INTERNATIONAL JOURNAL OF INTERDISCIPLINARITY IN THEORY AND PRACTICE
ITPB - NR.: 21, YEAR: 2020 – (ISSN 2344 - 2409)

INNOVATIVE APPROACHES TO DESIGNING PRODUCTION SYSTEM STRUCTURES

Naqib Daneshjo [1]

Abstract: *The use of digital enterprise should improve economic and production indicators, namely by reducing the respective costs. Any small savings that will be gained during the planning stage will be multiplied in serial production, significantly increasing the return on investment into the system of digital enterprise. The digital enterprise model allows for designing manufacturing procedures as well as technologies, including the insertion of a different degree of automation. It allows for running tests in virtual practice in which the physical properties of materials and specific production activities are programmed, as well as the assembly procedures in a particular workstation - including the preparation of tools in accordance with the worker's ergonomic requirements.*

Keywords: Production system, CAx systems, designs, modeling

1 INTRODUCTION

Engineering production design requires a system solution for a set of structural, technological, spatial and organizational factors resulting in the design of an optimal manufacturing configuration. The goal is the functional integration of people, information, production technology, materials and energy to prevent wasting these resources and to achieve high productivity. The efficiency of operation depends on the level of mutual synchronization, the ability to predict and eliminate adverse effects of these factors on the production characteristics of the production system. So the role of design activity is to design and, in the form of design documentation, to process the production configuration that can be executed under optimal financial conditions in the required space and time, capable to meet time-limited market demands.

The final design, taking into account the mutual synergy of these factors and guaranteeing the consistency of designed ideas with the achieved results, leads in practice to the complexity and variability of possible solutions. Capability of reconfiguration or building new innovative productions is, therefore, one of the most complex tasks in the company life cycle. It requires the application of adequate computer, information and software support for modern CAx systems capable to apply standardized design procedures and to modify configurations from "proven" designs.

2 PHILOSOPHICAL ASPECTS OF PRODUCTION STRUCTURE DESIGNS AND THEIR COMPLEXITY

Innovations in project activities require special knowledge and appropriate methods, procedures and tools. An important role is played by theoretical sciences. The development of engineering work is supported by several engineering disciplines. Design Science is important because it contains a set of logically clustered knowledge about solutions generated by engineering activities. Designing is a complex area of theories, methods and information, including a broad field of engineering activity. The knowledge base of design team members can be divided into [4]:

- General and special knowledge of technical systems and processes, including the manner of their expression, characteristics and quality, structures and principles of their development.
- General and special knowledge of engineering design, its structure, features, characteristics and management.
- Special, detailed, design-necessary knowledge of the technical, technological, economic, organizational and control nature of the aspect of design.
- Managerial skills in the field of design management and teamwork.

Designing today's manufacturing systems requires a comprehensive analysis of their activities in real space and time. Only this approach is a guarantee of identification, optimization, or elimination of design deficiencies before their future physical implementation. It is necessary to take into account the philosophical aspects of technological innovations, modelling, examples and studies of successful reference solutions, financial support and material provision for innovative changes, multi-purpose and purpose-oriented designs for the synthesis of technological innovations, etc. The frame methodology of application designated for the assembly of the production structure model is illustrated in Fig. 1. It takes place in four stages [1, 5]:

1. Creation of knowledge base and its analysis (in accordance with customer requirements).
2. 2D / 3D variant modelling - spatial optimization of the system’s structure.
3. Optimal production structure - functional simulation of the virtual production model.
4. Production of design documentation, GIS modification of the production model and its implementation.

Concepts of new production systems are currently designed as the systems of new generation [3]. The aim of such solutions is to increase productivity without losing flexibility, shortening production time, increasing the quality and the value of products and services, and so on. They are modified as social and economic systems and place high demands on design, implementation and operation. The numerous papers in professional literature deal with their development.

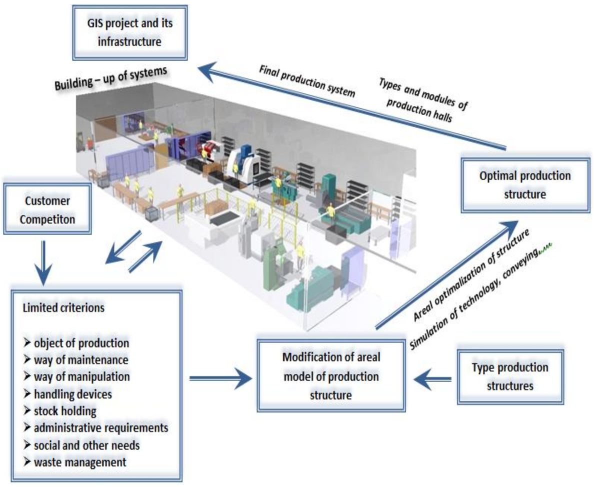

Figure 1 Design procedure characteristics of new production structure

Combination of software applications with hardware of 3D type beamers, cameras, 3D scanners, digitizers, etc., enables the future real image of the production system to be interpreted in virtual reality and by that:

- It reveals critical deficiencies before the real system implementation.
- Simulates the functional activity of system elements, i.e. verifies dynamic properties of static objects.

