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Management Systems in Production Engineering

2018, Volume 26, Issue 4, pp. 212-216

Date of submission of the article to the Editor: 07/2018
Date of acceptance of the article by the Editor: 09/2018

DOI 10.1515/mspe-2018-0034

CHALLENGES OF INDUSTRY 4.0 FOR PRODUCTION ENTERPRISES FUNCTIONING WITHIN CYBER INDUSTRY NETWORKS

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Abstract:
The globalization process and the marginalization of Europe in world production prompted the German economy to implement the Industry 4.0 concept called the fourth industrial revolution. As a part of the proposed concept, a close connection of physical objects with the information network should be made. Enterprises will connect by intelligent resources communicating through the modern Internet of Things technologies, big data, and cloud computing. Therefore modern enterprises have a new further challenge which means a need to build and cooperate within cyber-physical systems. The aim of the article is to present key challenges for Polish small and medium-sized manufacturing enterprises oriented to the cooperation within the Industry 4.0 concept. Furthermore, the results of surveys conducted on a selected group of Polish production companies in the metal sector are shown. These results present the condition of Polish enterprises, their concerns and expectations regarding the implementation of the Industry 4.0 concept. The paper contains also the new idea to create the Cyber Industry Network (CIN) which means a kind of the on-line available platform for exchanging production capacity of small and medium enterprises and allows for the efficient combining of free resources to realize joint production projects.

Key words: *Industry 4.0, Cyber Industry Network (CIN), production flow planning, small and medium production enterprises, the platform for exchanging production capacity*

INTRODUCTION

The globalization process, which is currently characterized mainly by the growing share of developing countries in the global manufacturing industry, is forcing the Western European economies to take steps to improve the competitiveness of local enterprises. Currently, in the metal industry, there is a very strong competition from developing countries such as China or India. The products which they offer have very low prices compared to European companies. It is not possible very often to produce such cheap products in Europe primarily due to the large labour costs. In order to gain a competitive advantage in the market, a completely new, incomparably more modern and innovative approach to manufacturing and management of a company is needed which dramatically increases productivity and also to help building very fast, efficiently managed supply chains [7, 16].

Furthermore, the process of moving enterprises outside Europe increases the danger of deepening the decline in the industrialization of countries such as Germany, France, Italy or Switzerland. Maintaining the potential of the industry in Western Europe is now becoming an important goal of the strategic development of these economies. Concerns about the marginalization of Europe in world production have prompted German experts to develop the concept of Industry 4.0, which will allow them to regain the status of the industrialization leader of highly developed countries. As part of the proposed concept, which is widely called the fourth industrial revolution, it is planned to closely connect physical objects with the information network. This means that sophisticated networks of enterprises will be created, connected with intelligent resources communicating via the Internet, using the Internet of Things (IoT), cloud computing, big data [9].

Modern enterprises have a new further challenge which means a need to build and cooperate within cyber-physical systems. The aim of the article is to present key challenges for Polish small and medium-sized manufacturing enterprises oriented to the cooperation within the Industry 4.0 concept. Furthermore, the results of surveys conducted on a selected group of Polish production companies in the metal sector are shown. These results present the condition of Polish enterprises, their concerns and expectations regarding the implementation of the Industry 4.0 concept. The paper contains also the new idea to create the Cyber Industry Network (CIN) which means a kind of the on-line available platform for exchanging production capacity of small and medium enterprises and allows for the efficient combining of free resources to realize joint production projects.

INDUSTRY 4.0 CONCEPT

The concept of Industry 4.0 assumes the creation of a fully integrated system of suppliers, producers and customers. Pursuant to the concept of Industry 4.0, IT solutions will be integrated with all subsystems, processes, system resources and networks of suppliers and customers. The newly designed IT systems will thus integrate entire supply chains creating cyber-physical systems (CPS), which will be open sociotechnical systems capable of implementing a series of new functions and actions imposed by production, logistics or management. CPS systems should ensure data collection, processing and impact on physical processes occurring within the entire logistics chain or enterprise network due to unlimited network connections at the same time with minimal human participation performing only supervision functions [12].

