CYBER - PHYSICAL MANUFACTURING SYSTEMS: FOUNDATIONS FOR INDUSTRY 4.0

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Key words: cyber-physical manufacturing systems, information-communication technology, Industry 4.0

ABSTRACT:

Cyber – physical systems represent a new concept based on linking physical and virtual elements of the system in a network environment. Based on the such systems new cyber - physical manufacturing systems are structured, and those systems integrate an advanced manufacturing and information technology in the network, a distributed manufacturing environment. Such systems are the basis for the upcoming new Industrial Revolution, which in scientific circles of the European Economic Area are appointed industry is 4.0. Cyber – physical manufacturing systems integrate information technology, agent systems and manufacturing automation in an integrated production unit that can respond to the challenges of todays, demanding markets.

1. UVOD

Cyber-physical systems (CPS) represent a new concept based on linking physical and virtual elements of the system in a network environment.
Cyber-physical manufacturing systems (CPMS), rely on the latest development of computer science (CS), information and communication technologies (ICT), manufacturing science and Technology (MST) may lead to a new industrial revolution, or frequently in scientific circles called Industry 4.0 [1].
The first industrial revolution was triggered by the invention of the steam engine and the mechanization of manual work in the 18th century. The second revolution involved the implementation of mass production techniques in the early 20th century, and the third was ushered in during the pas few decades by electronic systems and computes technologies for automating manufacturing processes.
Now a fundamental transition is taking place in the world of production. The real world and virtual reality continue to merge; modern information and communications technologies are being combined with traditional industrial processes, there by changing the various areas of production.
The aim of Industry 4.0 [2][3] is to increase flexibility and productivity. As such, manufacturers will be able to produce customer – specific components fast, cost – effectively, and in small quantities – while automated processes will simultaneously ensure that individual component parts are re – ordered and that the order remains fully transparent within the company.

The central aspects of the fourth industrial revolution can be further specified through three paradigms: the smart product, the smart machine and the augmented operator.

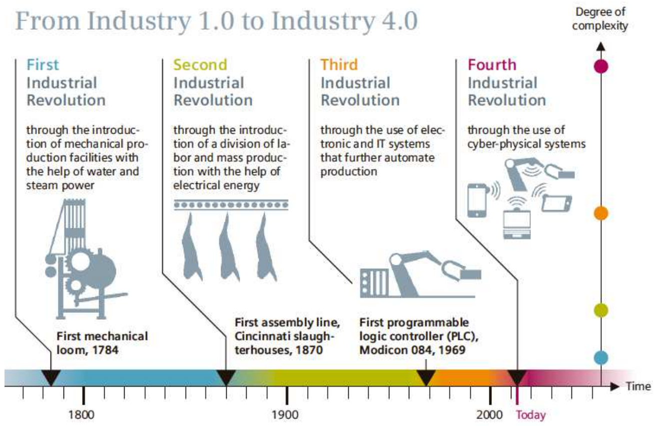

Figure 1. Evolution of manufacturing systems [4]

2. BASICS OF CYBER – PHYSICAL MANUFACTURING SYSTEMS

Cyber-physical manufacturing systems (CPMS) [2][3][5][6] consist of autonomous and cooperative elements and subsystems, connecting communications and interactions in different situations, at all levels of production machines, processes to manufacturing and logistics network. Their operational modeling and forecasting allows the implementation of a series of basic applied-oriented research tasks, and above all control systems at any level. The basic assumption in terms of CPMS is reflected in the research and defining relations through the prism of autonomy, cooperation, optimization and response to the assigned tasks.

By integrating analytical and simulation – based approaches this prediction can be described in greater detail than ever before. Such systems have to deal with a number of new challenges in terms of operational sensor networks, smart actuators, databases and many other primarily communication protocols.

A new mode of communication between man and machine must be established already in the implementation of new CPMS [6].

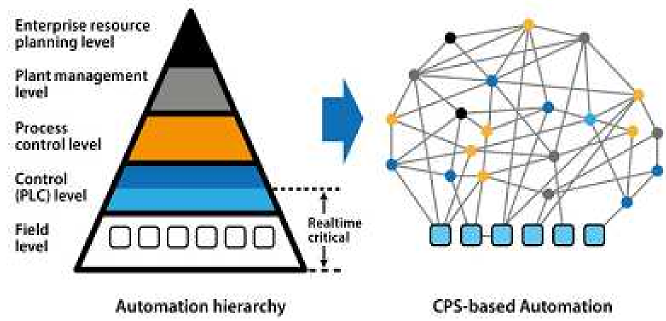

Figure 2. Automatic decomposition hierarchy with distributed service [3]

CPMS partially break with traditional programmable pyramid, as shown in Figure 2. Typical control on the field level, where still exist common PLC close technical processes are characteristics of traditional systems, while at higher levels prevailing decentralization as an essential peculiarity of CPMS.

