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Engineer 4.0 in a metallurgical enterprise

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INTRODUCTION

Industry 4.0 – initiated in 2011 as Industrie 4.0 (German) during the work of the German government, concerning the recognition and analysis of upcoming landmark changes of strategic importance for the German economy - creates new conditions for the functioning of enterprises. Industry 4.0 is the result of the development of cyberphysical manufacturing systems (eng. *Cyber-Physical Production Systems* – CPPS) and phone information technologies (eng. *Information and Communication Technologies* – ICT). The production lines are automated and robotic, and the individual operations: design, procurement, manufacturing and sales are carried out with a small share of employees. The results of the new production depend on the synchronization of the work of industrial robots equipped with artificial intelligence and computer systems supporting and optimizing production.

Industry 4.0 results in significant changes in the performance of work and the functioning of the industrial environment. This applies in particular to the role of man in a smart factory and related new qualifications and competences.

The purpose of this article is to characterize changes in production work resulting from the development of industry 4.0. The article is based on the subject literature and research reports conducted by specialized external companies. At the beginning of the article production in industry 4.0 is presented.

Next, the main changes in the structure of employment and professional qualifications of employees were characterized. At the next stage, the professional profile of engineer 4.0 was developed in a metallurgical enterprise. The article is concluded with a summary.

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PRODUCTION IN INDUSTRY 4.0

In industry 4.0, production takes place in intelligent factories as part of cyber-physical systems (CCPS) that monitor physical processes, create virtual copies of the physical world and make decentralized decisions (Wang et al., 2015). The use of cyber-physical systems (CPS) in production systems is defined as (eng.) *Cyber-Physical Production Systems* (CPPS) or (eng.) *Smart Factory (*Rudtsch et al., 2014). CPPS are integrated into communication solutions known as the Internet of Things (ang. *Internet of Thing* – IoT) (Ashton , 2009; Barciński, 2016; Kaliczyńska, P. Dąbek, 2015) and Internet Services (eng. *Internet of Services* – IoS). Through the Internet of Things, cyber-physical systems communicate with each other and cooperate with each other and with people in real time. Production in industry 4.0 is carried out by industrial robots using ICT technology to control and communicate devices (called Machine to Machine - M2M) and human with devices (People to Machine - P2M), and to integrate all processes.

Systems - CCPS - are structures combining information technology - IT and operational technology - OT. Such incorporation of two technologies in manufacturing processes widens the possibilities of producers who go beyond their enterprises and are not spatially bounded both within the organizational and inter-organizational (services are offered and used by various participants of the value chain). Intelligent factories have learning machines (machine learning), as well as information sets (cloud computing) and huge databases (Big Data).

Production technology in industry 4.0 is advanced (Advanced Manufacturing) due to the automatic search and implementation of the best solutions for manufacturing products with the existing resources of the company and taking into account the customer's personalized needs (Hermann et al., 2015; Blaik, 2018, pp. 2-11). The production lines consist of robots and industrial manipulators equipped with work organization tracking systems. Transport activities are carried out by autonomous transport devices. Access to process data (Data Processing) creates unlimited possibilities for process improvement through intelligent control systems and production of specific parts, subassemblies and finished products. Computers control production using data and digital product description (Lee et al., 2015). In a smart factory, product design is implemented in 3D systems, often on new materials and using new energy sources (Lasi et al., 2014, pp. 239-242).

The production is carried out for a specific customer who uses IoT (Kagermann Henning et al., 2013). Satisfying every customer's need is a prerequisite for competitiveness in industry 4.0. The individual completed personalized orders form a set of serviced clients that exceeds hundreds of millions (Korena , et. al, 2015). The created set of satisfied individual customer needs is a form of mass individualization due to overcoming spatial, temporal, communication, technological, cultural, financial barriers, etc. (Tadejko , 2015).

Integration of IT systems used in various stages of production and planning, material flows, energy and information creates unlimited possibilities for production that becomes intelligent (Smart Production) due to the wide range of possibilities of implemented changes and its flexibility with respect to resource capabilities and external conditions. In cyber-physical production systems, virtual connections even precede physical connections.