One of the assumptions of the transformation within Industry 4.0 is the use of mechatronic CPS products (machines, devices, robots, means of transport, etc.) in the PLM (Product Life Cycle Management) chain, starting from creating a new product concept, virtual documentation, printing models, their simulation, laboratory and industrial research, production decisions, virtual production documentation, product creation in a virtual production environment, verification of its accuracy, transition from the virtual production environment to the real environment, development of software-assisted and computer-controlled production and assembly documentation, logistics warehouse, transport and sales, control of the correctness of operation, compliance with inspection, repair and renovation dates, indication of the place and contractor of these activities, and finally controlled recycling. The authors of the concept point out the need to develop new legal standards at least at the EU level, enabling the network exchange of production and service data regarding the entire logistics chain related to the production and operation of the product, added value such as patents, utility models, license agreements, etc. Additionally, it is required to develop standards, open applications that enable network connection of enterprises involved in the production process, delivery to the customer and users of this product [12]. The problem of the security of network transmission between individual modules communicating via communication networks or IoT is of great importance.

The Industry 4.0 concept is oriented towards high productivity of industrial systems and high profitability of implemented projects. It indicates a number of benefits that may flow from its use. It is noteworthy to increase the flexibility of production and organize the production of more individualized products. This means the ability to meet customer expectations without deteriorating the profitability of the production process due to the dynamic adjustment of autonomous modules of the entire process of preparation, production and delivery of the product to the customer with the use of Internet of Things and information recorded in Big Data and Cloud Computing [3, 12]. The Industry 4.0 is therefore a combination of the advantages of custom production with the benefits that large batch or mass production offers today. In addition, there is the possibility of a significant improvement in production efficiency through the use of material, manufacturing and employee resources of cooperating network partners with unused production capacities. This intensifies the need for research on the problems of development of network forms of cooperation of enterprises operating in the era of the Industry 4.0 concept.

CYBER INDUSTRY NETWORKS (CIN) IN THE CONCEPT OF INDUSTRY 4.0

Designed and implemented by metal enterprises business models determine to a large extent on the profitability and competitiveness of the organization. Analyzing the essence, structure and conditions, which determine the shape and types of strategic models are therefore an important element of cognitive sphere of development and operation of enterprises. At the same time such research can serve to improve or even build new models that facing the challenges of the market, which become necessary [4].

The need to conduct research in the field of organization and management of business networks can also be demonstrated by the numerous benefits of cooperation indicated in the literature both for the enterprises themselves and for the client. Currently, the company's participation in the network is particularly attractive for small and medium-sized enterprises, which in this way can overcome the main competitive advantage of large enterprises in terms of access to all types of resources (capital, competencies, know-how, etc.) [1, 10, 14].

In the situation of the development of the Industry 4.0 concept, each company is perceived as offering an intelligent module for certain opportunities to be used in the production and delivery of the product to the customer, and the size of the enterprise therefore ceases to matter. This means that the level of technology used, the level of highly qualified staff employed and openness to unlimited communication using, among others, communication networks or the Internet of Things will be very important. By combining the potential of partners as a network organization, it will be possible to offer more complex, innovative products and services tailored to customer needs [11].

The company's participation in the network offers new opportunities and enables the use of modern organizational solutions that have a significant impact on the increase in efficiency of operations manifested by process orientation, decentralization of management, professional development of employees, etc. [2, 13].

In addition, the possibility of the occurrence of many alliances allows for better use of existing production capacities and an increase in the productivity of the available production and human resources of the enterprise. Functioning in the network also has a positive impact on the learning process through gaining experience, know-how and knowledge on the basis of mutual relations between cooperating enterprises [15]. Applying the concept of the Industry 4.0 to this networking approach would eventually allow the entire process to take place automatically. This means that the development of network forms of cooperation, solving a number of problems related to the formation and management of networks is an excellent basis for the rapid implementation of the Industry 4.0 concept, especially at the level of small and medium-sized enterprises.

