolute values of tuition fees, the cost of educational services at universities in Ukraine is significantly higher compared to income of Ukrainians.

So, comparing the cost of education in different countries, it is necessary to take into account not so much the hryvnia exchange rate, but the ratio of the fee offered by universities to the income received in a particular country.

Also, an important aspect of domestic comparisons should be considered regional differences in the parameters indicated and studied by us. Obviously, when getting less income in the Lviv region is not worth raising prices for studying in Lviv universities to the level of Kyiv ones.

4. Results and Discussion

The implementation of INDUSTRY 4.0 ideas in Ukraine requires appropriate staffing. Undoubtedly, the quality of education is placed high on in this context. Training of highly qualified personnel for Ukrainian enterprises should take place both in Ukrainian universities and in foreign ones. At the same time, it is important to bear in mind that in Ukrainian universities, training at a lower cost provides for obtaining at least equally qualified specialists. Obtaining knowledge and skills on innovative technologies is possible as a result of the active introducing the academic mobility of students and teachers of Ukrainian universities.

5. Conclusions

The key idea of the study is the proposal of a new characteristic for international comparison of the university's educational services quality - the simulated indicator of the ratio of tuition fees to the minimum wage in the country. Such a minimum wage can act as a characteristic of the solvency of educational services consumers.

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THE SHADOW ASPECTS OF CRITICAL THINKING FOR LEADERSHIP, SOCIETY AND INDUSTRY 4.0

doc. Ing. Mgr. Ullrich D. Ph.D., MBA[1], PhDr. Ing. Pokorný V. MBA[2], Mgr. Sládek P.[1]

University of Defence, Czech Republic[1]
Newton College, Czech Republic[2]

david.ullrich@unob.cz

Abstract *- The text focuses on selected aspects of critical thinking in the context of leadership in a modern security environment, from the point of view of selecting and preparing professionals and leaders. It discusses, in particular, the changes in the professional quality requirements related to the development of industry and society 4.0 as well as selected situational and systemic contexts in which the critical thinking applies in the process of cognition, decision making, and action of professional leaders.*

Keywords - INDUSTRY AND ENVIRONMENT 4.0, COGNITIVE CONTINUUM, COGNITION, RATIONALITY, INTUITION, CRITICAL, SITUATIONAL AND SYSTEMIC THINKING.

1. Introduction

The article discusses the area of critical thinking and selected personality aspects in relation to the characteristics and expectations of the development of a modern environment in the form of society or industry 4.0. It presents partial aspects of the complex analysis carried out for the preparation of a pilot project focused on the selection and preparation of professionals and leaders for the pursuit of activities and functions of security character in conditions of a modern environment. The first part deals with the characteristics of modern environment, in the second part we discuss the requirements for professionals and leaders, in relation to critical thinking. In the third part, we highlight the specific aspects related to the selection and preparation of professionals.

The purpose of the analysis and the research was to create background documentation for a pilot project aimed at the complex identification of the level of natural potential of human competences and the natural methods of their cultivation for professional action and leadership in the environment 4.0. Environment 4.0, or Industry 4.0 or "Revolution 4.0," is an environment characteristic of which are trying to address various initiatives responding to what is called the Fourth Industrial Revolution. Environment 4.0, or else Industry 4.0 or "Revolution 4.0," is an environment whose characteristics are trying to address various initiatives responding to what is called the Fourth Industrial Revolution. An example of this may be the German initiative of 2013, called Industrie 4.0, or the Industrial Internet Consortium or the Smart Manufacturing Leadership Coalition in the USA or similar projects and programs of Japan and China. All of them emphasize an entirely new philosophy of system usage, integration and interconnection of various technologies with the dominant role of information and communication technologies, considering their sustainable and fast development. This "brand new" philosophy in a number of its supporting characteristics corresponds to the implementation of the NATO Network Enabled Capability (NNEC) concept, i.e. the warfare with the use of modern information and communication technologies, which we have been focusing on since 2006, in the context of optimizing quality and human factor potential. It identifies and develops the qualities and competencies of professionals, leaders, and teams to pursuit functions and activities in such organized conditions and circumstances of missions, situations, and tasks in the security environment. In connection with the "National Industry 4.0 Initiative" prepared by the Ministry of Industry and Trade of the Czech Republic[1] in 2015, and taking into account the features of the so-called Revolution "5.0", emphasizing artificial intelligence, we consider useful to contribute with our experience and knowledge to the evolving debate and express willingness and openness to cooperation.

2. Analysis of Characteristics of Environment and Requirements for Individuals

Human Systems and Their Management. The environment that we create as human beings with specific ways of life in different communities is changing and transforming more dynamically than the natural environment. In relation to these changes and transformations the requirements on the quality and capabilities potential of the professionals and leaders, i.e. people who pursuit specific functions and activities related to the organization and management of human systems, are changing either. The environment created by people in the process of human community development has approached the parameters of the unstable environment due to various specific changes and transformations (modern information technologies, globalization, etc.). We identify the characteristic aspects that are indicative of this approach in several areas:

I. technologies, their development, and application
II. relationships and their development
III. thinking, cognition, and information

A partial summary: In terms of the natural potential of human resources in the 4.0 environment, the most significant is the problematics of digitalization of information, artificial intelligence, virtual reality, and mediated communication. All these aspects have, besides undisputed direct and obvious advantages and positive effects, also secondary and asymmetric, hidden or shadowed, complex and nonlinear influences and effects on the psychical condition, mind, and thinking of individuals or communities. The shadow effect of digitization and mediated communication is recorded in two modalities. The first suggests that their excessive use gradually transforms the quality of self-consciousness in the full sense of the term. The second effect associated with the growth of digitization, algorithmization and artificial intelligence is the reduction of intuition and analogy in cognitive processes and the creation of knowledge for decision-making and action in a particular situation, and a reduction in spontaneous adaptability to changes in the conditions and circumstances of task situations.

2.1. Systemic (ecological) and Situational Mobility

Systemic (ecological) mobility refers to the environment, and is characterized by the ability to stay in an environment with predominantly artificial characteristics and in environments with predominantly natural characteristics as well as in professional and collaborative environments. Situational mobility is shaped as

1 Available at http://www.businessinfo.cz/cs/clanky/narodni-iniciativa-prumysl-40-71386.html#!&chapter=3

proactivity in the adaptability of changing conditions and circumstances.

2.2. Mobility in Relationships

This mobility includes social and organizational mobility. It is manifested on the social continuum (individual vs. team member), on the organizational continuum (hierarchical vs. network organizational structures) and on the management continuum (management/ leadership).

2.3. Mental Mobility

It represents the thinking in terms of the ability to generate knowledge for decision-making and action in the process of fulfilling the task and its most effective management (energy / least demanding way of performance).

Mobility on a cognitive, ecological, situational, social, and organizational continuum requires, in the end, a change of the attitude of each team member (the individual), in favor of personal self-development and self-fulfillment, individual development and cultivation of natural potential in the profession and position (Ambrozová, et al., 2016, Koleňák, 2015). The above-mentioned trends and requirements for the level of quality potentials of individuals and human systems require an upgrade in understanding the terms of management and leadership. They also need new approaches to identifying and developing the resources, potentials, and qualities of professionals and leaders operating in the current environment.

3. Critical Thinking

The definition of the content and meaning of the term of critical thinking is accompanied by considerable variations. Critical thinking, as the specific quality of thinking for decision-making and action of people in various situational conditions, is sometimes ranked among key competencies for the 21st century. It is a necessary skill to pay attention to in educational and training systems, especially in higher education settings. The International Panel of Experts in 1990 formulated critical thinking as follows: [Critical thinking is an efficient, self-regulatory reasoning the result of which is the interpretation, analysis, evaluation, and derivation, as well as the explanation of the obvious conceptual, methodological, contextual justification on which the reasoning is based on.[2]]

The etymology of the word critical shows that the root of the word krinó means to judge and relates to judgment, reasoning. Critical thinking is a skeptical thinking, i.e. exploring, perceiving thinking. Skepticism, skeptical, critical, because conjectural thinking has characteristics of subtle skills including openness; distance (neutrality and impartiality); mobility (in and out of the situation as well as stay in the gap); skepticism (skeptical, exploratory thinking, allowing to formulate reasonable doubts - questions, and putting forth reasoned arguments that distinguish simple idea from an opinion). The critical, because skeptical, inferring thinking has the characteristics of subtle skills (Ambrozová, et al., 2016), i.e. it contains openness; requires distance (neutrality and impartiality); the mobility on the cognitive continuum[3] and under the circumstances and conditions (in and out of the situation, as well as a stay in the gap); it produces reasonable doubts and arguments, allowing to distinguish a view from an opinion. These are the qualities of thinking that each professional and leader should acquire for situational, tactical, operational (project) or strategic decisions.

It turns out that the essence of critical thinking in different task situations is always the distinction, the analysis and synthesis, and at the same time the assessment of similarities and observation, which allows insight into the situation of the task or overview of the whole situation and the environment. The insight and overview represent the aspects related to professional intuition, which is often considered as an opposite to the logic and analysis, or as its complementary, additional aspect in the whole process of thinking and cognition. Critical thinking is flexible, as shown by K. R. Hammond on the model of the cognitive continuum. The demand for mobility shows that it is necessary to free the critical thinking from the domain of formal logic and rationality and to place it in the area of reasoning, closer to the concepts of wisdom, knowledge, or quasi-rationality according to K.R. Hammond, as for instance P.M. Senge (2016) or Cognitive Management (Ambrozová, et al., 2016) do.

This allows thinking as a process to be better applied not only in linear tasks but also in all forms of heuristics (both by Hammond[4], and Kahneman[5] or other authors), or tasks requiring decision-making under uncertain conditions, permanent changes and transformations, or due to random processes, etc.

One of the possible versions of the positive operationalization of critical thinking, as the quality or ability that every individual, who has the right to lead other people and human systems should possess, is as follows: [Critical thinking is an individual's ability to create optimal conditions for correct judgment in a situation and a task that manifests itself in the mental mobility. The mental mobility saturates the following measurable parameters:

A) Cognitive variability and mobility between analysis and intuition[6]
B) Skeptical curiosity[7] and courage[8], openness and spontaneity of learning.
C) Psychophysical condition in terms of stability of quality and quantity of performance of psychical functions in time (attention and memory).] (Ambrozová, et al., 2016)

Critical thinking plays a dominant role in terms of situational and systemic leadership and is manifested as the mobility on a cognitive continuum. The central concept of the cognitive continuum is a quasi-rationalist (Kostroň, 1997, Hammond, 2000), which represents an adequate presentation of analysis and intuition, as modalities of cognition, for a specific situation and task. The pre-concept[9], often an individual's unconscious opinion, experience, cognitive model, methodical procedure or stereotype, from which

2 See www.insightassessment.com/dex.html.

3 Involves both the systemic and concrete thinking reflected and manifested in the entire conditions of cognition, decision-making, and action (tactics and strategy) as well as the mental mobility on the continuum of analytical-intuitive.

4 K. R. Hammond (2000) suggest the heuristics as tasks with multiple variations of solutions, i.e. offering more than one correct solution.

5 Kahneman suggests the heuristics as cognitive and decisive „shortcuts". „…simple procedure, which facilitates the search for adequate, even if, frequently incorrect answers to complex questions. The term originates from the same basis as the famous heuréka". (Kahneman, 2010, p. 28-41; 2012)

6 Includes the ability to simultaneously visualize the whole and the insight in terms of fine and precise detail resolution; both concrete (positive) and abstract thinking; work with similarities, differences and relativity. Cognitive variability refers to the quality of a professional, not an expert insight, and refers, for example, to the ability to pragmatically, situationally create
a "meta-method" for cognition in a current task (whether from familiar elements and principles of methods (innovation) or to create, "discover" a new one. There is a continuous relationship (continuum, transition) between the intuition and analysis resulting in the usage of the term of cognitive continuum theory. In the sense of an adequate way of cognition in relation to the situation of a task, the transition can also be referred to as the "common sense" or by K.R. Hammond as quasi-rationality.

7 Skeptic in the sense of exploratory, conjectural thinking, including distance, neutrality, and impartiality allowing to formulate reasonable doubts and to put forward reasoned arguments that distinguish the simple view from the opinion.

8 In the sense of exceeding the task, context within time, space, and conditions; think the „un/thinkable". (Taleb, 2011).

9 The basal pre-concepts can be divided into natural (reflective) and acquired (in a social and professional setting).

the individual examines, recognizes and acts, is also reflected in the preference of ways of cognition and the effectiveness of decision-making and action. This "inner attitude" supports also a different self-concept under the conditions of the situation, the relation to the environment, the situation and the task as well as the different ways of perception and cognition, decision-making and action. The importance of truly critical thinking in leadership for decision-making in challenging conditions, complex and dynamically changing conditions is increasing for a number of reasons. As mentioned above, these reasons include both quantity and availability of information and knowledge, as well as their timeliness and reliability, validity. For example, the rate of obsolescence of information and knowledge is so high that the ability to create own and "fresh" information and knowledge significantly influences the potential success of decisions in different situational contexts. Similarly, the amount of information (related to cognitive optimum) is important in decision-making, and the ability of rapid, fine, and precise differentiation, falling more into the domain of insight and professional intuition, is a highly valued skill (Cejpek, 2005).