Simulation of the processes of the proposed manufacturing assemblies means:

- A thorough analysis of CAE variants of generated structures and the complexity of their assessment as a result of a multidisciplinary solution.
- Application of prototype and the already existing knowledge databases enabling reuse of the data.
- Verification of the use of already approved analysis procedures, etc.
- Data management and effective handling of large data amounts related to simulation including solution parameters and results.
- Correction of functional visualization of the means of production of the real production model.
- High consistency of the design with the real production model (objectivity of the virtual reality model).
- On-line back-up design correction, etc.

3 NEW APPROACHES TO DESIGNING CUSTOMER-ORIENTED PRODUCTIONS

Design of today's complex structure of diverse manufacturing systems requires a comprehensive analysis of the activities involved in three spatial dimensions and in time. Only this approach is a guarantee of identification, optimization, or elimination of design deficiencies before they are physically implemented in the future. Greater requirements for design activity need significant computer support, i.e. information and computer technologies, without which the high quality of design, greater variety of solutions, innovative flexibility as well as other attributes, are difficult to achieve. The combination of software applications with hardware tools such as 3D beamers, cameras, 3D scanners, digitizers, etc., enables the future real image of the production system to be interpreted in virtual reality and by that:

- To identify critical deficiencies before starting to build a real system.
- Simulation of the functional activity of system elements, i.e. verification of dynamic properties of static objects (e.g. the course of technological processes, movement of workers flow of material).

The current market offers application software systems that support manufacturing system design in different application areas. The use of such systems allows to design the entire production system, to purposely situate the means of production in the production area, to design traffic paths, storage areas, to make their simulation, to display and describe them from any views, etc. Current development enables these different approaches to be included in a single integrated system. Synchronous work in real and virtual environments brings a number of effects. Integrated procedures ensure that all actions applied to real physical models are transferred to parallel work with computer models that are subsequently presented in virtual environment. An important innovative method of designing production systems is simulation and its methods, techniques and tools. Managing simulation means:

- A thorough analysis of CAE variants of generated structures and the complexity of their assessment as a result of a multidisciplinary solution.
- Searching and application of prototype, already existing knowledge databases enabling data re-use.
- In combination with supportive process algorithm procedures, it enables the verification of the use of already approved analysis procedures, etc.
- Visualization of simulation results of the time cycle of simulated action in a specific environment.
- The reliability and confidence of the reality of the results obtained and the possibility of online feedback on the development, or design status.

In the past, the concepts of creating production system configuration rested on the creation of two model types. The models were not integrated with one another or used together.

4 INNOVATIVE PROCESS DESIGN IN MECHANICAL PRODUCTION

Development and designing of new production systems is nowadays influenced by the global economic situation. The world markets have recently developed as:

- Globally open and developments therein are defined by the individual needs of the customers.
- Dynamic with a large scale of products manufactured and with a demand to shorten the production cycle of products as well as to change the price strategies.
- Markets with the most important assumption of a successful innovative action lying in meeting the demand to shorten the production cycle as well as to continuously improve the quality of basic production resources.
- Areas with intense competition, progressive depletion of natural resources etc., which call for the use of new approaches and thoughts in order to develop innovative activities.
- Systems of production flexibility, as they are able to produce a wider range of finished products with the minimum loss of time.
- Areas of flexibility and competitiveness in the technical preparation of production.
- Areas of project creation, searching, collecting and processing of information with the help of modern information technologies, which must support and develop the creativity of individuals and teams.
- Areas for the application of 3D modeling techniques making it possibly to simulate and eliminate the risks associated with new incoming designs and new production systems.

From the basic approaches to development of engineering design point of view, design methodologies are developed as knowledge based engineering. This taking over by knowledge based engineering is manifested in expert systems and differences from the classic program systems in more than one feature. In a competitive environment with the production volume changing dynamically having a permanent implementation of new production variants and technologies could translate into a high level of automation economically just as effective as is the case when the manual performance, required for the market indicated reconfiguration of the productive systems, is reduced to minimum [2].