The idea of a production network called the Cyber Industry Network (CIN) means the manufacturing of joint production orders using fully automated processes of individual network partners, in which communication takes place via the Internet, and the necessary data is stored in the cloud (cloud technology). This enables constant access of all participants of the network to selected, necessary information from anywhere in the world. Thus, the chance for development arises in creating a partnership consisting in the combination of specialized competencies and ability to change in order to better meet customer expectations and enable effective acquisition of competitive advantage in the market. The schema of the Cyber Industry Network (CIN) is presented in Figure 1.

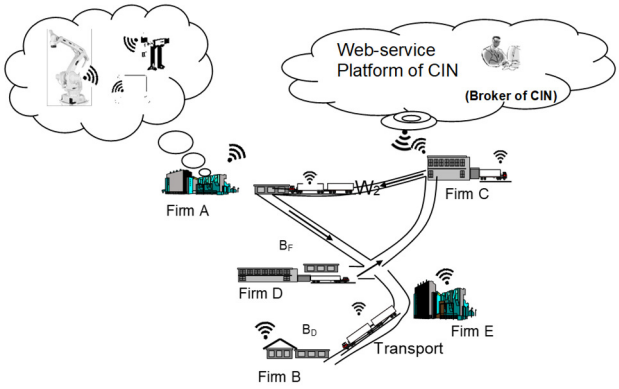

Fig. 1. Schema of the Cyber Industry Network (CIN)

This raises the question: What are the challenges for Polish enterprises in the era of developing the concept of Industry 4.0, especially in the area of forming production networks and at the same time acting as an integrated, intelligent module sending and receiving information streams via ICT networks?

Polish enterprises are characterized by a very low level of adjustment to the Industry 4.0, especially in terms of the level of technology used. According to the latest report of the International Federation of Robotics – IFR, the gap between implementations in the field of automation and robotics in Poland and in other countries is still very visible. In 2016, there were an average of 74 industrial robots per 10,000 employees employed in the global production sector. In Poland, the average robotic density was 32 robots. Compared to other countries of the region, we are still the worst. For comparison, in the Czech Republic 101, Slovakia 135, and in Germany the robotization density is 309. For comparison in the most automated countries in the world such as, for example, South Korea, the robotization density index in 2016 was as high as 631 [8]. Unfortunately, the Polish industry is characterized by a moderately weak state of automation and robotization of production. A survey conducted by Astor in 2015 shows that about 15% of enterprises in Poland are fully automated, which corresponds to the stage of development of industrial production in technology 2.0. Partial automation is characterized by about 76% of enterprises. However, stage 3.0, that is the stage of robotization and digitization of production, shows a low level of advancement. Polish industrial enterprises are still struggling with the challenges of the third industrial revolution [5, 6], which does not give good prospects for the rapid implementation of the idea of the Industry 4.0.

Similarly, an important barrier of the fast application of Industry 4.0 assumptions is the constant lack of climate for the cooperation of Polish enterprises, especially when it comes to small and medium-sized industrial enterprises. The research conducted on 150 companies operating in the metal sector shows a number of barriers related both to the experience of previous cooperation and the difficulties in creating various forms of network cooperation. Selected test results are shown in Figure 2. The most frequently declared problems are:

- the lack of technical infrastructure required in the Industry 4.0 concept;
- no specialized software;
- the risk associated with unfair partner practices;
- no entry and exit procedures from CIN.

