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SPECIFICS OF INDUSTRY 4 DEVELOPMENT IN THE CONTEXT OF AUTOMOBILE PRODUCTION

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Abstract: *Automobile industry is facing major changes. Digitalization plays the important role except the powertrain electrification, autonomous driving and opening new markets Combination of both physical and digital world is often referred to the motto "Industry 4.0". Cross-linking of the complete cycle of value added in real time is now for some car manufacturers more than just a vision. Center of attention is always a person as a customer and an employee. Article discusses the concept of industry 4 development, describes the specifics and main components of the system.*

Keywords: Automotive industry, industry 4.0, smart factory, digitalization

1 INTRODUCTION

The basic idea of digital revolution is the cross-linking of humans, machines and industrial processes. On the bases of these factors individual products can be made more quickly and in a high quality. Costs of production can be set up to stand up to competition. Another reason is flexibility, seeing that there is a demand for personal motor cars, commercial cars and mobility concepts across the world. Also the requirements of customers are diversified. While in the 70s of 20th century there were three basic models of cars, today there are about ten times more of them. There is also a wider range of drive - except the petrol and diesel engines, hybrid and purely electric drives are preffered. Product innovation cycles are becoming shorter. The vision is that the automobile manufacturing will change from mass production to "batch size one piece" - each car will be made entirely according to individual requirements of customer.

2 CONCEPTION OF INDUSTRY 4.0

The bases of industrial production in the the context of industry I4 will manufacturing plants that will be able to produce small batches of products, which are configured on the base of customer requirements, in a various modifications within a very short production and delivery time [3]. Industry 4.0 depends on four basic points [2]:

- Vertical integration of the production system.
- Horizontal integration through the medium of new generation of global value chain network.
- flow production throughout the entire value chain.
- Acceleration by the means of mart technology.

Industry 4.0 focuses on the so-called Smart process, which is a big change compared to the current conventional production. These factories will be able to face the fluctuations in demand, they will be more resistant to malfunctions while they can produce at the most effective. Machines, people and resources can communicate and cooperate together. Machines will report the maintenance man and also precisely define the problem by themselves. The product by means of a chip with radio frequency identification (RFID) is able to control its flow through production, it knows which parts it is made of and where it should be delivered later. The product itself participates in production process. Smart logistics, smart grid, smart buildings and smart distribution is interconnected in infrastructure of such enterprise [4].

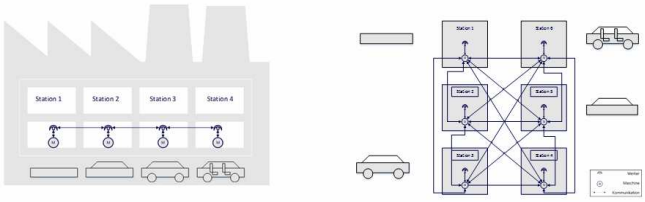

Fig. 1 Communication patterns in factories of today and the future. [11]

The basic elements of production model kit of "Smart Factory" include:

- **Augmented Reality**: The real current status on one screen is visually blanketed by virtual required state. Deviations are visible at first side. This procedure is used in the process of planning a factory and checking an assembly with virtual constructive component and in the manufacture of components and operating means, as well as in their putting into operation.
- **Virtual assembly**: In a virtual assembly, structural components are mounted into the vehicle. By examinining, experienced staff can estimate how to get the work under the control or if there are some changes needed for construction.
- **Digital chain of processes**: The ability to produce the vehicle is secured during the formation of product. The usage of digital methods for displaying digital chain of production processes enables it.

- **Crosslinking within 360° (body-in-white)**: Complex netwotk of equipments for producing body-in-white which contains several tens of programmable logic automata (SPS), several hundred robots and dozens of different technologies (spot welding, gluing, welding by laser, mechanical bonding etc.) is cross-linked by about 50 000 intelligent network participans (IP addresses).
- **Human-Robot Collaboration**: Robot with derated construction on trolley is used at calibration of projection display. Robot carries a targeting camera on the light support arm made of plastic reinforced with glass fibers. It is able to focus a left and right-hand variants through the unilateral approach. So far, calibration was performed by two strongly installed robots behind the protective fence.