Cyberphysical production systems (CPPS), which were used in industry 4.0, are regarded as Crucial Innovations, and their breakthroughs result from a wide range of technological changes, replacing human work. CPS systems ensure data collection, processing and impact on physical processes within the entire production network due to unlimited network connections, intelligent, mechatronic resources that communicate with each other (machines, devices, robots, means of transport, etc.) with a small human contribution new functions in production (Prahalad and Krishnan, 2010).

CHANGES IN THE EMPLOYMENT STRUCTURE AND IN THE PROFESSIONAL QUALIFICATIONS OF EMPLOYEES

Changes in production entail changes in employment. In the subject literature, various scenarios of changes in the structure and in the professional qualifications of employees are given. Scenarios of employment changes in the perspective of industry 4.0 are both optimistic and pessimistic. Directions of changes are available in publications of such authors, as: Becker (2015), Bendkowski (2017), Bothoff and Hartmann (2015), Kurz (2014), Spath et al. (2013), Windelband (2014), as well as in market research reports, among others, Whitepaper Astor (2017) and Boston Consulting Group (2015). These publications were used to develop the remainder of this article. This part of the work presents an overview of changes in production work during the development of industry 4.0 on the basis of this literature study. The paper assumes that industry 4.0 will affect the labor market and change the employment structure in enterprises.

Changes in production lines along with the development of automation lead to a drop in the demand for traditional professions at the level of direct equipment operators, such as: welder, turner, locksmiths and disappearance of a large number of posts at the level of average supervision (Durlik, 2007, p. 295). The operation of the production process is changing, the existing traditional engineering based on direct device handling and control is replaceable with a new one - customized engineering - with very short production preparation cycles for a personalized customer and oriented to new products. It is estimated that with the increase in the number of machines, employment will decrease in the production and operation of equipment. According to *Hays Global Skills Index* (research on trends in the labor market in 33 countries carried out by Hays and Oxford Economics) will inevitably mean work with an average level of skills. The index showed that improving technology will most likely lead to changes in the workplace, some medium-qualified jobs will disappear and lower and higher skills will increase (Dirk Hahn, 2018).

In robotic enterprises the number of employees is reduced and the employment structure is changed. The technique used limits human work. Intelligent factories need fewer employees with previous qualifications (Schlund et al., 2014). In studies conducted by the World Economic Forum, in which more than 15 million employees took part in 20 different countries, it was confirmed that automation will change the labor market.

The new technical environment - cyber-physical production systems - results in the limitation of employment in the scope of performing previous activities by employees. The development of new production technology (CPPS) results in the growth of new jobs and the exchange of more-skilled workers. In industry 4.0, repetitive (routine) work is displaced by incremental work (eng. *Adding work*). In enterprises that use advanced manufacturing technologies, people who do not have adequate qualifications, competences and skills lose their jobs. In a smart factory, man will be at the center of an intelligent pro- cessing system, where the technique supports his cognitive and physical abilities (Stolarczyk, 2017, pp. 73-81). In order for an employee to be able to operate in cyber-physical production systems, he must have first and foremost knowledge of IT and advanced manufacturing technology (eng. *High Technology*).

In industry 4.0, simple (traditional) activities performed by employees in manufacturing enterprises of various industries are replaced by industrial robots, and the existing decision areas of the first line managers or production managers are supported by software based on statistics, algorithms and probability calculus. Employees with low qualifications lose their jobs in favor of employees with high qualifications (Hirsch-Kreinsen, 2014). Cyberphysical production systems make production processes more demanding. Employees employed to service CPPS must have extensive process knowledge combined with the ability to use the available information from (eng.) Cloud Computing.

The knowledge of employees about cyberphysical production systems is called "digital knowledge" and analogously the employees' competences with "digital competences" (Bendkowski,2017, pp. 21-33). The scope of this knowledge includes the following areas: production, assembly, quality management, logistics, as well as auxiliary areas, such as: production preparation, production planning, and production maintenance. Organizations are growing in demand for engineers who can combine automation and robotics with information technology within the new mechatronics departments. Industry 4.0 favors engineers because of the prevailing importance of production and the importance of its technical security. "Engineer 4.0 (industrial engineer 4.0) is someone who moves smoothly at the interface between two levels: cyber and physical. 4.0 engineers need to combine knowledge about a specific production process, eg working with robots, or tuning machines with IT skills, from basic operations using spreadsheets and interface support to advanced programming technologies and information analysis (Report: Astor, 2017, pp. 40-43). "Engineer 4.0 should be able to process and analyze a large amount of data from many sources, assess the validity of this information, its credibility and draw accurate conclusions. It will help him in this ability to reach information using electronic media and Big Data tools (Astor, 2017, pp. 43-45). A large amount of information in smart companies requires the creation of teams for data analysis. Enterprises are looking for experts in programming, forecasting and simulation, processing and analysis of production data (Astor, 2017, p. 43).