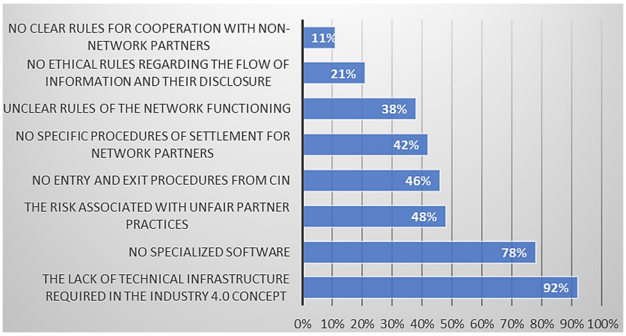

Fig. 2. Main barriers of the Cyber Industry Network building - results of the preliminary research

In addition, the surveyed companies declare a lack of trust to other enterprises, often resulting from negative experiences of previous cooperation. Unfortunately, this may be an important barrier to the positive adoption of the Industry 4.0 concept by the Polish SME sector. Additionally, the problem is the very low level of automation and computerization of Polish enterprises, including the use of IT systems for operational management and control of MES production (Manufacturing Execution System). One of the key reason may be the short adaptation period of Polish enterprises after transformation in 1989, often abounding in negative experiences related to the functioning of the capital market that is emerging from scratch. Other reasons include:

- lack of climate for investments in new technologies;
- still low level of employment of qualified engineering staff;
- low wages of employees;
- an advantage of concentration on the sphere of marketing and sales, and not on building a competitive advantage through the use of modern technologies.

Therefore, the need to develop a web service platform supporting the creation of the Cyber Industry Network (CIN), which will allow the use of the potential of Polish small and medium enterprises, will affect the need to invest in the latest technologies and develop a narrow specialization. Taking into account the level of Polish enterprises represented and the introduction of the Industry

4.0 concept, one of the methods of survival in the Western European countries is participation in created industrial networks.

THE PLATFORM FOR CREATING OF CYBER INDUSTRY NETWORKS

The main goal of future research is to develop the Platform for creating Cyber Industry Networks (CINs) which will be available on-line on the Web-site. The authors of the article propose to develop the standards which help to create and manage of the Cyber Industry Networks on the basis of simple rules. In this approach a key component is the broker who is responsible for supervising the collection of data about production order and bids (offers) from enterprises. In the future the data from enterprises will be transferred to the platform automatically from machines and devices using the Internet of Things technology. After that the platform will propose set of acceptable variants of CIN which guarantee production order execution on time and with assumed cost.

The proposed platform is a tool to help facilitate the exchange of information between the broker, who provides information concerning tasks, and enterprises with the specific production capacity sufficient to carry out these tasks. Based on information collected in the system, a set of network variants capable of timely implementation of the order, and a schedule showing the load on individual resources of companies in a given scenario for the implementation of the new order is generated. Each variant is characterized by a set of selected companies with an indication of resources used, cost of implementation and the date of commencement and completion of the production order. This ultimately allows the best variant to be chosen in the system and available capacity to be reserved for the implementation of the production order by individual companies. Data on resources of companies is only made available for the the broker. This means there is no access to confidential data from other companies and therefore increases the security of the system against unfair competition. Conversely, any of the companies registered in the platform have access to information on orders and planned tasks.

The broker is responsible for entering the data of production projects (orders) planned for implementation in the CIN. Each order is divided into subtasks dedicated to different kind of enterprises. For the planned order, the following data should be entered:

- the planned date for completion of the task (the deadline specified by the customer);
- expected number of pallets used in the delivery to the customer (standard Euro pallets);
- maximum permissible cost of the project (order).

After entering the tasks data of the planned production project (order), and after considering all on-line information about available resources from enterprises within a specified period, the platform starts the procedure of permissible variants of Cyber Industry Network planning to ensure the implementation of the order. The proposed procedure based on checking of sufficient conditions which can guarantee production order execution on time with assumed cost.

For each of the identified variants, a schedule of the production flow of the production network is generated (Figure 3), which allows for the efficient completion of all tasks in individual enterprises, coordination of manufacturing operations performed, transport and monitoring of the progress of the planned orders in the system. All information from the platform and between each enterprise will exchange automatically using the Internet of Things technology.