4. Results and discussion

The results of the environmental analysis suggest that the importance of mental condition and cognitive potential for critical thinking is growing, and it turns out that the quality of mind, thought, and knowledge of a particular individual is a common element or a central quality, potential and competence involved in all other competencies. This mental "vitality", as a central quality, has at least two modalities.

The first modality involves critical thinking; mobility on the cognitive continuum and optimal condition of mental functions involved in perception and cognition. The other modality can be considered as a mental mobility for decision-making and action in situations and tasks. Dominant characteristics of this modality are spontaneity (openness, curiosity, and courage) and flexibility (flexibility of thinking). The aspects of the first modality can be traced to a certain extent by various tests that measure the quantity and quality of performance of psychical and executive functions. The other modality level can be analyzed with the help of selected personality aspects that are identified by the different methods of personality questionnaires. Critical thinking as the mobility on a cognitive continuum, concerns both the functions and capacities involved in cognition for correct decision-making and effective action in the situations and the personality, in terms of the inner environment of individuals who evolve in this environment or are temporarily present within. In the concepts of analytical psychology of C.G. Jung and with reference to the concept of K.R. Hammond it is the finding of the state of balance of tension between the maxima of the cognitive continuum in relation to the requirements (conditions and circumstances). In situations, where the environment, by its characteristics, prefers forms of perception and models of cognition, linked to the digitization of information, mediated knowledge and communication, to algorithmization of "smart" technologies as well as artificial intelligence, there is a risk of loss of mobility, which is reflected in rigidity, standardization, and stereotyping, as well as non-cultivation, non-development, and thus the emptying of the natural qualities of abilities, or the shadowing of those natural ways of cognition, which relate, for example, to intuitive and analogical thinking functions that relate more to the logic of discovery than to the logic of reasoning (Alleau, 2008, p. 39).

A shift in this area may indicate not only the differences in the ability of professionals and leaders to move in solving various specific situations in the selection and preparation process as we have seen in recent years but also in partial changes in selected indicators that are related to this mobility. The selection and preparation practice shows some trends of change that need to be adapted to the selection and preparation methods. The selection and preparation practice shows some trends in changes that need to be adapted to the selection and preparation methods. Therefore, it must reflect not only the changes in the requirements of the environment but also the changes in the qualities of abilities of those who want to apply with the professional environment as well as those who already work in it. A possible hint of these changes may be partial shifts in preferences as indicated by the following results.

These are groups of professionals and leaders operating in the security environment. The first group consists of 115 people monitored for their quality of skills in the course of 2014 and 2015. The other group consists of 127 people from the same environment where these qualities were surveyed in the course of 2017 and 2018. For the purpose of the article, indicators of selected global scales were applied using the GPOP method (Bents, Blank, 2009). In the table, we present aggregate values in the form of averages and standard deviations.

Table 1: *GPOP aggregate values indicators of selected global scales in the form of averages (AVG) and standard deviations (SD).*

2014-2015	**S**	**N**	**T**	**F**	**J**	**P**
AVG	6,1	6	6,6	6,1	6,6	5,4
SD	1,7	2	1,9	1,8	2,4	1,8
2017-2018	S	N	T	F	J	P
AVG	7,1	4,3	6,5	5,1	7,9	3,8
SD	2,9	2,4	2,4	2,1	2,9	1,7

The function of sensory perception (S) and intuition (N) are functions called irrational functions as they do not evaluate but are dependent on the act of perception. The preference of functions in terms of perception as information sources affects cognition and decision-making in various task situations.

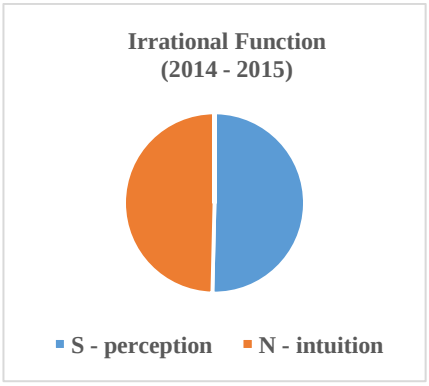

Fig. 1: *The preference of irrational perception functions as information sources; years 2014-2015.*

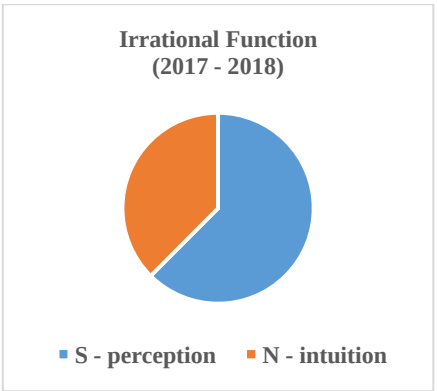

Fig. 2: *The preference of irrational perception functions as information sources; years 2017-2018.*

The functions of Thinking (T) and Feeling (F) are called rational as they allow rational evaluation of experience, information processing which reflects into a decision. Thinking "says" what a thing, an object, is, and usually works with facts, formal logic and the logic of reasoning, analysis, and synthesis. Feeling "says" what value a phenomenon, a thing has, it works by analogy, relationships and meaning.

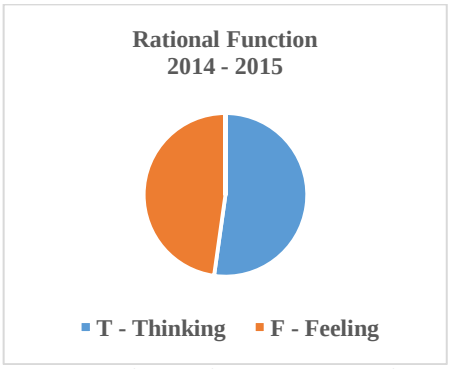

Fig. 3: *The preference of rational perception functions as information sources; years 2014-2015.*

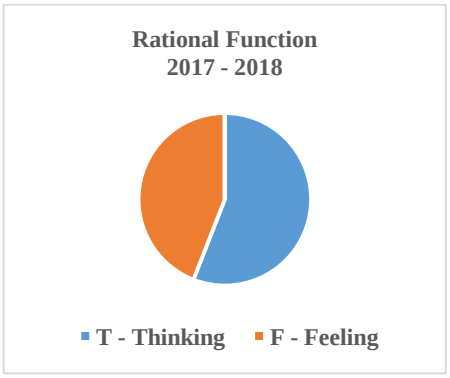

Fig. 4: *The preference of rational perception functions as information sources; years 2017-2018.*

For the correct situational and systemic decision-making, it is important to what extent the various cognitive models are involved in its constitution, creation, whether it is predominantly logical, factual or of a value. In general, the preference of a mode of cognition, decision-making, and action is growing and influenced by the coherence, positivist, direct, and rational thinking that prefers analysis and linear causality, developing and working with formal logic in language and mathematics. This is a modus from which the potential of digitization, algorithmization, artificial intelligence, mechanization, technology, and "dataisation" (Harari, 2017) originates. The ways of cognition and decision-making, based on correspondence and analogy, which are the natural "half" of the cognitive continuum of every living, recognizing person, are "receding into the shadows," as well as the potentials of the ability of analogous thinking, cognition, decision-making and action, based on the concept of correspondence, offer and enable.

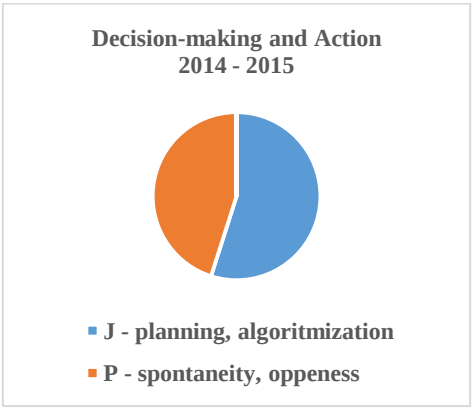

Fig. 5: *The preference of decision-making and action; years 2014-2015.*

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Fig. 5: *The preference of decision-making and action; years 2017-2018.*

Further features affect what the individual, in terms of decision-making and implementation, prefers, whether the plan, a goal, a structure, and procedure of algorithm or process and spontaneity. It turns out that the preferences of decision-making orientation related to algorithmization and planning have increased significantly, and the preferences of spontaneity, creativity, and openness to opportunities that are the basis for successful solutions to complex and complexly evolving situations and processes as well as heuristics has decreased.

5. Conclusion

The above results serve only as illustrations and suggestions for reflection. They correspond to our "intuitions"

and "feelings and insights" of the professionals involved in the selection and preparation, as well as to the need to innovate and adapt the methods of preparation and verification of results to changes in population and environment. Experience shows both the need for a comprehensive, multidisciplinary approach to identifying the qualities of their potentials and the need to incorporate elements that enable support, training and development of various aspects of critical thinking in favor of mobility on the cognitive continuum. This issue is being focused by the complex project, the program, for the preparation of which we used the analysis and the pilot study, from which we have chosen and presented only partial aspects.

The requirements of an environment and a situation for the pursuit of activities and functions are constantly evolving and changing. From the nature of the changes and the characteristics on their background, the basic features of the quality requirements and competencies of individuals in professional systems and environments are formed. These requirements, in various aspects,

emphasize the mobility, consistency and "adaptability" of the thinking process of every person who is involved in some way in the organization, management and leadership within human systems, from the "lowest" levels, with the direct practical consequence (task situation) to the highest" levels representing systemic, strategic decision-making and action.

The professional security environment is currently more structured, in terms of preferred cognitive models, due to the digitization and use of modern and sophisticated communication and information technologies. However, the situation of specific tasks or missions is far more complex and requires professionals and leaders to have mental fitness and mobility on a cognitive continuum.

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RISK MANAGEMENT IN CONTEXT OF INDUSTRY 4.0

Dr.h.c. mult. prof. Ing. Sinay J., DrSc. [1], Ing. Kotianová Z., PhD.[1], Ing. Glatz J., PhD.[1]
Faculty of Mechanical Engineering – Technical University of Košice, Slovakia [1]

juraj.sinay@tuke.sk, zuzana.kotianova@tuke.sk, juraj.glatz@tuke.sk

Abstract: *Prevention 4.0 as part of the enterprise's safety culture is developing HSE management system to address new challenges in prevention. Industry 4.0 anticipates new linkages between technology, man, and management systems to apply the most efficient IT systems to ensure the flexibility of the production process so that its output is a product that takes into consideration customer requirements. These changes include the existence of new types of risk due to the change of the position of man from the classical production centers to the area of superstructure activities, programmer, setter, maintainer, security technician for the digitization of production processes. Risk identification is based on defining the hazards and threats of a complex manufacturing system in the context of Safety and Security – Sa&Se, their formulation so that characteristic parameters can be efficiently digitized within the manufacturing process.*

Keywords: SAFETY, SECURITY, INDUSTRY 4.0, AUTOMATION, DIGITIZATION, RISK MANAGEMENT, W- DEPENDENCE, PREVENTION, MAINTENANCE, SMART FACTORY

1. Introduction

The formation of cyber-physical systems incites the world economy to constantly adaptation to the complex requirements of new systems, creating new requirements for businesses that have to adapt their activities to change. The same process goes through the man and his role within the Smart factory[6].

Industry 4.0 brings a great deal of change. Actually, functioning autonomous factories are no longer just the subject of debate and research focused on the implementation of Industry 4.0 elements to real industrial practice. Increasingly, the real world and virtual world are overlapping, even in this sector. Prevention 4.0 as part of the enterprise's safety culture is developing HSE management system to address new challenges in prevention[8].

2. Industry 4.0

The term Industry 4.0 (see Fig. 1) means a way of managing activity within technologies where production and logistics processes and within them machines and products communicate with each other and organize individual steps in the production process autonomously in synergy with the human factor. The goal is that processes take into account the requirements for safe operation so that products at the end of the production process meet customer requirements. Enterprises are targeting to creation of Intelligent (Smart) Factory[4].

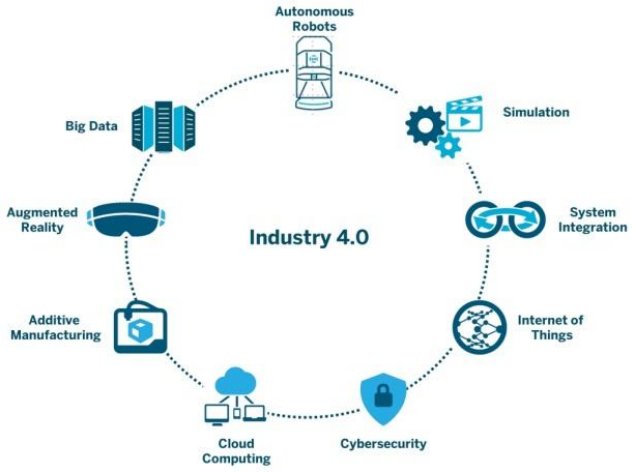


Fig. 1 *Industry 4.0*[3]

Industry 4.0 can be defined as a philosophy that defines the methods and methods of managing technologies that are already used in some areas of industrial production where machines, machinery and products communicate with each other and organize themselves individually in the production process (Fig. 2).