The key to achieve the Above-Mentioned Smart factory is to use a CPS. Through this technology, machines and equipment can control the production process to achieve high efficiency, optimum utilization of material, adapting of production cycle according to customer demand, providing small doses of products in various forms, and all in real time. All machines, conveyors, loaders, forklifts and products will be autonomous and decentralized [4]. Machines communicate with each other but also with employees, they are also able to respond to any failures and they know to modify the production time, so the production line does not have to be stopped. It leads to minimize waste, errors, production time and reduction of manual workers. The machines work physically while people focus on more creative tasks. Emphasis will be on creating skilled workers who will transform customer requirements into the language of machines. We will need high-quality programmers who will reach an optimum balance between time spent in work and leisure time, also called work-life-balance - the balance between work and private life. In a real situation, this concept will be followed:

1. The individual customers give an orders online through the internet and Web configurator directly on the production line. Customers can get the product for large-scale price. The whole production process is aligned from development to service.
2. Customer's request is processed automatically by computer under the programmer's supervision. Material is automatically released from warehouse. RFID microchip that will manage production program is built in semifinished product. Through the sensors, cameras, scanners, transmitters, CPS and Internet, the factory and production controls autonomous.
3. Finished product together with a computer program will plan the optimal route. Delivery will be carried through drones to the customer's doorstep. Through digitization and robotics, customers will receive their products already several hours after placing an order. [13]

Smart Factory - five main objectives:

- More flexibility: Smart Factory enables faster reaction of production to global market fluctuations and individual customer demand. Digital production also facilitates production of complex products.
- Improved efficiency: efficient utilization of resources and energy, buildings or inventory is a decisive factor of economic competition; coherent digital chain of processes leads to the continual inventory: structural components are identifiable whenever and everywhere. Devices can be controlled from all sides.
- Increased speed: flexible production process, simplified adaptation of existing production facilities and installation of new devices allow to make easier and more efficient production process. This leads to shorter innovation cycles, it means product innovation can be intorduced into several model series (time-to-market).
- Attractive working environment: active interaction of man and machine through the new user interface will change the working world in many areas, such as the qualification and ergonomics. Taking into account the demographic changes there will be new perspectives in the design of future living and working patterns.
- Smart logistics: from configuration and order of car, through finding needs of structural components and their procurement to manufacturing and export. The vision is that "the ordered car will find a place of production and machinery by itself.´´

Conception of Smart Factory will be implemented articulately in global production network. The first two steps in this context are clearly defined and largely achieved:

- Modern automaker today offers a global standard components, standardized system architecture and standardized automation, regulation and control technology.
- In case of all investments, the world market has standardized technology modules in robotics and manufacturing.

Smart factory can be known as factory that can dynamically respond to market changes. It offers customers the ability to modify he product according to their needs, prompt delivery and perfect after-sales service using a PULL principle. Smart factory includes many elements (see Fig.2). The heart of the plant is CPS, or linking of machines, workers, smart systems and products primarily to the network through which they can communicate and collaborate with each other

effectively. Wireless communication is also applied. Smart Maintenance is important for continuous production. Sensors, controllers and cameras will form together an autonomous maintenance of machines, when the machine is able to predict failure, tool change or the need for maintenance. Smart logistics will ensure transportation, it means material, parts and finished products will be transported through autonomous means of transport. Supply chain management will be based on a holistic approach and using LEAN principles that bring optimization and shorter times.