CONCLUSION

After three industrial revolutions, the fourth is coming which moves a production to sophisticated networks of companies equipped with intelligent devices, machines, means of transport communicating with each other through the use of new technologies such as Cloud Computing, Big Data and Internet of Things (IoT). This poses new challenges for Polish industrial enterprises, and requires significant investments in automation, robotics and digitalization, which will allow in the future more intelligent communication technologies, especially those related to the Industry 4.0 concept, to be used.

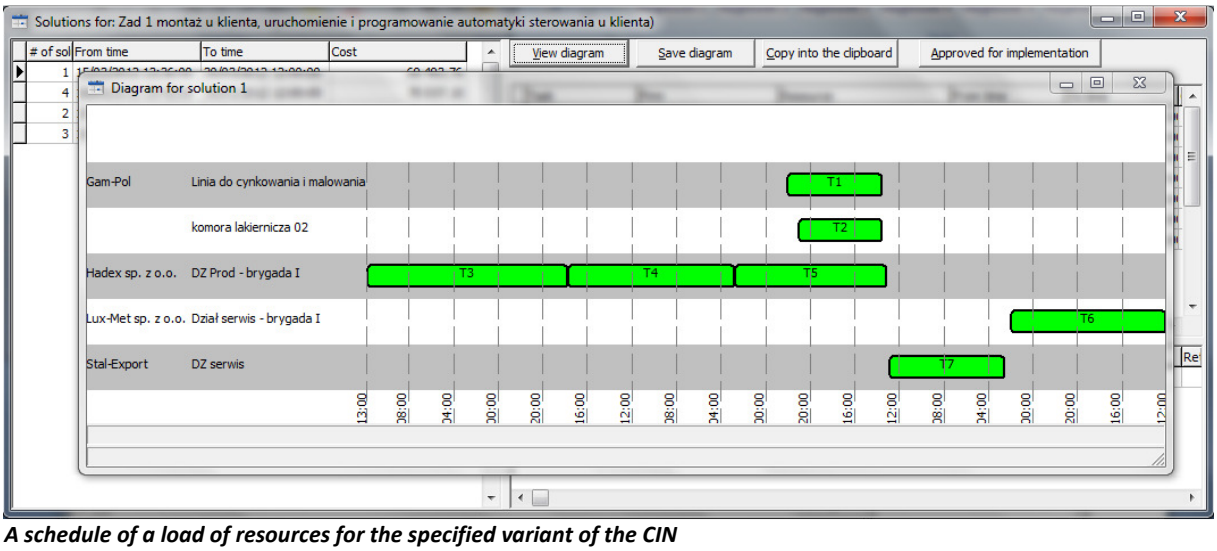

Fig. 3. A schedule of a load of resources for the specified variant of the CIN

The article presents selected problems of Polish enterprises in the metal sector related to the adaptation process to the challenges of the Industry 4.0 and the new idea of creating the Cyber Industrial Networks (CIN). The CIN are supported by a platform which is serviced by a broker. This solution is dedicated especially to the group of small and medium-sized enterprises. The idea of focusing enterprises around the platform can be an excellent introduction to the process of adjusting the potential of enterprises to the conditions of the Industry 4.0.

The proposed concept of the platform allows the integration of cooperating enterprises, sharing of production capacity of enterprises and the possibility of production order execution significantly exceeding the production capacity of any single enterprise. Furthermore, the proper functioning of the proposed system will improve the productivity of the production resources of cluster enterprises and will have a positive effect on the development of small and medium enterprise belonging to the cluster.

Furthermore, the proposed method of exchanging information in a computer system uses a trading broker to avoid the risks of unfair competition (e.g., use of load state information resources, use of resource unit costs by a dishonest partner, etc.). Trusted broker supervision over the information allows the level of trust between partners to be increased and also allows the integration of the enterprises involved in the platform.

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