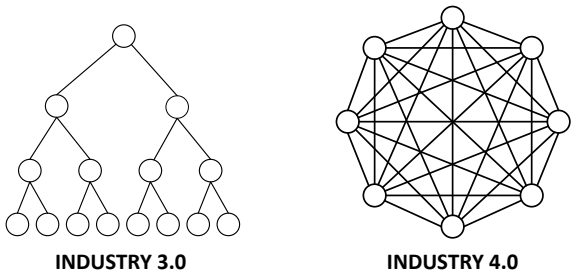


Fig. 2 *Difference in information transfer - Industry 3.0 and 4.0*

The term Industry 4.0 represents[7]:

- linking production to information and communication technologies,
- linking customer requirements directly with machine and device data,
- communication machines to machines - M2M,
- autonomous data acquisition and processing at both vertical and horizontal level,
- decentralized management,
- separate production created by communication between semi-finished products and machinery - a flexible, efficient and cost-saving resource[2].

It follows that meeting the requirements of Industry 4.0 will have the necessary impact on[5]:

- quality of work,
- requirements for qualification,
- new ways of organizing work and changing of many interactions and interactions in the human-machine-environment interface that we can imagine as new forms of collaborative work in the context of a digital factory.

Individual companies according to the degree of implementation of Industry 4.0 elements can be partitioned, for example, to five levels. Each level has a specific division of Integrated Safety & Security.

The individual levels of Industry 4.0 implementation:

1. Level - Basic level of digitization: The company does not address sector 4.0, requirements are not met or only partially met.
2. Level - Digitization between departments: the company is actively engaged in the topics of Industry 4.0. Digitization is implemented in various departments and the first

requirements of Industry 4.0 are implemented throughout the company.

3. Level - Horizontal and vertical digitization: The company is digitized horizontally and vertically. The industry 4.0 requirements were implemented within the company, and the information flows have been automated.
4. Level - Full digitization: The company is fully digitized beyond enterprise boundaries and integrated into value networks. Approaches in industry 4.0 are actively pursued and embedded within the corporate strategy.
5. Level - Optimize Full Digitization: The Company is a model for industry 4.0. Strongly cooperates with its business partners and therefore optimizes its value networks.

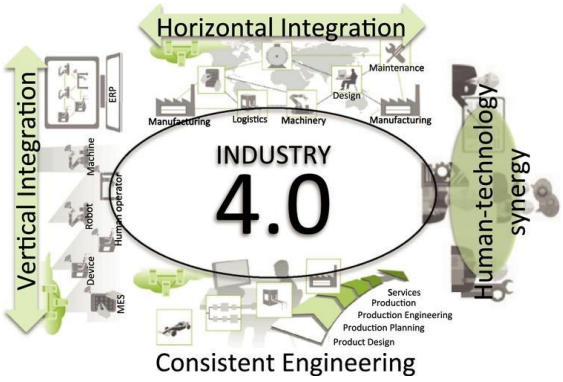
3. Safety& Security context

Industry 4.0 in its implementation in the company is emerging new safety requirements. On the one hand, such systems may not endanger people and the environment - "corporate (internal) safety" and, on the other hand, such devices must be protected for misuse and unauthorized interference - particularly in the area of data misuse, protection against unauthorized interference – Security[1].

Hence, the risk management methodologies in both production and logistics processes, and therefore also individual machines and machine systems, must meet the requirements of interconnection on the basis of Integrated Safety & Security at all levels of organization management[4].

Integration of Safety & Security must take place (Fig. 3):

a. in a horizontal plane (from the receipt and confirmation of the order to the end of life of the product);
b. in the vertical plane (from the lowest level of automated physical process management to the planning of production resources)
c. as well as in the level of integration of engineering processes (product lifecycle management).



Obr. 3 *Horizontal a vertical integration in Industry 4.0*[2]

Safety and Security ratios vary depending on the Industry 4.0 elements implementation level. This dependence can be called W - dependence. (Fig. 4). With the higher level of implementation of Industry 4.0 and the implementation of a higher number of robots, cobots in the factory, the number of workers exposed to work risks will decrease. Workers' safety will be more dependent on the security of digital technologies in the factory. In the area of security, cybersecurity will become more and more important, as a result of the threat of HSE over digital ways.

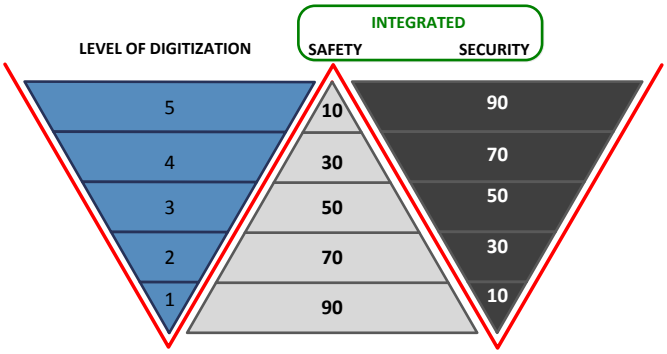


Fig. 4 *W – dependency - Example of Safety and Security Ratio (%) depending on the Industry 4.0 elements implementation level*

4. Results of discussion

The process of implementing Integrated Security Industry Sector 4.0 elements is divided into 6 steps (Fig. 5).

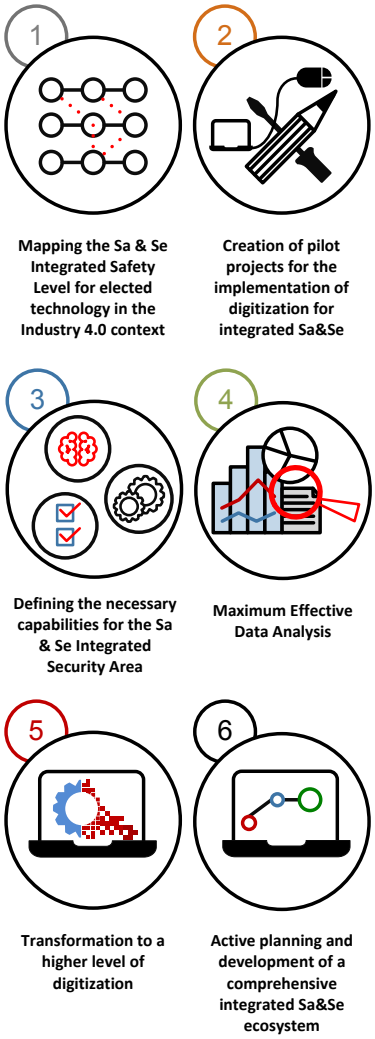


Fig. 5 *The Implementation of elements of Industry 4.0*

1. Mapping the level of integrated Sa&Se for selected technology s in the Industry 4.0 context - analyzing the processes that have the greatest impact on HSE from the point of view of Safety and Security, critical process analysis with the highest priority, and analyzing the devices with the highest added value …etc.
2. Creation of pilot projects for the implementation of digitization for integrated Sa&Se - demonstration of a

suitable concept for integrated Sa&Se and demonstration of business value.

3. Defining the necessary capabilities for the Integrated Sa&Se area - analyzing information from pilot projects, developing a strategy for the implementation of elements of Industry 4.0 and defining the needs and requirements for recruiting suitable staff.
4. Maximum Effective Data Analysis - data collection between different levels of Industry Platform 4.0, a follow-up analysis for the need for effective implementation of Integrated Sa&Se elements at Industry 4.0 level and above, and the creation of "multifunctional" expert teams.
5. Transformation to a higher level of digitization - digital culture support in the company, experimentation with new technologies, innovative ways of operation, implementation of Industry 4.0 elements to all areas of the enterprise.
6. Active planning and development of a comprehensive integrated Sa&Se ecosystem - introduction of complex platforms.

5. Conclusion

Industry 4.0 strategy includes the integration of Safety and Security. Safety and Security supposed to be interconnected (influencing). Application of Safety and Security control systems changes the static principle to dynamic, assumes identification of all production and distribution processes, data mobility as part of BIG DATA technology and human factor activity to ensure the functionality of relevant applications. Industry Strategy 4.0 requires a proactive approach to risk analysis, the essence of which is to implement the Safety and Security principles into the development and construction of machines and complex technologies in the context of using the Cyber Physical Systems principles.

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BUSINESS CRISES AND THEIR IMPACT ON ENTREPRENEURSHIP IN BULGARIA

Associate Prof. Alexieva-Nikolova V. PhD.[1], Assistant Prof. Valeva K. PhD.[2]
Business Faculty – University of Food Technology -Plovdiv, Bulgaria, , valentina_nikolova@abv.bg [1]
Business Faculty – University of Food Technology -Plovdiv, Bulgaria, tomika_888@yahoo.com [2]

Abstract: *Every business organization faces a crisis at a certain point in its development. Crisis phenomena for overcoming preventive measures can lead to serious economic and social problems for the organization or its bankruptcy. The crisis is a widely held view and its indications affect different aspects of the financial, social, spirit life of the nation. It's important to accent not only to the consequences of its manifestation but also to the opportunities for overcoming. This study focuses to analyze the factors for creating conditions for business entrepreneurship in order to draw attention to the opportunities for achieving lasting success for the Bulgarian society. This report aims to systematize key factors for the emergence of crises and their impact on innovation and entrepreneurial mindset. A questionnaire was used to collect data from a sample of 215 entreprises which were selected through stratified random sampling method. Collected data were analyzed using descriptive and inferential statistics with the aid of Statistical Package for Social Sciences (SPSS). The study revealed that innovativeness, creativity, business alertness and risk taking were significant for successful implementation of innovations and affecting performance of Bulgarian enterprises. The results show that crises are somewhat the driving force behind the creation of innovation and are a prerequisite for the emergence of modern forms of entrepreneurship so necessary to stabilize the economic system.*

Keywords: BUSINESS CRISIS, ENTREPRENEURSHIP, INNOVATION, BUSINESS ALERTNESS

1. Introduction

Crisis phenomena for overcoming preventive measures can lead to serious economic and social problems for the organization or its bankruptcy. Business crises occur at different intervals, provoked by a number of factors, characterized by different scales and forms of manifestation, and have the ability to repeat, i.e. have a cyclical character.

Every business organization faces a crisis at a certain point in its development. The etymology of the term "crisis" is of Greek origin. It is associated with a phenomenon or a set of phenomena, both personal and social, bearing negative changes. Personally, the concept of crisis is identifiable as a stressful state due to health, financial or other reasons. In the public context, the concept is associated with an unstable and dangerous situation caused by economic, political or international problems. The crisis, according to the glossary of foreign words [1], means "acute change, turning, decisive moment, verdict, decision on a question in a questionable situation. "In ancient times, the Greek philosopher Hippocrates considers the crisis limited only to the human organism [2]. In the field of international relations, the "crisis" is related to the emergence and development of conflicts characterized by a threat to basic social values (independence, freedom, etc.). In the economy, as a common feature of economic crises, "there is a shortage of resources for the effective realization of the assigned functions of enterprises, corporations, economic systems, the national economy of the country or the world as a whole" [3].

From the point of view of the company, the concept of crisis has been studied by different authors, who can generally be grouped into three groups:

- According to the *first group* of authors, the company's crisis

is predetermined by the environment in which businesses operate, under the influence of a specific combination of multiple external and internal factors. This group includes: according to Andreeva A. "An enterprise is in a critical situation when it does not meet the influences of the external and internal environment that bring it out of balance." [4]. According to her, "the crisis of the individual company (as a stage in the company's life cycle) may not coincide with a wider economic crisis - regional, national, global. It may be a consequence of a company's cycle of development, subjective mistakes, or natural disasters. The coincidence of the corporate crisis with each of the above-mentioned economic crises leads to deepening of the negative consequences in the company but also creates prerequisites for its faster overcoming" [5].

- The *second group* of authors saw the corporate crisis as a

state in which the economic sustainability and equilibrium of the enterprise was violated. This group includes: Popov R. who defines the crisis as "a state of instability characterized by a sharp exacerbation of the contradictions in the organization, threatening to preserve its effectiveness"; volatility is a feature of the economic performance indicators of the crisis enterprise [6]. On this basis Velchev K. argues that the sustainability of the indicators and their fluctuations characterize the progressive, respectively the crisis development of the enterprise [7].