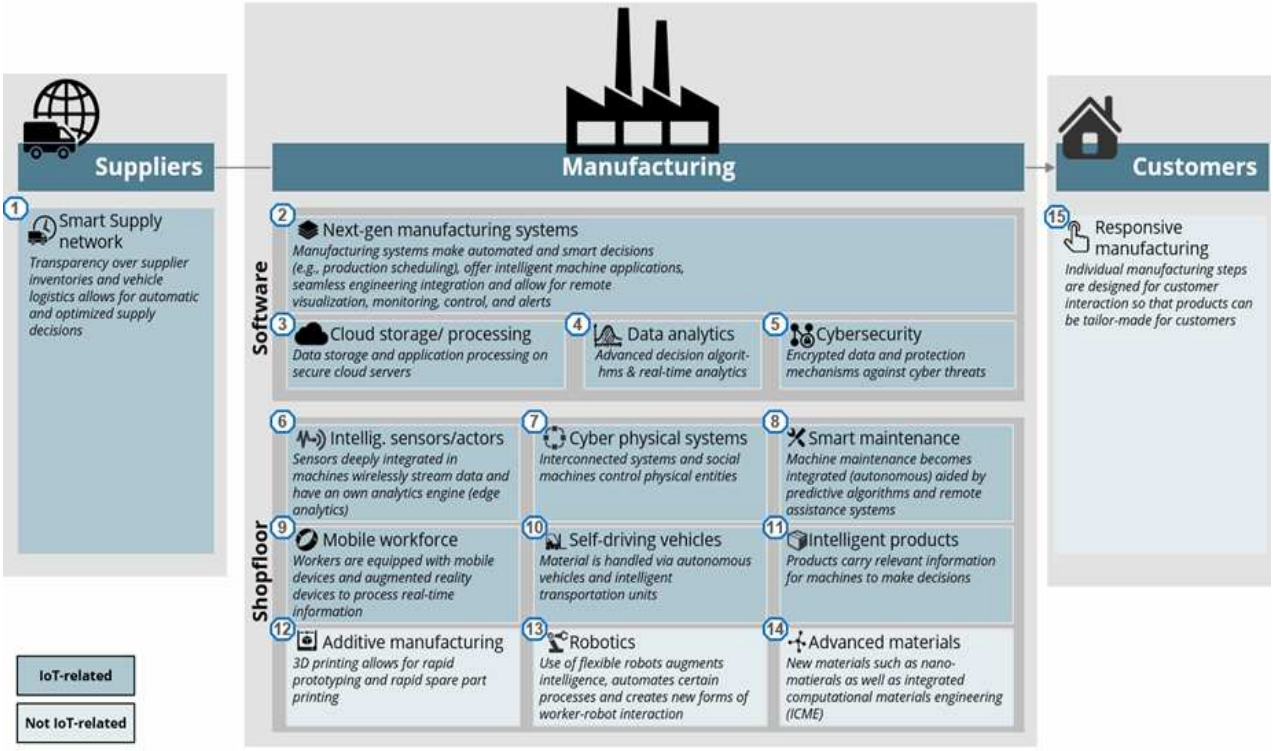

Fig. 2 Components of the Smart Factory

3 TECHNOLOGIES FOR INDUSTRY 4.0

Cyber physical systems

The idea of decentralized management and autonomy originated in Germany, by German researchers. Prof. H. J. Warnecke already in 1992 presented his Fractal company. He drew an attention of researchers on decentralized, autonomous and intelligent structures that could bring synergistic effect to industry. The idea of a fractal enterprise became the basis of cyber-physical systems (Cyber-Physical Systems CPS) in Germany.

Cyber physical system is a complex system, with its own decentralized control unit. There are connected smart objects, which are connected to a common communication network via the Internet, specifically the Internet of Things and Services. These objects operate independently [9]. CPS systems represent all objects that are found in the production, from material through the machine and apparatus, robots, sensors, building, logistics elements, compositions, and systems to finished products. All objects within the CPS are interconnected through communication network, which allows to communicate reciprocally and also provides required communications services. Only through the CPS the concept Industry 4.0 is realistic. CPS concept helps to improve industrial processes related to production, engineering, material consumption and supply chain. Production systems are interconnected both vertically and horizontally throughout the entire chain and beyond boundaries of individual firms. Through the sensors, CPM system can "sense" its external and internal surrounding. A man with such a wide-spread and complex CPS system communicate via appropriate interface, referred to as HMI (Human Machine Interface). HMI support communication of man and machines in natural language or by means of touchscreen. There are also some solutions for controlling the objects by man's mind.

RFID technology

RFID has been used since 1999. It is a modern technology that uses radio frequency identification system of objects using radio frequency waves. This technology is used in data processing in many sectors and replaced old barcodes, because it is faster. The transmission goes on immediately, precisely and in two-way (see Fig.3). The information is electronically transmitted and stored into small chips. Thus stored information can be reloaded and rewritten. The main advantage is public reading - it means reading device can simultaneously download hundreds of tags (identifiers) per minute [8].

Technology / Capability	Bar Code	RFID	RFID Benefit Example
Line of sight requirement	Required	Not required	No need to orientate scanned items
Number of items that can be scanned	One	Multiple	Very fast inventory scan
Automation & Accuracy	Manual read errors & prone to mis-scanning	Fully automated and highly accurate	Error free inventory count
Identification	Only series or type	Unique item level	Targeted Recall
Data storage	Limited codes	Up to several kB data	Real time data access in any location

Fig. 3 Comparing of technologies for electronic transmission of information

RFID technology includes three main elements - an antenna, reader and transponder (eg.: card, bracelet, key pouch). Reader modul is connected to the antenna. It usually has a shape of coil and transmits electromagnetic waves [8]. If some RFID tag (identifier) approaches to the antenna, it will automatically connect and it will start to feed the electronic chip using electromagnetic induction. Electronic chip will send back information about itself via antenna of reader module. This module will processed these data again. In Smart factory, RFID chip will be implemented to semifinished product. The chip includes information about product and its characteristics, particular status and history. In combination with the CPS, product is able to communicate, collect data, manage the flow of its own production on on-line basis [12].