Using the Internet of things (IoT) [7] and the CPS [8] as the basic technology, the goal of this revolution is the Smart Factory. The change sustains on the connection of the production with the network connectivity world via the IoT. "Smart production", based on CPMS, becomes the norm in a world where intelligent IT – based machines, systems and networks are capable of independently exchanging and responding to information to manage industrial production processes.

Industry 4.0 will involve the technical integration of CPS into manufacturing and logistics, and the use of the Internet of things in industrial processes. The IoT makes it possible to create networks incorporating the entire manufacturing process that convert factories into a smart environment. CPMS compromise smart machines warehousing systems and production facilities that have been developed digitally and feature end – to – end ICT – based integration.

By the integration of information – communication technologies and the Internet a global domain is created in the form of cyberspace within that form the environment that consists of interdependent network of information-communication infrastructure, including the Internet, telecommunications networks, computer systems, and embedded processors and controllers. Cyber space is a virtual space in which circulating digital data is being exchanged in the communication between participants CPS.

In the field of industrial process, Internet has contributed to the creation of smart environments representing the main factor of integration in a production environment that makes possible to link the physical and cyber system elements, building a smart systems on that way. Such systems lead to the creation of smart factories that represent the factory in real time [5][9][10][11][12].

Based on an analysis of future manufacturing literature, features that are desirable for the smart factory would relate to being flexible and reconfigurable, low cost, adaptive or transformable, agile and lean. One of the ways to achieve some of those functionalities would be to apply modular structure with respect to both product/process technology and organization. Therefore as for a conceptualization we would suggest to a definition as follows [12]:

A Smart Factory is a manufacturing solution that provides such flexible and adaptive production processes that will solve problems arising on a production facility with dynamic and rapidly changing boundary conditions in a world of increasing complexity. This special solution could on the one hand be related to automation, understood as a combination of software, hardware and / or mechanics, which should lead to optimization of manufacturing resulting in reduction of unnecessary lab our and waste of resource. On the other hand, it could be seen in a perspective of collaboration between different industrial and nonindustrial partners, where the smartness comes from forming a dynamic organization.

2.1. Interconnection cyberspace, ICT and production automation

Looking at CPMS through the prism of development computing science, information – communication technology (ICT) and manufacturing automation, we get the following picture.

The development of computers has led to a numerically controlled machine tools and robots, and microprocessors are at the heart of computer numerical control (CNC). The use of computer graphics has resulted in the development computer - aided design (CAD) system. The development of production systems has enabled the development of computer networks. The data in computer-integrated manufacturing (CIM) are organized on the principle of databases. The development of artificial intelligence, neural networks and machine learning, requires the development of intelligent manufacturing systems. Computer vision and vision development preceded the development of robotic systems we have today. The emergence of the Internet as carrier applications of social networks has contributed to the expansion of the company (EE), the possibility of supply chain management (SCM), as well as the creation of production networks (PN).

Modeled on multi – agent systems have created a production – based agents and Holonic production systems (HMS). Era of wireless networks, wireless sensors and actuators, the Internet of Things and communication protocols has enabled the production of high – performance and fast response [6].

2.2. The roots of the CPMS in production

As in any revolution, as well as in industry it is preceded by some significant events. Though, limited to the area of the International Academy for Production Engineering – CIRP, CPMS are prior to the systems that are in some way caused the creation of new CPS and which in some way represents the roots of these new systems.
These are, among others:

- Intelligent Manufacturing Systems (IMS) in which artificial intelligence , machine learning and self – learning play a decisive role,
- Biological manufacturing systems (BMS), which are based on biologically inspired ideas self – organization, adaptation and evolution,
- Reconfigurable manufacturing systems (RMS), based on the reconfiguration of machines and controllers,
- Digital factory and digital production is based on the digital world,
- Holonic manufacturing systems (HMS) based on agents with distinct characteristics autonomic and cooperativeness,
- Production Network,
- Co – evolution of products, processes and manufacturing systems,
- Complex manufacturing systems,
- Cyber – physical systems that preceded the creation of CPMS.

All of these approaches are rooted in research, development and description of the CPMS and their implementation in the upcoming Industry 4.0.

2.3. Architecture CPMS

For the presentation of architecture, in general, production systems it is necessary to have a vision from two aspects, namely: creative vision and integration vision or concept.
CPMS need to link the physical component and cyber world, including the inescapable factor of each production system – man. So, CPMS should allow uniform communication between the physical world of machines and products, virtual environment – digital data, database, simulation and modeling tools and methods, and the ubiquitous world of people, Figure 3 [13].