- According to the *third group* of authors, the notion of crisis

is associated with a decisive moment in the development of the enterprise, where the unsustainable situation threatens its economic, financial and resource condition. Crises threaten the priority goals, challenge the traditional patterns of behavior and the values of the organization and put pressure in the form of a shortage of time for decision-makers [8]. This group includes Marinov P. [9], which defines the concept of crisis as a "phenomenon accompanying the development not only of various economic structures, the crisis is a spiritual, human, technological and natural phenomenon, where there is a collapse in the adaptation capabilities of a certain system an organism, an individual, a group, a community) with two possible outcomes: the first is a fatal one leading to death and death of the system, and the second is a positive, successful, relevant response to the challenges share of behavior. "Similar is the opinion of Jarni V. which defines the business crisis as "a period of instability, a situation in which serious changes are coming [10]. However, the outcome of the changes can be both extremely unfavorable and positive, but it is unambiguous that every crisis poses a threat to the organization. "This group also includes Luke R. [11], who defines the crisis as:" ... change - sudden or gradual, giving rise to an urgent problem requiring immediate intervention to resolve it. "

For business, the crisis is "any situation that has the potential to cause sudden and serious adverse effects on employees, reputation, or which may ruin it as a whole" [12]. In other words, a company in a crisis situation is struggling to achieve its goals, its stability is disturbed, and this may lead to its bankruptcy. According to Christov Ch. "The first signs of a crisis situation show that a moment has come solutions to emerging problems in the company may cause a development to turn into improvement or deterioration" [13].

2. Exploration

In summary, the crisis of the business organization is such a condition that there is a danger to its existence [14]. The analysis of the above definitions shows that the notion of "crisis" can't be unified. This gives reason to propose the following work definition necessary for the purposes of the survey: A crisis in an enterprise is a condition caused by the factors that have the potential to cause urgent problems in the economic, social and financial development of the enterprise requiring immediate intervention to solve them. The analysis of the above definitions shows that the notion of

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In its development, the crisis, as a phenomenon in the enterprise, passes through several stages [15]:

- *Latent (hidden) period*. At this stage, the prerequisites for the emergence of a crisis mature, but are not yet manifested externally.
- *Crash period*. During this period, all contradictions quickly exacerbated, resulting in a sharp deterioration of the dynamics. The firm's resilience is impaired.
- *Crisis mitigation period*. At this stage, prerequisites are created to overcome the crisis, providing a temporary equilibrium in the enterprise.
- *Period of exit from the crisis*. Every company crisis is over.

The concept of crisis can be studied not only as a process of disruption of the economic condition of an enterprise but also as an opportunity for transition to a qualitatively new state. Possible consequences are its destruction or renewal, exacerbation or smoothing of contradictions, rescue or deepening of the crisis. The timing of anticipation of the crisis and its adequate governance depends on the prospect of mitigating its negative impact, overcoming the crisis and even using it as a stimulus for development.

Business crises can be provoked by the impact of various causes and factors or by their cyclical development. In order to be governed, they must be determined by the various features and characteristics that give rise to or limit them. It is also important to distinguish the causes of a crisis from the symptoms of the crisis.

Causes of crisis are specific events or phenomena, resulting in the factors of crisis development, ie they are the sources for the development of the crisis and the growth and bankruptcy. General and specific reasons are distinguished [16].

General reasons - they relate to the cyclical development of the socio-economic system. For example, a common cause of insolvency and crisis in an enterprise is the "narrowing" of the market, which leads to a fall in demand for goods and services and a reduction in sales revenue, ie the solvency of firms is directly proportional to sales revenue. If, for a certain period of time, the growth rate of the company's liabilities exceeds the rate of increase in sales revenue, the entity will normally default into insolvency and crisis. A slowdown in sales revenue growth rates is observed when:

- reducing demand as a result of unsatisfactory quality, high price or reduced need for goods and services;
- increasing indebtedness in the period of cyclical crisis and recession, when firms fail massively or with unfair debtors;
- artificially restricting the market through customs barriers, quotas or other non-tariff restrictions, etc.
- an overwhelming rate of growth in companies' liabilities to the revenue growth trend is observed in the following cases:
- in the implementation of inefficient long-term capital investments with a long repurchase term;
- in the case of stocks that do not increase the volume of production;
- in the case of increases in non-production costs and not recouped through the sale of output;
- in dealing with other loss-making activities in the enterprise.

This complex of common causes is characteristic of all enterprises and is manifest in the development of the macroeconomic environment of the national economy.

Specific reasons are observed in particular periods of development of the socio-economic system, for example in transition periods. The macroeconomic framework of the Bulgarian economy in the post-1990 period is characterized by sharply decreasing production, rising inflation, devaluation of the national currency, devaluation of the basic and working capital of the companies, and the shortening of the national and international markets of the Bulgarian producers. The peculiarities in the cyclical development of the Bulgarian economy during the period 1990-2003 revealed some specific reasons, which generated the massive bankruptcies of the enterprises, especially those from the public sector.

The reasons for the occurrence of crises in enterprises can also be seen as: [17]

• objective, addressing the cyclical needs of modernization and reconstruction of the enterprise;

• subjective, error-prone and conflicting management, choice, and follow-up of a high-risk strategy;

• natural, climate-related, natural disasters, etc.

Symptoms of crisis development and its growth in bankruptcy are manifested in various indicators, such as changes in sales and profits, capital turnover, efficiency, profitability, etc., and especially in the trends of their changes. Early detection of symptoms is the most important condition for establishing the crisis development and establishing the magnitude of the crisis that has begun. The slow deterioration of results leads to a number of compromise solutions. In the positive case, an enterprise is still able to undertake remediation through job losses, claims, and liquidity, but in the short period of time the typical symptoms of the crisis need to be identified in order to identify adequate measures to neutralize it.

The *distinctive symptoms* of the crisis [18] that can be noticed in relations with business partners and can be categorized as important external factors in the following way (see Table 1).

Table 1: *The symptoms of the crisis in terms of external relations*

External relations	***Distinctive symptoms***
1. Clients	✓ offering high discounts; ✓ often offering goods for advertising purposes; ✓ easy price negotiations; ✓ diversity in the assortment becomes unsystematic; ✓ special discounts are accepted without any overcharge; ✓ quality problems and deadlines; ✓ the average volume of orders decreases; ✓ permanent customers are counted "on fingers".
2. Providers	✓ leverage of the company to suppliers due to a decrease in liquidity; ✓ cancellation of orders; ✓ orders of small quantities; ✓ wish to pay installments; ✓ change of suppliers.
3.Credit institutions	✓ the provision of the annual balance sheet, plans and monthly statements of business activity is delayed; ✓ exceeding the credit limits; ✓ searching for new credit institutions; ✓ cancellation of bills of exchange; ✓ return checks.
4.Auditors/ tax advisers	✓ stocks (stocks of raw materials are too high); ✓ determining too high value of unfinished and finished products; ✓ lower turnover of inventories; ✓ tax depreciation options that are not fully utilized; ✓ not using the legal possibilities for creating reserves; ✓ late preparation of the balance sheet; ✓ suspicious inventories to cover up the real financial results.
5.Business consultants	✓ leaving managerial staff; ✓ lack of information, critical remarks; ✓ worse capacity load; ✓ worse labor productivity; ✓ reduction of cost coverage; ✓ neglecting accounting records; ✓ neglect of the equipment; ✓ stagnation in investment and repair activities.

In parallel with the above mentioned symptoms, the symptoms of a possible crisis from the point of view of the internal relations of the company can be identified and suggestions and recommendations for overcoming it can be made (see Table 2)

From the studies of the symptoms of crisis in enterprises, it can be concluded that often before an enterprise experiences a crisis, typical symptoms are noticed prematurely by outsiders, such as clients, suppliers, credit institutions, auditors and consultants, and etc., as well as by the entrepreneurs and managers themselves. The quicker the response, the lower the intensity of the on-going crisis.

The reasons for the crisis in enterprises are the result of **the impact of various factors.** The first attempts to assess and predict

the change in the factors and their impact on the crisis situation of the companies date back to the 1920s and are grouped in two directions:

- *the first* is realized within the framework of the retrospective analysis, when the factors for the already existing crisis are revealed and evaluated;
- *the second* is realized through forecasting when these factors, which have the most significant impact on the development of the crisis in the future, are revealed and evaluated.

In real diagnostic practice, these two strands are most often intertwined and used together to assess the current, regular recurring activity of an enterprise when the process of generating the performance indicators continues in the future. Investigating the location and the capabilities of factor analysis in economic forecasting, Kovalev V. points out that this analysis is "important not only for itself, it is done for itself but only when it is active" [19] .

Table. 2. *The symptoms of the crisis in terms of internal relations*

Internal relations	***Distinctive symptoms***
1. Management	✓ adherence to old concepts; ✓ omission of the delegation; ✓ deficiencies in decision making; ✓ lack of control; ✓ patriarchy in the management style; ✓ lack of collective behavior; ✓ increasing the number and duration of conferences; ✓ interruption of communication; ✓ heterogeneous management circle.
2. Human Resources	✓ insufficient motivation (termination of employment contracts); ✓ inadequate qualification of staff; ✓ the remuneration system generates criticism in the company; ✓ the level of aggression among workers rises; ✓ fear of losing jobs.
3. Placement	✓ the characteristics of the products do not meet the requirements of the market; ✓ wrong pricing policy; ✓ unsatisfactory service; ✓ inconsistency of distribution channels; ✓ decrease in the volume of orders; ✓ the sales agents leave.
4. Production	✓ focusing on a single product group; ✓ obsolete / untested technology; ✓ unused production capacities, production in stock; ✓ stagnation in investment and repair activities; ✓ disorder in the organization; ✓ quality problems and sales times; ✓ replacing expensive products with cheap ones; ✓ obsolete production in stock.
5. Organization	✓ unclear tasks / rules; ✓ lack of adaptive organizational behavior; ✓ deficiencies in the organization of production; ✓ lack of planning of the activity and control; ✓ duplication of work; ✓ fear in decision-making in middle management.
6. Investments	✓ too early investment; ✓ lack of investment; ✓ incorrect assessment of the capital investments; ✓ implementation gaps; ✓ funding errors; ✓ missing the reduction of the capital investments.
7.Research activity	✓ lack of research; ✓ research without: main purpose, planning and design, control, return of capital investments ✓ isolation in the company.
8. Supply/ Logistics	✓ strong dependence on suppliers; ✓ too high capacity and too high costs of the fleet; ✓ accumulation of performance warnings; ✓ suppliers reduce the deferred payment terms.
9. Finance/ Controlling	✓ gaps in the cost and calculation report; ✓ lack of financial planning; ✓ lack of early warning systems; ✓ high interest costs; ✓ limiting creditors; ✓ request security collateral.

The disclosure of factors means the opportunity to manage the development of the crisis process in the future. All the factors that influence the development of the business process in the enterprise also determine the results of its business activity. The disclosure and assessment of a larger number of significant and viable factors provides a better opportunity to determine and manage changes in the enterprise's crisis situation. Depending on the direction of their action, factors can be defined as positively acting (constructive for the company) and negatively acting (destructive to the company). Every crisis has a strictly individual character because it carries a unique combination of internal ones and external factors. The identification of factors in anti-crisis management of companies begins with the establishment of their place in the internal or external environment of the enterprise. By this feature, the factors are subdivided into two groups:

- **exogenous (external**) or independent of the business.

External factors are those on which the firm cannot directly influence. For their part, according to the level of research, they can be divided into *international, national and sectoral*.

- **endogenous (internal)** or business-related.

Internal factors influencing the development of the company's crisis are the result of the business itself. They may be associated with the adoption of innovative and high-risk investment strategy imperfect management, poor organization of production, risky marketing strategy, production of uncompetitive production, high cost products, low profitability and others.

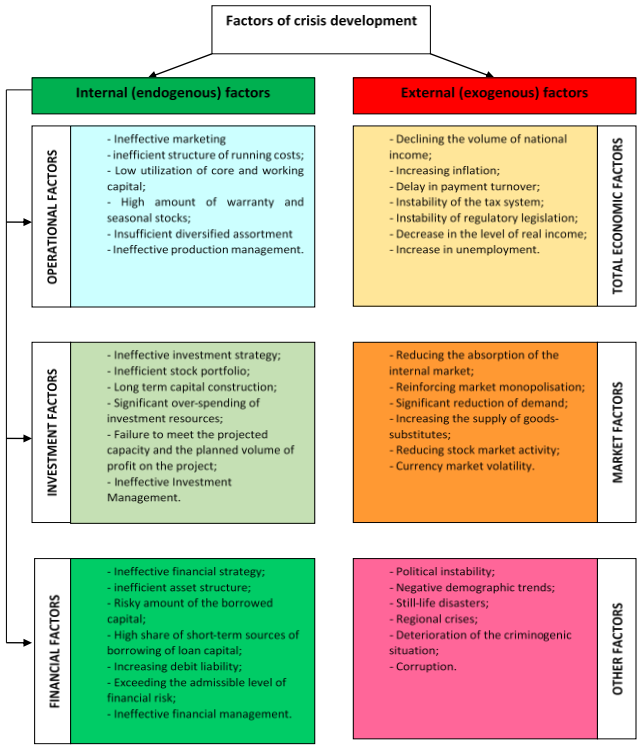

Fig.1. *Factor's classification for crisis development*

The research implies the summary that the external factors for a crisis in the company are related to the formation of the competitive environment and its ability to protect itself from the competitors, while the internal factors concern the company management, the management of the human resources, production, organization, finance, controlling. Both internal factors and external factors can be constructive or destructive. In both cases, the management of the company - management of human resources, sales, production, organization, finance, controlling - is affected.