Big Data

Developed technology of sensors allows the collection of huge amounts of data in real time, their processing, data mining, analysis, and getting new knowledge, which can be used to predict the future behaviour of industrial systems and creating decisions. These systems are also marked as big data. The concept Big Data (known as a buzzword in the IT field) together with Cloud Computing serve for data acruisition, their archiving and analyzing in data management systems used in modern production [1]. The aim of information retrieval and its analysis is to obtain data for future predictive systems and find the possibility of application these elements. By linking IoT, iOS and IoP, mutual communication will be in progress. It will be connected with mass of data which will generate new information. Big Data, together with Cloudy enables data collection, analysis and processing of large data files. The wishes and requirements of customers, it means data from the Web configurator and social networks will be recorded to the Big Data and then to the Cloud. These data show changes in demand. After that follows data collection from sensors, Internet, RFID, research, shared disks and data management therefore archiving, infrastructure, data sources for databases [10]. This data is then used for planning, forecasting sales, virtual manufacturing, supply chain management, project management, maintenance. All members of value chain, who have access to a central could will use this data. It means that data will be obtained not only from the factory, but also externally from customers, suppliers, transporters etc. It will be just one-way flow of information. Information availability is key element for information systems, seeing that data will serve as a source of information for the database. Data size grows exponentially, in consequence of participation the sensors, Internet and other technologies. Therefore, it is necessary to provide an online archive.

Cloud computing

For storing of data and most software systems that enable its processing through rapid computing, this technology is called cloud computing. It is a new model for providing service of information technology (IT) through the Internet, where the user gradually outsorces most IT functions and uses these functions as external services mediated by service providers. The ability to collect huge amounts of data from real processes gives scientists the ability to create a virtual image of industrial processes. Virtual image of reality allows experimentation with the real system in a virtual environment without the risk of threat the activities of real systems. The idea of cloud computing was presented by McCarthy and expanded by Lickliderem in 1963. It is a computer service operated via the Internet (public IP network) using virtual servers [6]. Everything must be virtualized, it means access from software to hardware through a Web application. The installation of model could be divided into public, private, community and hybrid. Cloud computing is available in three models of service [6]:

- SaaS - Software as a Service - allows to carry on many software applications through the internet without having their property (Gmail, Microsoft Online).
- PaaS - Platform as a Service - provides computing platform to support web applications through the Internet (Google Apps).
- IaaS - Infrastructure as a Service - allows the usage of computer hardware and system software, including operating and communication systems. Service provider (Amazon EC2) takes care of installation and maintenance.

It is likely that Cloud computing in the Smart factory will be widely used. For example as a storage of large data volumes of communication on the Internet or providing of computer technique and IT support. Based on the benefits that result from Cloud Computing, these services will be offered to SMEs, which will specialize in IT services that can ensure the protection of information flow, so called Cyber Security.

Smart product

Each product or semi-finished product will be able to make calculations, data storage, communication and influencing the surroundings. Smart product

contains sensors, RFID chip, transmitter, memory, decision-making module with elements of artificial intelligence. Such product in Smart factory communicates with machines and equipments to make a production flow the most effective. All the previous steps records in history and already knows the steps to the future. Smart product registers its position, it also creates references to the material, decides which path to choose in order to meet the customer's assignment from the configurator [7]. Smart product is connected to the IoT and forms a system of objects that can be remotely controlled and receive information from them [5]. These products, together with after-sales service and services bring new business models and opportunities. Smart product is built on the skills of monitoring, control, optimization and autonomy (see Fig.4), where each product follows on the previous one.