The solution for the "production of tomorrow", are innovative applications enabling flexible production and assembly systems, combining the advantages of production techniques based on automation and robotization with the advantages of maximum adaptability. I.e., designed production structure enables efficient production of individual products and helps decrease the sale turbulences of the market and eliminate production dilemmas of the managers [3, 7].

The customer-oriented production systems of today make their headway thank to high flexibility, based on their high-functional adaptability. These "self-optimizing systems" are able to conceive new system targets based on continuous observation of the state of the current system and to allow simultaneous adaptation of systems behavior in synergy with new targets. They could be characterized by the following activities:

- "In-time" analysis of the functions the system performed.
- Decision about new system targets.
- Adaptation of the system to new environmental conditions.

The changes in the production environment could be triggered by different factors (products, components, process attributes, user interaction, etc.). In the system, these factors are requalified and other system targets are defined based on the comparative analysis. The evaluation is based on the selection of the most relevant targets from a predefined list or based on the adaptation of present targets to the current situation. The adaptation is achieved with the change of system parameters, configuration and behavior of the system in accordance with the newly defined targets [6, 9].

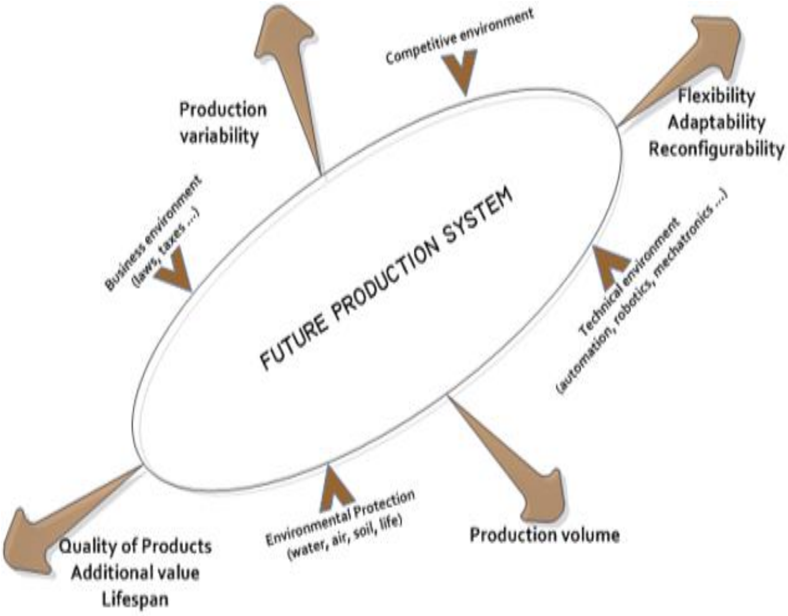

Figure 2 The concept of adaptive modification of the production structure of the future

The behavior of these production systems is considered to be intelligent, which means they possess the ability to interact autonomously and flexibly with the environmental demand, as well as with the external users / systems or their dynamic behavior. These systems are usually able to learn from their own experiences and are able to remember past events which could be helpful in forecasting new events and in optimizing their behavior under several conditions in the future based on this. The basic pillars of creating a highly flexible system are as follows, Figure 3.

1. Flexibility and permanent ability to provide the basis of system adaptation to dynamic factors affecting the various external stimuli resulted from environment. Flexibility could be understood as a connection between the individual parts of the system, which are predicted and defined during their planning stage. When the predicted flexibility is not sufficient for the systems feasibility under the required condition, its diversity could help reconfigure the organizational and technical parameters of the individual connections with the aim to maintain correctness and integrity.
2. Operation autonomy allows for proactive reactions to changes in the market environment. It independently guides the system to the required and safe condition during long term operation of the same without any intervention from external operators. The higher the level of automation, the greater the likelihood of breach process. With the aim to control such breach autonomously, the integration between the components and the modules of the system, as well as the resistance to failures, must be ensured.
3. Recognition, evaluation and decision making thanks to the ability to sense the external environment. It evaluates relevant information, collects it, learns from its previous own experience to make intelligent decisions based on such information resources and to act in a safe and direct way. The decision, learning and thinking processes must be based on statistical calculations, probability analyses, available information, as well as the complex artificial intelligence tools.

The construction of production systems based on the pillars of "flexibility / diversity, autonomy, recognition ability" is possible with the help of technologies that could be synergistically functional, mutually combined. Such technology is the modularity of production technology, robotic technology with exchangeable tools and sensors, multi-sensor integration, data fusion, etc. The robotic technology, together with the standardization elements, plays the key role [5, 6].