3. Research methodology

A survey research design was used in this study. This enabled the researcher to collect responses of owners/managers of food industry' companies in South-Central Bulgaria, with regards to the study variables. The total population was 256 licensed companies established in Plovdiv and region. The population statistics was obtained from Bulgarian Chamber of Commerce and Confederation of the Employers and Industrialists in Bulgaria – CEIBG. Stratified sampling was used to select 215 companies from food industry. A stratified random sample was a useful blend of randomization and

categorization, which enabled both a quantitative and qualitative process of study to be undertaken. This study focuses to analyze the factors for creating conditions for business entrepreneurship in order to draw attention to the opportunities for achieving lasting success for the Bulgarian society. This report aims to systematize key factors for the emergence of crises and their impact on innovation and entrepreneurial mindset.

The study used a structured questionnaire in data collection. The questionnaire was carefully designed and administered to the respondents. The questionnaire was designed on a four point Likert-Scale which ranged from strongly agree (4 points), agree (3 points), disagree (2 points) and strongly disagree (1 point). The items were structured to capture information on the dependent variable (organizational performance) and the independent variables (innovativeness, creativity, business alertness and risk taking).

Factor analysis were used in this study to measure the validity of the instrument. **Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA)** were used to assess the construct validity of each variable in the study.

The Cronbach's coefficient alpha was applied on the results obtained to determine how items correlate among them in the same instrument. Cronbach's coefficient Alpha of more than 0.7 was taken as the cut off value for being acceptable which enhanced the identification of the dispensable variables and deleted variables. It is evident through the Cronbach's Alpha values that the reliability coefficients of all the study variables are high and suitable for the current study objectives.

Table 3*. Reliability coefficients of the study variables*

Variables	***№ of items***	***Reliability coefficients***
Organizational performance	*4*	*0, 673*
Alertness	*4*	*0.872*
Risk-taking	*3*	*0,743*
Creativity	*3*	*0,754*
Innovativeness	*6*	*0,824*
Overall Reliability		*0,722*

Source: Own field survey, 2017

All the above statistical tests were analyzed using the Statistical Package for Social Sciences (SPSS), version 19. All tests were two-tailed. Significant levels were measured at 95% confidence level with significant differences recorded at $p < 0.05$.

Table 4. *Correlations statistic for relationship between variables*

Variable	**Organizational performance**	**Innovativeness**	**Creativity**	**Business Alertness**	**Risk-taking**
Organizational performance	1				
Innovativeness	*0,781*	1			
Creativity	*0,654*	*0,466*	1		
Business Alertness	*0, 478*	*0,673*	*0,523*	1	
Risk-taking	*0,532*	*0,356*	*0,428*	*0,651*	1

******* *Correlation is significant at the 0.01 level (2-tailed).*

Pearson's measures the strength and direction of the linear relationship between variables. From the results, a significant relationship exists between the variables (table 2). I*nnovativeness* was shown to contribute 78.1% of the change in organizational performance as indicated by the correlation coefficient value of 0.781 which is significant at $\alpha = 0.01$. *Creativity* was positively correlated to organizational performance as indicated by correlation coefficient value of 0.654 indicating that the creativity was a significant factor and contributed up to 65.4% of the change in organizational performance. *Business alertness* was also shown to contribute 47.8% of the change in organizational performance as indicated by the correlation coefficient value of 0.478 which is significant at $\alpha = 0.01$. The correlation for *risk taking* showed that 53.2% of the change in organizational performance was significantly accounted for by risk taking as shown by correlation coefficient value of 0.532 (significant at $\alpha = 0.01$). This paves way for multiple regression analysis.

Table 5. *Multiple regression model*

R	***R²***	***Adjusted R²***	***Std. error of the estimate***	***Durbin Watson***
0.834*	0.923	0.679	0.802	1.566

**Predictors: innovativeness, creativity, business alertness, risk taking*
***Dependent variable: organizational performance*

Conclusion

Innovativeness has significant effect on organizational performance in times of crisis in the companies from food industry in Plovdiv and Plovdiv region. *Creativity* has also significant effect on organizational performance in times of crisis in Plovdiv region. *Business alertness* has no significant effect on organizational performance in times of crisis in Plovdiv region. This indicates that for each unit increase in the positive effect of business alertness, there is 0.678 units increase in organizational performance. *Risk taking* has significant effect on organizational performance in crisis. This indicates that for each unit increase in the positive effect of risk taking, there is 0.782 units increase in organizational performance.

The purpose of this study was to explore the effect of entreprenerial mindset in the organizational performance in the condition of crisis. Managers/owners with an entrepreneurial mindset see needs, problems and challenges as opportunities and develop innovative ways to deal with the challenges, and exploit and merge opportunities throght implementring innovations. Acquiring aentrepreneurial mindset and process maturity requires re-learning how to motivate themselves, identify business opportunities, take risk, and become creative and innovative.The study revealed that innovativeness, creativity, business alertness and risk taking were significant for successful implementation of innovations and affecting performance of Bulgarian enterprises. The results show that crises are somewhat the driving force behind the creation of innovation and are a prerequisite for the emergence of modern forms of entrepreneurship so necessary to stabilize the economic system.

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ИННОВАЦИОННОЕ НАПРАВЛЕНИЕ ПОВЫШЕНИЯ ЭКОНОМИЧЕСКОЙ И СОЦИАЛЬНОЙ ЭФФЕКТИВНОСТИ ОБЩЕСТВЕННЫХ СИСТЕМ В ТРУДАХ ОСНОВОПОЛОЖНИКОВ МАРКСИЗМА

В.Н. Григорьев
Институт экономики, менеджмента и информационных технологий, доцент каф. Экономической теории и экономики предпринимательства, Санкт-Петербург, Россия

Аннотация: *Инновационное направление повышения ресурсного потенциала общественно-экономических систем предполагает переход к новой, жизненно-необходимой в современных условиях парадигме общественного воспроизводства. Рассматриваются фундаментальные положения основоположников марксизма и формулируются условия перехода к качественно отличной - возвышающейся над экономической формации.*
Ключевые слова: *общественно-экономический потенциал, рациональный выбор, двойственная природа человека, сознания, над экономическая формация.*

INNOVATIVE DIRECTIONS OF INCREASING THE ECONOMIC AND SOCIAL EFFICIENCY OF SOCIAL SYSTEMS IN THE WORKS OF THE FOUNDERS OF MARKSISM

V.N. Grigoriev
Institute of Economics, Management and information Technologies, Associate Professor of Department of Economic Theory and Business Economics. St. Petersburg, Russia

Abstract:
The innovative direction towards increasing the resource of socio-economic systems presumes the transition to a new paradigm of social reproduction, indispensable in the present-day conditions. The article considers the fundamental principles of the founders of Marxism and formulates the conditions for transition to a qualitatively different supra-economic structure.
Keywords: *spiritual, moral, intellectual, development, conscious, rational, choice, supra-economic structure.*

“Введение”

То, что марксистский экономический детерминизм, психоанализ или структурная лингвистика фонологического бессознательного выявили спорность или сомнительность некоторых знаний, с объективной необходимостью подтверждает их преходящий характер и знания общественно-экономических наук также не являются исключением. В то же время, истинным является то, что мы обладаем способностями не только приблизиться к реальному как таковому, но и в значительной степени овладеть им в результате непрерывного их совершенствования - совершенствования собственного интеллектуального и, прежде всего, исключительно человеческого - *духовно-нравственного* капитала.

Гуманитарные науки призваны служить всестороннему изучению исторически сложившихся общественно-экономических отношений и развития личности во всех ее многообразных измерениях. Пренебрегая этой реальностью, гуманитарные науки рискуют превратиться в антигуманные.

“Результаты и дискуссия”

В учении Маркса, веровавшего в отличие от Фейербаха не в божественную любовь, а в революционную практику и в экономические реформы, человек рассматривается как. элемент функционирования экономики, определяется ею и представляет собой совокупность всех общественных отношений и прежде всего отношений экономических. В человеке, утверждал Маркс, все обусловлено действием материально-экономических общественных факторов. В свою очередь экономика - базис, определяющий надстройку, или комплекс политических, правовых, нравственных, философских, религиозных и иных условий формирующих сущность человека и его поведение. В любом случае Маркс рассматривает человека не как индивидуальную личность, но как представителя вида, общественное и общинное существо

способное к самореализации только в качестве родового существа. Он считал, что род человеческий в целом имеет большую ценность, чем отдельная личность, а общество, как связующее звено между человеком и природой - практически необходимое условие самореализации и достижения экономической свободы человека [1. Маркс, 1844, с.44,45,59,64.].

Диалектический материализм Маркса и Энгельса наибольшего успеха добился во второй половине XIX начале XX вв. Центральным положением этого учения утверждается, что все сущее есть материя и только материя; в процессе развития материи, утверждается в учении, происходят диалектические скачки, которые и вызывают к жизни качественно отличные - более высокоорганизованные реальности, породившие человека и общество, что представляется весьма спорным и, с чем невозможно согласиться.

Упрощенный, механистический подход к объяснению сокровеннейшей истины - тайны происхождения человека, его природы, эволюционной целеустремленности и предопределил утверждение авторов этой теории, рассматривавших человека лишь как результат «диалектического скачка», исключительно как совокупность всех общественных отношений и прежде всего отношений экономических. Все в человеке «в последней инстанции», считают сторонники этой теории, обусловлено действием лишь «материально-экономических общественных факторов». В ней нет места человеку, личности как таковой наделенной сознанием; духовным устремлением, разумом, волей и уникальным веером желаний. Получается, что, с одной стороны, в процессе общественного воспроизводства материально-экономическая, а также и технико-технологическая предопределенность сознания, в том числе интеллектуального потенциала человека, лишенного важнейшей его половины - духовно-нравственного устремления, волевого начала и божественной любви - ограничивает его (сознание) лишь удовлетворением потребностей низшего «я» человека – удовлетворением его животных желаний и земных страстей. Будто бы это вовсе не человек, а этакий биоробот, человекоподобное существо – полу-человек, лишенный собственно человеческой составляющей - своего ВЫСШЕГО «Я» творит свою историю. Уж не сон ли разума человеческого породил это половинчатое чудовище и с упорством достойным лучшего применения и по

сей день вскармливает его не жалея ни средств, ни поколений - на свою погибель?

Нескончаемая вереница социально-экономических систем и непрекращающихся войн, неизбежных при этом лишений и невообразимых страданий народов - это вполне закономерный результат нашего невежества, незнания собственной природы - двойственной природы человека, собственного сознания, включающего как Высшее «Я», так и низшее «я» - механизма их взаимодействия, взаимопроникновения и взаимообусловленности.

С другой стороны, получается будто, упоминаемые в теории Маркса «материально-экономические общественные факторы» - результат деятельности, образно говоря, каких-то «инопланетных» существ, подаривших людям в придачу еще и «всю совокупность социально-экономических отношений» их определяющих»!

Из положений философского наследия Маркса, с настоятельной необходимостью ответов на них, рождается ряд вопросов: Каков механизм самореализации человека и от чего человек должен освобождаться? Может быть от определенных общественных условий, например, от классово организованного общества или некоторых его атрибутов? Каковы горизонты самореализации и освобождения человека и нужно ли…? Ведь линия горизонта – недостижима! О какой же самореализации и экономической свободе человека в этом случае может идти речь?

Конечно же, согласно марксистской теории, лишь о самореализации человека, личности в условиях существующих, «материально-экономических общественных факторов», говоря о взаимосвязи и взаимодействии которых утверждается ведущая и определяющая роль производительных сил (и только!?) в их диалектическом единстве с производственными отношениями.

Действительно, развитие производительных сил меняет структуру и характер собственно производственных отношений, то есть отношений непосредственного производства, что безусловно ведет к изменению и уже существующих экономических отношений наемных работников и их хозяев. При этом остается без ответа: «Под влиянием каких сил и каким образом складывается эта «ведущая и определяющая роль производительных сил» в особенности за пределами самого производства, то есть в их (производительных сил) взаимодействии с экономическими отношениями по поводу этого производства? Да еще, речь идет о самореализации человека лишь как «общественного и общинного существа способного к самореализации только в качестве родового существа». То есть, о самореализации человека низведенного до «родового существа» - лишенного своего собственно человеческого, унаследованного божественного начала, или Высшего «Я».