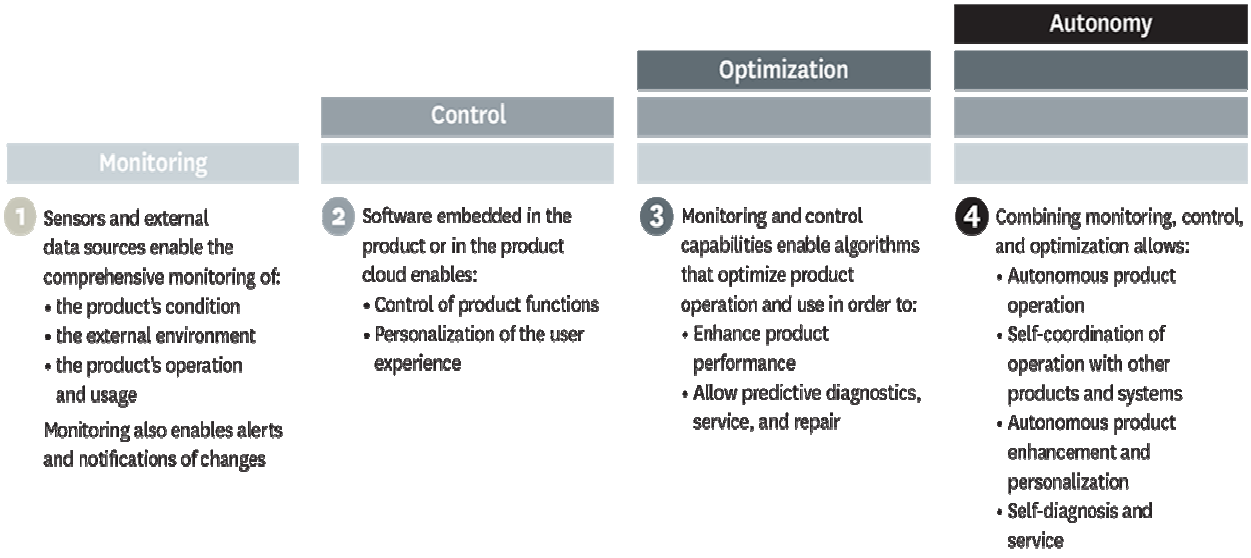

Fig. 4 Smart linked product and its capabilities

Smart sensors

Smart sensors will be a supporting tool for higher level of robotics, automation, and achievement of autonomous factory. The whole line will be equipped with sensors, actuators, cameras and feelers. These modified machines will know exactly parameters, environment, and they will know to generate their own decisions and work effectively. They will also be able to work with people and other objects of Smart factory. Data from sensors will be stored in a central repository, also will be a source for analysis, statistics and management decisions [9]. Capable workers are able to reprogram production line into the digitized version, what enables to track the deviations in real time. If the actual production deviates from the digital simulation process, CPS immediately seek correctional solutions. For example, Smart maintenance can reach the transition from reactive to predictive maintenance.

4 SUMMARY AND CONCLUSION

The new industrial revolution would not be possible without rapid progress of other discipline: artificial intelligence nanotechnology, robotics, sensors, reconfigurable systems, digital enterprise, big data, knowledge systems, virtual reality, wireless sensory networks, simulation, new methods of detection and identification of objects, etc.

In this new environment, the approaches to the organization and management of production are changed. Each object acts as an intelligent entity, and therefore it is logical that instead of the classic pressure control, each product will have to manage the processing by itself. Manufactured products become a central element of management, independent agents, which will determine the sequence of their processing and ensure necessary resources (varieties, plant, tools) and resources (machinery, equipment, logistics elements) for their processing. These will be also intelligent and will work autonomously - as agents. Management of the large number of independent agents will be assured by multi-agent systems of management able to cope with emergent behaviour of independent agents.

It is important to understand that smart production is based on communication and technical equipment. They cannot operate with incomplete or deficient data. Companies generate a lot of data about products, their production, changes, variants, customers, suppliers, workers, etc. Most of the knowledge and data is saved uncontrolled, a lot of information is just in the minds of employees. It means it is almost out of reach and too little applied. IoT requires complete, accurate immediately available data. Then its volume will be larger than it is today. Regulation in data and implementation of management system is the first step to successful implementation of smart manufacturing.

A second parallel steps should be digitization. Most companies already have their products modeled

in 3D, and this digital model is used for further detailed processing. Minimum companies work with digital model of production. This allows to design and optimize a large variety of manufacturing processes, what cannot be implemented by commonly used tool Excel. PLM systems should be one of the most important business system that control processing and data collection, cooperation and communication. Also some new applications are created. They are built on a model of digital production and product, and they are also advance preparation for IoT.

First solution is the operational planning of production, which is directly prepared for specific digital production model of customer. The result is a much better utilization of the production capacity and accuracy, as in the universal solutions that issue from ERP systems. When company introduce IoT communication between machines, this solution is adapted and brings greater benefits. The second solution is processing of calculations into the offers - so called product costing. It is a tool that detects any space to reduce costs. In the process of increasing product diversity, the complexity of production and the need to make a fair price, currently it is an indispensable tool. It is based on a digital model that is relatively easily adaptable to future changes. Another example is a system tool called Virtual commissioning, designed for quick commissioning, so the period of implementation of physical production line will be eliminated. These three examples show our readiness to gradual passing to IoT technology.

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