The level of performance is responsible for direct coordination and checking of the functionality of the production technology, its elements and components (sensors, reacting members...), which are the source of important information about the current process of production, or about the final product assembly. The safety level supervises the functional integrity of all members of the system with the aim of capturing and eliminating unfavorable deviations, or "Keep them in an acceptable, feasible, qualitatively acceptable range".

The basic assumption of the functionality of so conceived production systems is a complex modular hardware and software composition of the system allowing for a rapid change and integration of subsystems. The application of the sensing element in the production control systems is usually accomplished by the methods of artificial intelligence, also known as knowledge based systems. Examples of such systems appear in the application of expert systems and probability methods.

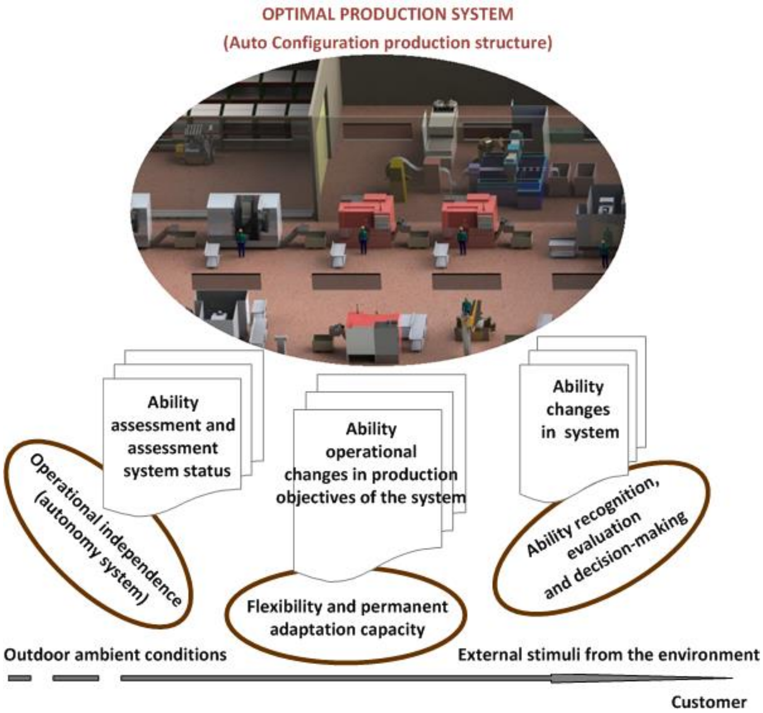

Figure 3 Pillars of customer oriented production systems of the future

Requirements placed on modern machine production are eco-innovatively oriented, they aim to achieve high productivity and flexibility of small-batch production assortment, to shorten the time of continuous production and to ensure efficient use of machines to improve quality of production and its outputs (articles), to reduce inventory, to minimize production costs and to achieve other, well-known objectives [8]. In today's environment of global recession when it comes to machine production, market stocked with low-cost Asian goods, etc., the dominant requirement and key factor of a company success are, apart from continues improvement of article functionality, the ability to react dynamically to customer demands and the ability to transform those requirements into future properties of the articles in a very short time period. Fulfilling the requests while quoting a reduced overall production cycle from its proposal to dispatching the goods to the end-customer at the lowest possible production cost is the most important prerequisite of a successful company.

5 CONCLUSION

The vision of the adaptive, fast configuring production systems of the future points to subsystems of natural intelligence which communicate together and cooperate in synergy with the predefined target functions. The key role in such systems is the permanent monitoring of the execution of the production target, with the aim of avoiding or minimizing negative effects on quality. The integration of sensing technologies and the fusion of different data sensors is necessary to ensure the quality evaluation of different products and processes. From the currently available IT technologies and hardware components point of view, this autonomous check and synchronization could be implemented to a wide range of technical options which are able to sense the environment and which are able to make decisions in a target oriented way - (MAS-multi-agent system).

On the level of tasks, detailed sequence of execution of the planned tasks, together with their detailed specification and determined methodology and with the sequence for achieving the required tasks is determined. This level is responsible for functional communication between a team on the planning level and the individuals on the task level.

Acknowledgements: *This work has been supported by the Scientific Grant Agency of the Ministry of Education of the Slovak Republic (KEGA 032EU-4/2020)*

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AUTHORS ADDRESSES

[1] Doc. Ing. Naqib Daneshjo, PhD.
Department of Marketing
Faculty of Commerce of the University of Economics in Bratislava, Dolnozemská cesta 1
852 35 Bratislava 5, Slovak Republic

E-mail: daneshjo47@gmail.com