Расцвечиваемое соответствующими ему (низшему «я» человека) духовно-нравственными устремлениями и проявлениями разума в рамках заданных (кем то?) «материально-экономических, общественных факторов и отношений» это полу-человеческое существование и формирует тот или иной уровень и характер экономической и социальной его (человека, личности) свободы. То есть - свободы в удовлетворении, в сущности, животных желаний и земных страстей человека, воспринимаемых «от своего носителя, являющегося вместилищем всех этих желаний и страстей» - от инстинктивной «животной Души» человека [2. Блаватская, 1996, с.31]. Не секрет, что «для обычного человека горизонтом его мечтаний является удовлетворение его личных потребностей. Стрелки его компаса указывают, как правило, на объекты его вожделения. Разум, его интеллектуальный потенциал подчинен чувствам, порождающим желания и пристрастия, человек творит себя по образу и подобию своих желаний. В основном мы руководствуемся своими желаниями, обладающими определенной интеллектуальной силой, но обделенные под-час *духовной мудростью* они являются, в большинстве случаев, движущей силой животной жизни».(из высказываний Е.П. Блаватской)

К. Маркс и Ф. Энгельс справедливо считали, что труд является самосозидающей человеческой деятельностью потому, что воздействуя «на внешнюю природу и изменяя ее, он в то же время изменяет свою собственную природу. Он развивает дремлющие в ней силы и подчиняет игру этих сил своей собственной власти» [3. Маркс, 1978, с.188-189.]. Именно Маркс и Энгельс подняли на невиданную высоту ценность труда как первой жизненной необходимости. «Выдающаяся роль труда, человеческой практики составляет основу всего учения Маркса. Он считал, что в капиталистическом обществе труд порождает отчуждение трудящегося от продукта его труда. Труд превращается в товар, поэтому человек, проводящий свою жизнь в труде, тоже становится товаром. Такое положение, считал Маркс, должно быть упразднено в результате революционной экспроприации экспроприаторов». Так что же: путем кровопролития и насилия!? Но ведь известно, что насилие порождает насилие, о чем и свидетельствует вся история человеческая.

К. Маркс подчеркивал, что система рационализируется и революционным путем обратится в общество без частной собственности и без классов, люди станут невинны, справедливы, свободны, уравновешены и счастливы! «Царство свободы, писал Маркс, начинается в действительности лишь там, где прекращается работа, диктуемая нуждой и внешней целесообразностью, следовательно, по природе вещей оно лежит по ту сторону сферы собственно материального производства…которое , однако, может расцвести лишь на этом царстве необходимости, как на своем базисе.».[4.Маркс,1978,с.892-893]; С уничтожением частной собственности «труд в условиях торжества коммунизма, как предполагал Маркс, станет первой жизненной потребностью, условием полного и счастливого развития человеческой сущности» [5. О Марксе G.R. de Yurre, El marxismo…, 1976]. Вот только непонятно: кто же эти рационализаторы-революционеры и откуда они вдруг возьмутся, если, по утверждению Маркса «человек – лишь функция экономики и экономика - основа, базис определяющий сущность и поведение человека? В результате каких природных или социально-экономических явлений, процессов свершится это историческое событие? Ведь человеку в марксистской теории преобразования общества отводится пассивная – наблюдательно-ожидающая роль пассажира поезда, направляемого и ведомого локомотивом экономики, «определяющей сущность и поведение человека».

Самосознание человека вопрошающее самое себя: кто я, для чего я живу, страдаю и в конце концов умираю? — несомненно уже предполагает некоторое пред-знание и некоторое «учёное незнание», без которых такое самосознание и самовопрошание было бы невозможно. В поисках ответов на эти и многие другие вопросы наше вопрошающее «я» блуждает в лабиринте собственного сознания, так или иначе отражающего реальность, с желанием узнать о себе — кто «я», в качестве человека как такового, элементарной составляющей той или иной социально-экономической системы и что предопределило мое появление, положение и роль в этой системе, среди людей, где я родился, живу и должен умереть?

Опережая собственное изложение и рискуя быть в данный момент не вполне понятым все же замечу, что именно экономика и вся совокупность общественно-экономических факторов общественного воспроизводства – функция человека, личности, общества, но никак не наоборот. Незнание природы человеческого сознания, механизма его рационального выбора и сегодня является огромным препятствием на пути эволюционного преодоления материально-экономической парадигмы, но уже в постиндустриальном обществе.

Дальнейшее эволюционное развитие человека, общества и объективно необходимый его переход на более высокую историческую ступень своего развития - над экономическую – следующий, объективно необходимый и неизбежный шаг

приближающий нас к экономической свободе согласующейся с фундаментальной целью эволюционного развития человека и общества. Он не произойдет сам по себе лишь под влиянием экономико-максимизирующей парадигмы, но предполагает переосмысление роли человека, его сознательной духовно-нравственной деятельности и в том числе использование интеллектуального капитала в процессе общественного воспроизводства в современных условиях. Понимание эволюционной логики перехода от доминанты в общественном воспроизводстве непрерывно растущих и неуклонно возвышающихся потребностей человека, общества к осознанно рациональному их удовлетворению всех членов общества – объективно необходимый рычаг имеющий решающее значение для увеличения (по существу почти неограниченного) ресурсного потенциала экономических систем уже сегодня.

Пока приходится констатировать – этого не произошло, да и не может произойти в современных условиях, предшествующих чрезвычайно продолжительному периоду эволюционных преобразований человека, общества, как не могло произойти превращение обезьяны, занимающей более низкую (точнее, тупиковую) эволюционную ступень, чем человекоподобное существо наделенное сознанием - в человека. [6. Блаватская, 1998, с.763, 781].

Говоря о возможности реального познания глубинной природы человека: Высшего «Я» личности – проводника божественного духа - взаимодействующего с физическим, земным его воплощением, которое наделено реальными атрибутами: божественной любовью, разумом, волей и органами чувств, конституирующими его низшее «я» - мы говорим о возможности познавать особенности их взаимосвязи, взаимообусловленности и взаимодействия. Ведь именно эти факторы сознания - важнейший рычаг целенаправленного, обоснованного повышения ресурсного потенциала экономических систем, когда доминирующими в развитии человека, общества становятся духовно-нравственная составляющая и интеллектуальный капитал человека, личности. Когда в условиях постиндустриального общества максимизирующая парадигма уже не в состоянии обеспечить рациональное расходование ресурсов и производительное потребление. Примеров можно было бы привести бесчисленное множество: от сверх изобилия произведенных и никому не нужных товаров, выполненных работ (гражданского и военного назначения), до неоправданно завышенного удовлетворения потребностей человека, общества, ведущего к их деградации как физиологической, так и духовно-нравственной.

“Заключение”

Не будет преувеличением сказать, что и сейчас доминирующим фактором, определяющим отношения между людьми, остается эгоизм.. Современные общности людей — это общества, в которых господствует материально-экономическая парадигма, экономика-политическая деятельность, жажда наживы, стремление к извлечению наибольшей выгоды, любой ценой, за счет всех остальных. Всемогущий бог этих обществ – ненасытный Маммона.- от первобытно-общинного объединения людей и до современного постиндустриального капиталистического общества владеет сердцами и умами подавляющего большинства человечества. Высшим достижением и смыслом жизни для большинства наших собратьев остается максимизация собственного дохода, неограниченного материально-экономического благополучия.

Манящим и обманчивым золотым блеском расцветает эгоизм, мучающий и уничтожающий миллионы людей, которые живут в отчуждении от продуктов своего труда, в нехватке необходимого. До сих пор многие не поняли, что важнее не наличие огромного количества денег, растрачиваемых в подавляющем большинстве случаев на удовлетворение человеком своих животных желаний и земных страстей низшего «я», а умение быть прежде всего достойным гражданином, другом, супругом и отцом. Еще не поняли, что в подобной ситуации, как правило, происходит не освобождение человека, а его духовную-нравственная деградация. Между тем, эволюционирующий практикующий человек «гуманизирует» природу и, в том числе, себя в направлении фундаментальной цели бытия, тогда как глубинная перспектива марксистской философии - экономико-материалистическая»[7.Valverde, 1979,с.481]. Животная составляющая эгоистичного человека – его низшее «я» - подавляет в его сознании духовно-нравственный потенциал высшего «Я», направляя его интеллектуальный капитал на удовлетворение животных желаний и земных страстей, усугубляя и отягощая последующую кармическую зависимость его и его близких.

Бесспорно актуальное и сегодня суждение Маркса, в котором ведущую и определяющую роль он отводит сознанию человека, осознанной его целеустремленности, как ослепительная вспышка сверхновой в космической тьме засвидетельствовало прорыв гения в пространство иного – духовного, предсуществующего физико-математическому - измерению реальности : «Мы предполагаем труд в такой форме, в которой он составляет исключительное достояние человека. Паук совершает операции, напоминающие операции ткача, и пчела постройкой своих восковых ячеек, посрамляет некоторых людей-архитекторов. Но и самый плохой архитектор от наилучшей пчелы с самого начала отличается тем, что, прежде чем строить ячейку из воска, он уже построил ее в своей голове. В конце процесса труда получается результат, который уже в начале этого процесса имелся в представлении человека, т.е. идеально» [8.Маркс,1978, с.189.]. Он не только производит формальное изменение в естественной материи, но реализует осознанную цель. Он представляет себе эту цель - совокупность одухотворенных форм, результат деятельности его сознания (духовного и интеллектуального), который определяет, подобно закону, его образ действий, и подчиняется их велению без страдания или в умеренном страдании; в нем живет образ человека, сохраняющего изначальную естественную целостность.

Эпоха общественно-экономических формаций Маркса подошла к своему завершению. Мы на пороге перехода в принципиально новую - над экономическую формацию, где доминирующее влияние в развитии личности, общества будут иметь иные - не экономические , но качественно отличные и прежде всего духовно-нравственные факторы и критерии оценки социальной и в том числе экономической эффективности общественного воспроизводства. Важнейший из них – духовно-нравственный потенциал личности, общества - окончательно укрепит свое доминирующее значение в оценке достигнутых результатов социального развития, их согласованности с эволюционным развитием в направлении фундаментальной цели общественного воспроизводства. Довольно украшать узорами, полировать и лакировать свой социально-экономический фундамент! Пора уже, в конце концов, приступить к строительству этого величественного здания – человека РАЗУМНОГО, рационального! Пора, наконец, сказать человеку ЖИВОТНОМУ – нет!

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Приложение 2

Заявка

1.	ФИО (полностью)	Григорьев Виктор Николаевич
2.	ФИО (полностью) на англ. языке	Grigoriev Viktor Nikolaevich
3.	Учёная степень, учёное звание	К.э.н.
4.	Должность	доцент
5.	Должность на англ. языке	Ph.D in economics, associate professor of Economic Theory and Business Economics
6.	Организация (полное официальное название)	УТУ и Э, институт экономики, менеджмента и информационных технологий
7.	Организация (полное официальное название) на англ. языке (если имеется)	UTU and E, Institute of Economics, Management and Information Technology
8.	Форма участия (очное, дистанционное, заочное)	очное
9.	Название статьи	**“Инновационное направление повышения экономической и социальной эффективности общественных систем в трудах основоположников марксизма”**
10.	Название статьи на англ. языке	“Innovative directions of increasing the economic and social efficiency of social systems in the works of the founders of marksism”
11.	Область (край), город	Санкт-Петербург
12.	Почтовый адрес (с указанием индекса)	195271. СПб, ул. Замшина, д, 52, корп. 2, кв. 120.
13.	Контактный телефон	8.9118381135
14.	**e-mail**, факс (если имеется)	Teosofia2006@jandex.ru

НЕКОТОРЫЕ АСПЕКТЫ ТЕОРИИ И МЕТОДОЛОГИИ ПРИРОДОПОДОБНОГО УПРАВЛЕНИЯ

SOME ASPECTS OF NATURE SIMILAR MANAGEMENT

As. Prof. PhD Yegorova-Gudkova T, Economics – Law Faculty of Odessa National Mechnikov's University, Odessa. Ukraine.
Tatiana_e@mail.ru

Abstract: *The main issues are considered in this topic:. Creation of newtheory and methodology of nature similar management*
***Keywords**: NATURE SIMILAR MANAGEMENT, SELF-ORGANIZATION, MODELLING, INVARIANTS, HARMONIOUS DEVELOPMENT, MACROECONOMIC PROCESSES*

1. Введение

В современных условиях распространённость кризисных и чрезвычайных ситуаций достаточно высока. Главной причиной является структурно-функциональная неустойчивость систем, т.е. недостатки, заложенные при проектировании сложной системы.

В целях профилактики возникновения подобных ситуаций необходимо разработать метод структурно-функциональной нормализации сложных систем, в котором общее, инвариантное по отношению к предметным спецификациям отраслей или секторов, где может возникнуть кризисная или чрезвычайная ситуация, составит основу разрабатываемой методологии

Эволюция системы управления, использование моделей природоподобного или биогенетического управления в условиях негативного антропогенного влияния на окружающую среду призваны изменить существующую мировоззренческо-методологическую парадигму. Проектирование искусственных систем как целостных распределённых систем со сложной динамикой должно осуществляться подобно естественным системам, модели которых представлены в Природе и основаны на математических константах Мироздания, наделяющих систему свойствами самоорганизации, самогармонизации и оптимального расходования ресурсов.

2. Предпосылки и средства для решения проблемы

Без теоретического и методологического обеспечения работы с информацмей невозможно достигнуть управленческого эффекта и поставленной цели. Процесс управления является информационным и незнание законов образования и протекания информационных процессов, отсутствие методологии работы с информацией не даёт возможность правильно оценить влияние факторов воздействия среды на систему что, приводит к неэффективности использования всех видов ресурсов и их избыточного потребления.

