THE NEW GENERATION OF MANUFACTURING SYSTEMS

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Abstract
The increase of aggressive competition and growing instability of the business environment as well as advancements of ICT (Information and Communication Technologies) determined many of manufacturing enterprises to change their processes and production systems. From the theoretical point of view, over the past several decades, new paradigms for manufacturing and engineering systems have emerged as results of interdisciplinary research and development projects focusing on the design, specification, performance modelling and implementation of an intelligent self-healing, self-adaptable, self-improving, agile production system. The aim of this article is to present a partial analysis of the challenges to structural changes in production systems and also a schematic model of the intelligent manufacturing system conception is presented.

Key words: production systems evolution, innovation, intelligent manufacturing system.

INTRODUCTION
The primary requirement of manufacturing is to produce as many products as soon as possible, at the lowest possible cost, but with the highest quality. With the evolution of the production systems, different philosophies was developed, such as lean manufacturing, agile manufacturing, flexible manufacturing, re-configurable manufacturing systems, e-manufacturing / Internet-based manufacturing, self-organizing decentralized manufacturing systems, sustainable manufacturing, holonic manufacturing systems, distributed virtual manufacturing systems, balanced automation manufacturing systems, biologically-inspired manufacturing systems (e.g. Breathing Factory) etc.

In this article the most important impulses of progress at manufacturing systems for the following years are presented. The subject of the article deals with the different driving forces to development of the production structures and the new requirements for manufacturing system are discussed. The interpretations of information presented in this article are based on the combined data set of many papers published recently. Primary data were obtained through mapping of different reports and analysis of the studies and relevant documents that were publish from reputable institutions, mainly carried in online version.

THE SCOPE OF MANUFACTURING SYSTEMS EVOLUTION
In general, the goal of the production systems evolution is to satisfy customer needs at the most efficient level for the lowest possible cost. The efficient and competitive production of new products requires new manufacturing technologies, equipment and processes. Rapid changes in process technology require designing and creating production systems easily upgradeable and into which new technologies and new functions can be integrated. [2] Technology plays a major role in manufacturing these days - advanced automation and ICT supports manufacturing processes. Can be alleging that ICT was the major contributor to manufacturing innovation and increase productivity and quality. ICTs have an impact on the processes also related to material flows (e.g. manufacturing and monitoring, production optimisation, automation, real-time testing etc.).

Over the past several decades, manufacturing system has experienced significant change and a number of factors have enabled this evolution. To comparison, the diverse production system conceptions are briefly characterized in table 1.

The main driving forces for manufacturing systems innovation, identified in the paper [3] are:

- increasingly competitive global economic climate;
- market saturation in developed countries and continuous increase of customer demands;
- rapid advances in science and technology (specifically in the fields of nanotechnologies, materials science, electronics, mechatronics, ICT and biotechnology);
- environmental challenges and sustainability requirements;
- socio-demographic aspects (the size of the labour force);
- exacting regulatory environment, standards (environmental and safety regulation, the intellectual property rights system etc.);
- values and public acceptance of new technology (the need to take ethical concerns into account when science and new technologies are being adopted and exploited).

The key characteristics of advanced manufacturing system are summarized in fig. 1.
Tab. 1: Main approaches to different manufacturing systems [4]

<table>
<thead>
<tr>
<th>Manufacturing system</th>
<th>Focus</th>
<th>Main strengths</th>
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<tbody>
<tr>
<td>Mass production</td>
<td>Reduction of product cost</td>
<td>Full utilization of plant capacity</td>
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<tr>
<td>Lean</td>
<td>Continuous improvement in product quality</td>
<td>Decreasing product costs</td>
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<tr>
<td>CIM</td>
<td>Integration of computers and computer-based tools</td>
<td>Use of computers to support different activities</td>
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<td>Flexible</td>
<td>Manufacturing a variety of products on the same system (adaptation of the manufacturing system to new market conditions)</td>
<td>High diversity of manufactured products</td>
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<td>Reconfigurable</td>
<td>Rapid adjustment of production capacity and functionality (e.g., changes on product demand, production of a new product on an existing system, integration of new process technology into existing manufacturing systems), by rearranging or changing its components</td>
<td>Modularity, Integrability, Convertibility, Diagnosability, Customization</td>
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<tr>
<td>Agile</td>
<td>Strategy focusing on thriving in an unpredictable business environment (adjustment to unexpected changes or events)</td>
<td>Quick response to changes</td>
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<tr>
<td>Intelligent</td>
<td>Systems enhanced with human intelligence (e.g., concerning decision making)</td>
<td>Acceptance</td>
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<tr>
<td>Holonic</td>
<td>Holons (autonomous and cooperative manufacturing block for transforming, transporting, storing/validating information and physical objects)</td>
<td>Preserves the benefits of hierarchy and heterarchy structures</td>
</tr>
<tr>
<td>Balanced automation</td>
<td>Optimal mix of machines and humans (considering the socio-economic context)</td>
<td>Balance of automated and human-based activities</td>
</tr>
<tr>
<td>Bio-inspired</td>
<td>Based on bio-inspired approaches (aspects on self-organization, learning, evolution and adaptation; systems easily adapt to unforeseen changes in the manufacturing environment - e.g., to continue operating when one of the units stops working)</td>
<td>High adaptability, Flexibility</td>
</tr>
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Fig. 1: Characteristics of advanced manufacturing system [6]
Summarized demands to modern production systems are [6]:

- reduction of cost; reduction of lead times; reduction of production waste (lean);
- easy integration of new processes, sub-systems, technology and/or upgrades;
- transition from vertical to horizontal structures; from highly centralized to decentralized structures;
- full integration of heterogeneous software and hardware within an enterprise and across a supply chain: open system architecture to accommodate new (hw or sw) sub-systems;
- communication (information flow) within an enterprise and across enterprises;
- include of human factors (ergonomic conditions) into manufacturing systems design;
- quick response to external changes and unexpected troubles from internal and external business environments;
- a zero fault tolerance at the system and sub-system level: detect and quickly recover from system failures and minimize their implications on the working area; adequate equipment and machines (e.g., sensors);
- fast adaptation, re-configurability of production base: to accomplish the changing clients’ demands;
- intelligent manufacturing system, which has the ability to solve problems (e.g., related to control, collaboration) and make decisions taking into consideration human values and human’s subjectivity.

These above mentioned requirements reflected the framework of manufacturing systems formation. In practice, it was established many progressive concepts of manufacturing systems with ICT support, for example [2]:

- **Adaptive manufacturing**: focuses on agility and anticipation to permit flexible, small-scale or even single-batch-oriented production through integration of ICT for optimal efficiency and by focusing on the human user through adequate human-machine interfaces (HMI).
- **Digital manufacturing**: aims at a digitisation of all manufacturing, involving the modelling, the planning and the simulation of new production facilities through digital models and advanced integrated ICT.
- **Networked manufacturing**: allows a dynamic and value-adding global cooperation and distribution in fast changing markets using global sourcing and a closer customer and supplier integration.
- **Sustainable manufacturing**: considers optimisation of material and energy consumption as well as reduction of waste. With sustainability improvement in manufacturing is meant: energy efficient with minimal impact on environment and society.

In the future, the further implementation of ICT solutions will positively affect efficiency, sustainability and quality of the production systems based on ICT - enabled intelligent manufacturing.

[5]

**THE INTELLIGENT MANUFACTURING SYSTEMS**

The new generation of manufacturing systems are also called intelligent manufacturing systems. According to definition [1] the term “intelligent manufacturing system” can be explain as: system which improves productivity by systematizing the intellectual aspect involved in manufacturing and flexibility by integrating the entire range of corporate activities so as to foster the optimum in relationship between men and intelligent machines. The intelligent production systems consist of subsystems like automatic manufacturing systems (technological, supervisory, transportation, manipulating, controlling). Subsystems have to be equipped with aids, which give to subsystems specific level of intelligence.

The concept of intelligent manufacturing [4] combines the ability of decision-making support systems in generative systems to obtain knowledge, to learn and to adapt to a changing environment and to the actual arrangement of system components. The nature of intelligent manufacturing is system’s possibility to learn and its self-development as well as the possibility to generate information necessary to control the integrated production system. Components of intelligent manufacturing systems (see fig. 2) consist of intelligent: design, operation, control, planning, maintenance. [8]

The advanced manufacturing systems for the future defines these main characteristics [4]:

1. **self-improving** (e.g. able to monitor and assess the economic performance of a manufacturing process, unit or subunit, diagnose the causes of lower performance and take appropriate decisions for the overall unit/ system’s performance improvement);
2. **self-adaptable** (e.g. by detecting abnormalities and taking decisions to recover from them);
3. **self-healing** (e.g. being able to monitor itself, diagnose causes of failure and recover from them, and may concern a single service or...
manufacturing unit, or address a more global level, such as manufacturing network).

The production system with these attributions has the ability to self-regulate and / or self-control, self-configuring, self-monitoring and self-repairing to manufacture the product within its design specifications.

The flexible and adaptive automation technologies can be used in advanced manufacturing systems and they include e.g. new intelligent controls units, cognitive human machine interfaces, self-learning systems, ambient intelligence and wireless communication. [7]

In the context of the issues formulated in this article can be presented the example of the intelligent manufacturing system solution that was designed in the conditions to agile automotive production. The automotive industry has always set standards in automated production. It is a source of impulses for innovative technologies focused on reducing costs, increasing flexibility and assuring availability. [10] Flexibility and agility factors in automotive business are considered as priority.

Flexibility is reflected through capacity utilization. When demand falls, or shifts away from one market segment to another, the most flexible automotive manufacturers will find a way to respond to that change without closing plants.

To optimally fulfil individual customer wishes in the automotive production, the right component has to be ready for installation on the respective body at the right time and in the right workplace. Precise identification of each individual component in assembly lines is crucial. This logistical challenge can only be mastered with an appropriately dimensioned “manufacturing execution system” with advanced ITC tools support. [7]

Figure 3 illustrates the example of Vision System for Robotic Welding that is used to monitoring of process and represents the element of advanced intelligence in workplace.

The agile factories in automotive represents future production sites for a large variety of sophisticated products that are offering flexible, short cycle time and variability controlling
manufacturing capability. These manufacturing approaches ensure energy-efficient, reliable and cost-effective production. [11]

CONCLUSION

This article reflects some partial results of analysis that offers a perspective on where the manufacturing systems progress is headed.

Manufacturing is and will remain a significant component of economic activity in the world. Over the past few decades, manufacturing has evolved from a more labour-intensive set of mechanical processes (traditional manufacturing) to a sophisticated set of information-technology-based processes (advanced manufacturing). Manufacturing innovations will have displaced many of today’s traditional manufacturing processes, replacing labour-intensive manufacturing processes with automated processes that rely on sensors, robots, and condition-based systems to reduce the need for human interventions.

References


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