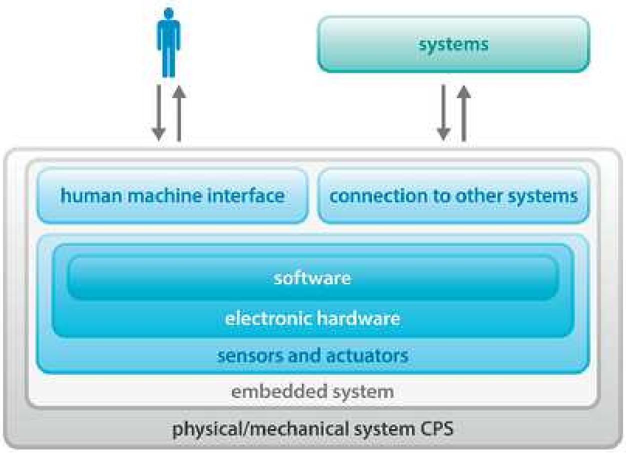

Figure 3. Interaction between humans and machines in Cyber – physical systems [13]

This show represents a generalized picture for understanding the structure of CPMS pointing to software integration, hardware systems, sensors and actuators, installed systems and man as a vital participant of the process within the manufacturing system.
Once developed the idea of a control system of cloud – based machines, it is necessary to develop solutions for complex control systems such as robot control, smart machines and so on. Upcoming changes that bring CPMS are changing the current practice of management and control, and these activities are taking place in cyberspace.

2.3. Expections of CPS and CPMS

The development of cybernetics – the physical system, and therefore their implementation in a production environment, one can expect significant improvements in production systems which will be reflected in the form of [8]:

- Robustness at all levels,
- Self – organization only – keeping only – refurbishment, generalization,
- Security,
- Remote diagnosis,
- Controlling in real time,
- Autonomic management
- Transparency,
- Predictability,

Through the development of CPS can be expected to develop new business models and new services that will be used in various aspects of our lives. Potential areas of application are broad, such as medicine, industry, transport, energy systems, and many others. CPS contribute to finding answers to the key challenges of our society and are very important in many industries and application areas. CPS provide enterprises support in the process of optimization and therefore also in the price of striving for saving time, and providing help in saving energy, reducing CO_2 emissions. For residential customers, the benefits of CPS are mainly on the level of comfort, such as assistance in mobility, the networked security, the individual medical care for the elderly in the area of maintenance.
CPS are also of great importance in industrial production in order to meet customer requirements. Production systems will be structured so that they can respond to almost any market changes in real time and using the cyber supply chain – physical systems, and to cooperate with the ultra – flexibility beyond the boundaries of the enterprise.
This not only makes production fast and according to specific individual customers, allows production processes within the company, also be optimized through a network of global cooperation, adaptive, evolutionary and self-organizing production units that belong to different operators. The potential for savings and innovation in such plants is huge.
The following topics, related to CPMS and of the utmost importance for the production and engineering.
Further research and development of innovative methods so that they are able to offer new products for the global market:

- Ongoing research into new production processes;
- Further scientific breakthrough manufacturing processes and machines production in order to be properly established models available and which can be used as a CPMS;
- Robust, fast, efficient manufacturing processes that can be run safely without human intervention and verification;
- Stable machines with predictable properties and behavior in order to understand the security of automation, even under fluctuating environmental conditions;
- Models and simulation procedures for processes and machines to present automation systems with methods of assessing the implications of their decisions;

- Safe processes cyber – preparation of physical systems, which can be launched even under difficult circumstances and conditions of the system and at high speed, to ensure that neither people nor machines are not in danger;
- Security in networks, in order to avoid the abuse and neglect intervention and externally;
- Extreme ability in real time to reach even the fastest processes, incidental and interdependent;
- New models of operators;
- Hybrid systems and architecture models that are specific for engineering jobs, and

3. CONCLUSIONS

Industry developed countries of the world today is facing a new industrial revolution, which German academics and industrialists called Industry 4.0. Like all its predecessors, this industrial revolution was launched with new scientific knowledge and the development of new technologies on the one hand, and socio – economic demands on the other.
On the economic development and social demands above all directly affects the rapid development of ICT, for example, the IoT, by which industrial companies become global and connected, their products are smart, and more closely linked to a worldwide network. In this context, emerging new ideas about coping and connecting to one side of the communication related digital – or virtual cyber world with the real or physical world, which constitute things and living beings, particularly humans, which brings us to CPMS. Since these systems are expected harmonious interaction with people, objects and virtual elements, and create synergies among the participants.

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