Рассматривая природные объекты, которым присуще такое проявление самоорганизации, как самовоспроизведение цикла, что является главной характеристикой системно-динамического подхода, имеющего в качестве математического обеспечения обобщенные золотые сечения, системно связывающие организацию и дезорганизацию, хаос и порядок в строении и непрерывном динамическом изменении сложных природных систем..

Исследование свойств динамического формообразования живых объектов, изучение математических пропорций и процессов динамического формообразования может быть использовано при проектировании искусственных систем с заданными свойствами самоорганизации, в т.ч. экономических, как совокупности нелинейных процессов с положительной обратной связью

3. Решение рассматриваемой проблемы

Теория природоподобного управления и её методы в современный период только разрабатываются. Однако, очевидным является трансдисциплинарное содержание этой теории.

Методологические ошибки при проектировании систем, отсутствие анализа структуры систем, в том числе на основе инвариантного подхода формируют высокую вероятность совокупного отрицательного результата при практическом использовании такой системы.

Фактически, в практике управления и экономики отсутствуют самоорганизующиеся экономические системы без структурных деформаций, а в практике природоподобного или биогенетического управления такое явление невозможно, поскольку живые объекты со структурными или генетическими деформациями нежизнеспособны.

В хозяйственной практике объекты с некорректно заданной или деформированной вследствие внешних и внутренних воздействий структурой малоэффективны, поскольку нерационально используют ресурсы. В результате такие бмзнес- структуры продуцируют конфликт между техносферой и биосферой и являютя катализаторами будущих масштабных кризисный возмущениц.

4. Результаты и дискуссия

. Как спроектировать «геном» природоподобной экономической системы? Ответ должна дать разрабатываемая на основе анализа моделей биогенетических объектов и синтеза их пропорций теория и методология природоподобного управления. Исследуя такую тему как филлотаксис на основе инвариантного подхода, основных положений теории структурной гармонии систем, методов системного синтеза мы приходим к выводу, что это тема методологического масштаба, способная дать ответ на вопрос о проектированияя генома природоподобныз объектов в экономике. «По-видимому, все или почти все возможные элементы её решения давно уже выявлены, — и
задача исследователей состоит прежде всего в том, чтобы согласовать их друг с другом, указав границы разумной применимости каждого из подходов». «Результаты численного моделирования приводят нас к предположению о том, что филлотаксис Фибоначчи возникает не за счёт абсолютно точного отмеривания углов, приводящего к «предустановленной гармонии» оптимального расположения зёрен, — но в результате действия динамических факторов, сообщающих системе структурную устойчивость» [1]..

Алгоритм разработки теоретико-методологического обеспечения природоподобного управления может быть следующим:

1. Применение ценологического подхода, как вероятностного метода, характеризующего структурные составляющие системы и их иерархичность

2. Исследование качества существующих систем управления экономическими объектами. При этом следует основываться на таких законах и принципах как:

– системогенеза;

– неравновесной динамики,

– устойчивого функционирования самоорганизующихся систем,
– самосогласованного строения сложных структур,
– принципом самовстряхивания сложных структур в ходе приобретения ими устойчивого функционального режима и системного качества,
–законами гармонизации действия малых факторов и микровключений

3. Для тестирования качества системы может использоваться энтропийное тестирование систем – на основе расчёта относительной информационной энтропии. Согласно теоремы Лебега: если на одном и том же множестве заданы две меры, то они кратны [4, с. 155].
Меру количества информации события определяют логарифм вероятности этого события, взятый с противоположным знаком: – log p. и логарифм невероятности этого события: – log (1-p). Из кратности этих
мер log (1-p) = k log p следует уравнение: p k + p – 1 = 0. Его корни: 0,500; 0618...; 0,682..., когда k = 1, 2, 3,... и есть узлы меры p – обобщенные золотые сечения (ОЗС) [5, с. 177], Они имеют онтологическое значение и играют фундаментальную роль как в содержании информа ционной картины мира, так и, при разработке модели экономической системы, Под информацией понимается структурная информация, – как ограниченное разнообразие, подлежащее гармонизации [6, с. 87–89].

Между узлами меры расположены антиузлы. - 0,570…; 0,654…: 0,705…. Это точки фаз дисгармонии, динамического хаоса всех самоорганизующихся сложных систем.
Энтропия становится выразителем количества информации, связанной в распределении компонентов системы
4. Расчёт математических констант модели филлотаксиса и их сравнение с математическими параметрами реальных экономических структур в экономическом ценозе.
5. Обоснование параметров модели проектирования экономических систем с о свойствами самоорганизации, подобными природным или биогенетическим объектам.

Заключение

Идея природоподобного или биогенетического управления на основе исследования объктов живой природы, обладающих свойствами динамического формообразования, расчёт математических констант и пропорций таких моделей в результпте должна привести к обоснованию генома природоподобной экономической системы. В качесте объекта исследования, на данном его этапе, выбрана модель филлотаксиса, которая повсеместно распространена в Природе, является системно-динамической и обеспечивает непрерывное воспроизведение жизненного цикла системы и оптимальна с ресурсной точки зрения.

Задание параметров этой модели искусственной экономической системе при её проектировании позволит заложить свойства целостности, самоорганизации и самогармонизации, структурно устойчивости на основе гармонических пропорций закона Меры или пропорций золотого сечения. Фформообразующие свойства этой модели могут быть использованы в системе антикризисного управления и управления чрезвычайными ситуациями при разработке мер по возвращению системы, попавшей в зону бифуркаций к нормальному состоянию. При этом, в качестве рамочной методологии может быть использован логико-структурный подход в управлении проектами. Данная научная гипотеза находится в стадии исследования и требует дальнейшего обоснования.

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ОПТИМИЗИРАНЕ НА МЕБЕЛНАТА СИСТЕМА ВЪВ ВАРНЕНСКИТЕ УЧИЛИЩА, СЪОБРАЗЕНА С НУЖДИТЕ НА УЧЕНИЦИТЕ ОТ I ДО IV КЛАС

OPTIMIZATION OF THE FURNITURE SYSTEM IN VARNA SCHOOLS CONSISTENT WITH THE NEEDS OF THE STUDENTS FROM I TO IV GRADE

Ас. д-р Добрева, Д. Н., Доц. д-р Мурзова, Ц. Р., Проф. д-р Братанов, Пл. В.
Технически университет – Варна, България
darina.dobreva@tu-varna.bg, murzova@tu-varna.bg, bratanov@tu-varna.bg

Abstract: *The subject of the study concerns the school furnishing in the generalized image of the modern Varna school. The object of the study focuses on school furniture - the school desk. The goal of the research is to offer adequate optimized solutions for the design of school furniture for the needs of students for the educational process in the contemporary Bulgarian school.*

Key words: FURNITURE SYSTEM, SCHOOL FURNISHING, STUDENTS FROM I TO IV GRADE

1. Увод

Ергономичните фактори, работното място и дизайнът на мебели оказват влияние при постигане на високопроизводителен труд при учениците в активния учебен процес.

При наблюдението и анализа на състоянието и тенденциите при училищното обзавеждане в България се установява незадоволително ниво на разработките по темата. Това се дължи на факта, че липсва традиция, синхрон и комуникация между специалистите по медицина, специалистите по ергономия, дизайн и педагозите. Основният проблем, свързан с избора на подходяща училищна мебел във варненските училища, би могъл да се разгледа в няколко аспекта:

- липсват институции и специалисти, които да определят критерии за избор на подходяща училищна мебел;
- водещият мотив при избора на училищна мебел не е свързан със съвременните антропометрични нужди на учениците, а е съобразен изцяло с бюджета на училището;
- не се разграничават понятията „чин" и „маса и стол";
- при обзавеждането на стаите се допуска училищната мебел, предназначена за един клас от начален курс (например III-IV клас), да се използва и от гимназиален курс (например IX клас). Среща се и обратното явление;
- не се вземат под внимание връзката между увеличаването на процента на гръбначните изкривявания и продължителната седяща поза на ученика в училище върху неудобен чин;
- наблюдава се погрешно схващане, че щом чинът е нов, той е качествен - добър за учениците, а не се взема под внимание това дали той е ергономичен за антропометричните размери на децата.

Основен проблем, който срещнахме при изследването ни за състоянието на училищното обзавеждане, е свързан с трудния достъп до материалната база на учебните заведения.

Успешната практическа реализация е свързана с решаването на следните **задачи:**

- Създаване и обосновка на идеята за оптимизиране на училищната мебел в съвременното българско училище;
- Осъвременяване и актуализиране на съществуващите термини в областта на ергономията и дизайна, съобразени с актуалните антропометрични характеристики на децата от I до IV клас на началното училище;
- Изследване на състоянието на училищната мебел в България и в световен мащаб, изграждане на съпоставителна характеристика, както и трудностите, които възникват при проектирането на тази мебел от ергономичен и дизайнерски аспект;
- Анкетиране на учениците за практическите аспекти на проблемите, свързани с използването на училищната мебел, използване на статистически данни и изследвания от различните дисциплини и области в науката;
- Предложение за икономически достъпен и лесен за изпълнение вариант в съвременните условия.

2. Варненските училища днес

Проучването ни сред директори на централни варненски училища, установи, че обзавеждането в класните стаи на учениците от начална училищна възраст се осъществява на базата на личния избор на мебели от директора, в зависимост от бюджета, с който разполага за учебната година. Това е продиктувано от факта, че от няколко години в образователната система в страната е въведен делегиран бюджет (всяко училище разполага с различни финансови ресурси). Класните стаи на учениците от I до IV клас са обзаведени с чинове, прототипи на конструкцията на Ерисман (маса с плот за писане, седалищен плот и облегалка, свързани помежду си) или маси и столове (плотът за писане и седалищния плот не са свързани помежду си). При втория модел на училищната мебел (маса за писане и отделен стол), се наблюдава затруднение на учениците да регулират разстоянието между стола и масата според техните антропометрични характеристики. Не се спазва основното изискване за дистанцията [Антропова, 1970: 271]. Поради липса на навици за работа при правилна работна поза, за учениците от началния курс този модел училищна мебел е абсолютно неподходящ. Друг съществен факт, който се откроява, след направеното от нас проучване е, че в една класна стая учат ученици от различни възрастови групи. Например в едно от изследваните училища в учебните стаи в начален курс се използват чинове с един размер, като допълнително в стаята е поставен чин, който е подходящ за по-големи ученици. Това е направено с цел да се задоволят нуждите на по-едрите ученици от начален курс, но той не отговаря на антропометричните характеристики на учениците от 7 до 11 години. В друго училище се наблюдават училищни чинове с един размер за учениците от II до XII клас. След направените изследвания е установено, че тези факти са предпоставка за наличие на гръбначни изкривявания.

Класната стая е част от училищното пространство. Тя е мястото, където учениците прекарват по 5-6 учебни часа. В

тази връзка, класната стая се явява както работна среда, така и място за игри и отдих в паузите между учебните занятия. В този ред на мисли трябва да отбележим, че е необходимо класната стая да се аранжира особено внимателно. Нужно е да се вземат под внимание възрастовите потребности на учениците. В последните години учениците от I-IV клас имат задължителна занималня в училище. Там те пишат своите домашни работи, упражняват се, играят. По този начин те прекарват допълнително по 4-5 часа на ден (общо 10). Условията, които предлага занималнята са същите като в класната стая. Мебелите, които изграждат интериора на класната стая и стаята за занималня са чин, дъска, шкаф (не навсякъде), закачалки и бюро за учителя. На учениците се налага да прекарват по 10 часа върху своите чинове. Това е различна форма на обучение от целодневното обучение, което включва в себе си и следобедно спане. Целодневното обучение позволява на децата да почиват. За съжаление тази форма - целодневно обучение, не се предлага в момента в държавните и общински училища.

В съвременната предметно-пространствена среда в класната стая в българското училище не е предвиден кът за отдих. Учебната стая е обзаведена по „класически тип"- бяла (зелена, черна) дъска, маса и стол или чин като работна мебел и в някои училища - шкафчета за дрехи, учебни помагала и аксесоари. Мебелите са проектирани от твърд материал, което не позволява на учениците да отпуснат тялото си в паузите между учебните занятия.

Необходимо е да се предвиди отделен кът в класната стая, който да служи за отдих, почивка и игра. Поради периода на адаптацията на учениците от I клас (от детската градина → към училище) тази концепция е особено подходяща за тяхната възраст (6-7 години).

В Русия дизайнерите В. Ф. Рунге и Ю. П. Манусевич [Рунге, Манусевич, 2009: 163-168] обръщат специално внимание на училищното обзавеждане. Според дизайнерите специалисти, „Куб-модулът" на авторите Грашин и Кузмичев е подходящ за учебно-игровата дейност на учениците. След приключване на учебно-възпитателния процес тези модули се преаранжират в място за игри. По този начин децата могат да отпочиват. Манусевич и Рунге коментират, че тези елементи трябва да се допълват конструктивно-технически и стилистично.

Д-р Дитер Брайтекър [Breithecker, 2009: 68] акцентира върху динамиката в обучението. Той е на мнение, че учениците в началното училище трябва да се движат повече. Столовете трябва да позволяват движение на учениците. Неговата концепция е, че „тялото е създадено за движение".

Ергономичността на училищната мебел е важен фактор, който оказва влияние както върху здравето на ученика, така и върху концентрацията му при усвояването на учебния материал.

От гледна точка на възрастта на учениците от I-IV клас (7-11 години) и предвид данните от литературния обзор се налага заключението, че за децата от начален етап по-подходящ термин за работна мебел е **чинът**, тъй като той представлява свързана конструкция от писалищен плот и място за сядане. Предимство на свързаната конструкция е фиксираната дистанция на сядане. По този начин на учениците не се налага да регулират сами височината и дистанцията между двете части на работната мебел (писалищен плот и седалка). При масата и стола децата ще се затруднят да преценят на какво разстояние да поставят стола от масата, за да заемат ергономична поза за работа.

3. Адаптивен ергочин

Адаптивният ергочин включва фиксирани габаритни размери (височина, дистанция на сядане, диференция на седалката, дистанция на облегалката). Този тип чин включва вдлъбната седалка за по-голямо удобство, облегалка, която фиксира естествената извивка на гръбначния стълб в лумбалната област с цел поддръжка на гърба и по-бавно настъпване на умора. Чинът включва фиксирана зона за ученическата чанта. Върху плота за писане е отделено място за химикалки, чаша за вода за часа по рисуване, а под него е поставена плоскост за помощни материали – тетрадки, помагала, учебници.

Дефиницията на работното понятие **адаптивен ергочин** определяме, като се базираме на основните функции, които могат да се обобщят като **приспособимост и удобна за работа поза.**

Характеристиките, които откроява адаптивния ергочин, са следните:

- универсалност: подходящ за приложение в различен тип класна стая, позволяващ съчетаване с други училищни мебели (за занималня и редовни часове);
- приспособимост: адаптация към антропометричните характеристики на учениците;
- удобство: поради създаването на комфорт при децата с цел запазване на тяхната концентрация в учебния процес;
- многофункционалност: поради възможността за употребата на чина по различни учебни предмети (писане, четене, рисуване);
- традиция и приемственост: обогатяване на класическата конструкция на чин с ергономични приложения за краката, гръбначния стълб на малките ученици, както и разчупване на съществуващия облик на ученическия чин и ученическата мебел с традиционни и славянски етноелементи.

Образованието на подрастващото поколение е основна грижа на съвременното общество. Днешният динамичен и технологичен свят налага някои промени и във визията на съвременното училище.

Трансформации се налагат както в процеса на обучение, така и в интериора на работната среда на учениците. Безспорен е фактът, че изминалите години са оказали въздействие върху мебелите и оборудването в учебните стаи. Първоначално промяната се усеща в обзавеждането на компютърните зали, тъй като там се налага функционална смяна на мебелите с оглед на по-честото използване на компютърните конфигурации. Нашето изследване е свързано по-специално с класните стаи на учениците от I-IV клас, тъй като те имат специални нужди, свързани с възрастта и растежа им. Именно това е причината да акцентираме вниманието си върху проблема с ергономичните характеристики на учебния чин. Беше предприето задълбочено изследване, свързано с материалната база на съвременното българско училище и по-специално в град Варна. В хода на необходимите действия, свързани с настоящото проучване, бяха установени редица административни и субективни причини за събиране на необходимите за изследването данни.

Известно е, че класната стая има стандартни размери. Те са предвидени при проектиране на училището. Мутафов, Иванов отбелязват, че в България класната стая се изчислява с 1, 25 кв. м. площ и 4 куб. м. обем на ученик. Това се равнява при 30 ученика на правоъгълник, притежаващ 40 кв. м. площ и височина 3, 4 м. Стаята трябва да има дължина 9 м., ширина 6 м. и височина 4 м. Стандартно входната врата трябва да бъде поставена на стената към коридора в близост до черната дъска. Авторите отбелязват, че подът е препоръчително да бъде дървен от иглолистен материал и линолеум [Мутафов, Иванов, 1996: 108]. В направените от нас проучвания забелязахме, че някои от вратите на класните стаи се намират зад последните чинове, т.е. зад гърбовете на учениците. Размерите на някои стаи са по-малки от стандартните. Това важи за по-стария тип училищни сгради. Оборудването също има стандартни размери при своето проектиране. То се състои от училищен чин, шкафове, учебна дъска, бюро за преподавателя. За съжаление в повечето училища мебелите не са сменяни от години. Амортизираните елементи са сменени с нови. В други училища са закупени нови чинове, които са подбрани по цена, а не по антропометрични характеристики и да отговарят на ученическите потребности.

Методиката за провеждане на статистическите измервания и оценки на ергономичността на училищното обзавеждане включва:

- Физиологичния метод (събиране на данни за ръст и тегло на учениците от I до IV клас);
- Тест за графична тремометрия;
- Анкета на ученици и директори.

Изследвани са 21 училища в град Варна. Те са разпределени в пет района в града (Център, Аспарухово, Чайка, Младост и Владислав Варненчик). Този подбор не е случаен. Направен е с цел да се покаже обективно състоянието на материалната база общо и в частност - училищното оборудване- училищни мебели. Някои от тях са основни училища, а други средно общообразователни (общо 21 броя). Изследвано е оборудването в класните стаи от I-IV клас.

Бяха измерени наличните мебели и по-специално училищния чин (маса и стол) - височина, дължина, широчина, дистанция. Отбелязани са размерите на чиновете, масите със столовете по описателния метод в таблици по класове. Например размери в първи клас, размери във втори, съответно в трети и четвърти. Състоянието е онагледено със снимки. След това чрез физиологичния метод обобщихме резултатите с антропометричните характеристики на учениците по класове. Анализирани са и медицинските заболявания на учениците (от I-IV клас). След това съпоставихме антропометричните характеристики с размерите на училищните чинове, които малките ученици използват.

Съставена е анкета от седем въпроса, която има за цел да сондира мненията на малките ученици относно удобството на училищния чин. Поднесени са и тестове под формата на игри, за да се определи каква е степента на умора в процеса на обучение. Тестовите документи се наричат: Тест за графична тремометрия (пътечка); Анкета с въпроси. Изследването е извършено с помощта на Медицинския университет - Варна, катедра «Хигиена». Анализирани са и са обобщени чрез статистически методи. Изчислени са процентите на умора при учениците в учебния процес. Учениците са анкетирани относно ергономичността на чина, който ползват през целия ден в учебния процес. Изследването се проведе в началото и в края на учебната година при едни и същи ученици от I до IV клас в четири училища, в различни райони на град Варна. Беше избрана по една седмица в двата учебни срока. Дните от седмицата са подбрани според критерия начало, среда и край (понеделник, сряда и петък), както и начало, среда и край на деня. Анализите показват следните изводи:

- На територията на Община Варна, в по-голямата част, оборудването в класните стаи не е съобразено с ергономичните компоненти. За съжаление, ергономичната мебел се открива на много малко места в изследваните от нас 21 училища.
- Известен факт е, че училищата са общински, т.е. финансирането и поддръжката се поема от Общината. Това обяснява, че реновирането на базата не е ежегодна дейност. То се осъществява според необходимостта в момента.

Фиг. 1. *Изглед на класна стая на първи клас*

Фиг. 2. *Класна стая на първи клас*

Фиг. 3. *Естествената светлина идва отляво и зад гърбовете на учениците*

Прието е естествената светлина в класната стая да идва от лявата страна на учениците. В тази класна стая освен отляво, има и прозорци, които се намират зад гърба на учениците.

Директорите проявяват своите мениджърски умения и се стремят да осигурят нови мебели за учениците от I-IV клас. Те целят да създадат нормални условия, близки до ежедневно-битовите условия на малките ученици. По този начин учениците не усещат рязко границата при смяната на домашната обстановка с учебната.

Благодарение на помощта от родителите, някои от учебните стаи са много уютни. Те освежават козметично стаите, осигуряват средства за закупуване на интериорни аксесоари като пердета, балатуми, саксии с цветя и учебни пособия.

В изследваните 21 училища на територията на град Варна учениците от първи до четвърти клас, в зависимост от антропометричните си характеристики, имат необходимост от четири размера чинове с цветови код по БДС виолетово (за ръст без обувки 1080 мм – 1210 мм), жълто (за ръст без обувки 1190 мм – 1420 мм), червено (за ръст без обувки 1330 мм – 1590 мм) и зелено (за ръст без обувки 1460 мм – 1765 мм). Така един ученик с ръст между 1080 мм и 1210 мм може да седи върху чин с виолетов или жълт цветови код в зависимост от неговото тегло, което определя дистанцията на сядане. Ако детето е с ръст между 1080 мм и 1210 мм, но килограмите са повече, то трябва да седи върху чин с жълт цветови код, а не върху виолетов, тъй като дистанцията на сядане няма да е удобна за него, ако седи върху по-малкия размер чин.

При изследванията забелязваме, че във всички класове от първи до четвърти клас, учениците имат необходимост и от четирите размера чинове. По този начин, ако в класната стая има два размера от чиновете, които се подразделят на още два, ще се осигури възможността на децата да седят върху чинове, които отговарят на техните антропометрични характеристики.

- Изводите от анкетите ни показват, че за по-голяма стабилност на ръцете, училищният чин трябва да е

съобразен с антропометричните характеристики на децата.

- Децата, които седят на чинове, съобразени с техните габаритни размери, допускат по-малко грешки в сравнение с учениците, които седят и работят върху чинове с един размер.
- Направените изследвания показват, че в изследваната възрастова група (7-11 години) акселерацията в град Варна не е затихнала. Деца със затлъстяване, включително и с тежко затлъстяване има във всички изследвани възрастови групи.
- При направения сравнителен анализ между ръста и теглото на учениците през 1977, 1992 и 2010-2012 год. забелязваме, че преди 37 и 22 години учениците са били по-ниски в сравнение с учениците през 2010-2012 година (децата са по-едри и по-високи).
- Във всички изследвани възрастови групи (I- IV клас) и при отчетените конкретни размери на ръста и теглото, учениците се нуждаят от четирите конфигурации за размери за чин (виолетов, жълт, червен и зелен цветови код).
- При избора на мебели директорите трябва да включват медицински лица, ергономи и дизайнери.
- От направената анкета на учениците от първи до четвърти клас забелязваме, че децата не се чувстват удобно върху чина/ масата и стола през целия учебен ден. Те отбелязват, че нямат достатъчно място за учебниците, тетрадките, пособията и поставят чантата си на земята или на стола.

Всичко това налага обобщението, че е актуално и необходимо да се проектира нова конструкция чин, веднъж по габарити, които отговарят на антропометричните характеристики на учениците от I до IV клас (отчитайки статистическите обработки) и втори път с конструктивни възможности за регулиране на функционалните му габаритни размери. Възможността за регулация ще намали необходимият брой нови чинове, което ще намали икономическия праг при внедряването в училищата на новите габаритни чинове. Съществуват два типа чинове: едноместни и двуместни. С оглед на адаптацията на учениците към процеса на обучение, тенденциозно избираме нашата авторска концепция да бъде ориентирана към двуместен чин. По този начин учениците:

- не се чувстват изолирани, наказани;
- по-лесно се ориентират в училищната среда при изпълнение на задачите;
- двуместният чин създава условия за екипна работа, това е важно за психологическата нагласа на учениците;
- при изпълняването на учебните задачи децата могат да разчитат и на помощта на своя партньор. Така те се чувстват спокойни и уверени в работния процес и изграждат умения за комуникация при работа по двойки - изказване, обсъждане, анализиране по дадена тема.

Нашето предложение за съвременен **ергочин** се реализира като двуместен чин (състоящ се от работна повърхност и седално устройство, свързани посредством регулируема метална конструкция) от олекотен материал със заоблени безопасни форми.

Според своето предназначение и начин на употреба, ергочинът има основни и допълнителни функции.

Първата основната функция на ергочина е да поддържа тялото (лумбалната област) на учениците в процеса на обучение. Втора основна функция на чина е да се осигури удобно работно място на учениците при тяхното обучение. Трета основна функция на чина е позиционирането на учениците на едно място в рамките на един учебен час, с цел да се осигури по-лесно наблюдение върху поведението и работата на децата. С помощта на тази функция се свеждат до минимум факторите, които могат да въздействат разсейващо.

Допълнителни функции на чина. Възможност за използване на пособия за рисуване (чашка за вода, поставка за химикалка, молив, четка). Възможност за поставяне на ученическа чанта, торбичка за спортен екип за часа по физическа култура в кошници, монтирани зад седалката. Възможност за регулиране на размера на височината на чина.

Фиг. 4. *Изглед на класна стая, оборудвана с ергочинове*

4. Заключение

Чрез прилагането на ергочина в училищния интериор може да се постигне оптимизация и да се намерят решения на проблемите, породени в учебния процес, свързани с целодневния престой на учениците в класната стая, както и от липсата на определено място за отмора и почивка.

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