In 4.0 industry organizations, IT departments work more closely with operational OT departments. Previous hierarchical decision structures are flattened, and IT and OP departments are at the same organizational level of manufacturing enterprises (Astor: 2017, p. 40).

The employee at CPPS mainly participates in continuous process improvement. Engineer 4.0 must get rid of the routine for creative work. Engineer 4.0 must have a set of skills and technical, IT, analytical and soft skills (eng. *soft*), such as: good communication, creativity, persuasion, argumentation, innovation, decision-making (Stolarczyk, 2017, p. 76). 4.0 industry engineers and technicians are learning to respond to changes brought about by digital transformation. Employees of CPPS assume the role of managers or process leaders, and their work involves, among other things, planning and coordination of activities necessary to carry out, monitor and report on the process (Schlund et al., 2014, p. 26).

Work with robots results in the emergence of demand for robot trainers (digital coaches). The demand for such specialists is growing along with the increase in the number of industrial robots in industry. The main task of the trainer is to translate activities into a programming language. Machine learning is one of the most important areas for the development of artificial intelligence. Coaches train industrial robots by installing software, teaching their work, controlling and supervising their activities. Robot trainers (robot caretakers) also carry out conservation work. In the future, robot training will take on a new dimension because one of the main tasks of robot trainers will be "humanization of artificial intelligence, or to celebrate robots, to behave like people" (https://businessinsider.com.pl/technologie/trzy-rokujace-zawody-przyszlosci-o-ktorych-istnieniu-byc-moze-nie-miales-pojecia/e3xfy6w).

In industry 4.0, there are also specialists in system design, machine building engineers, robot coordinators, operations coordinators, production controllers and service engineers using digital technologies (instead of a service technician). Developers need to understand very well how and why production uses IT solutions, and production operators should have a full understanding of how IT solutions affect production (Astor, 2017, p. 43). Basic competences also include the ability to solve complex problems, workplace learning and flexible activities. The intelligent factory will increase the demand for employees who are able to interact with robots to achieve a common goal in the process of creating value (Bendkowski, 2017, p. 26).

In factories with cyber-physical production systems, the competences associated with providing cybersecurity in the enterprise are also significant (Astor, 2017, p. 38). With full automation, it assumes that the responsibility of engineers and IT professionals for safe process control in a smart factory.

New forms of logistics organization (intelligent warehouses, unmanned warehouses, autonomous means of transport) and marketing in industry 4.0 result in an increase in the demand for representatives of smart marketing, i.e. remote service. Marketers cooperate with product visionaries (VP Department) when creating unique products in accordance with the expectations of a specific customer (personalized orders).

At the level of management positions, new positions of strategic importance are created for the development of intelligent production, including: the director of industry 4.0, director of digitization. Employees in managerial positions in industry 4.0, ie managers 4.0, have a wide range of hard and soft skills. Manager 4.0 should have more extensive capabilities than managers 3.0: perceptual, organizational, intellectual, prognostic, motivational, decision-making, intuitive (Kiełtyka, 2016, p. 9). Requirements towards middle-level employees relate to the ability of analytical and model thinking, systemic knowledge as well as the ability to cope in unpredictable situations. An important role in the profile of professional qualifications is also played by: responsibility, creativity, ability to cooperate and self-organization and self-navigation (Kurz, 2014, p. 108).

In industry 4.0, managers will be able to make decisions more than ever based on information obtained in real time. Therefore, their current decision-making competences will be systematically shifted to the operational level (Spath, 2013, p.

100). A lot of emphasis is put on responsible leadership, so that managers can make ethical choices using new technology - protect people (Bishop: https://bluesky-pr.net/industry-4-0-and-the-future-of-work/).

Employees in industry 4.0 must constantly learn how to function in cyber-physical production systems. The learning process takes place using digital media, blended learning and learning at work by gaining experience during cooperation with robots. Employees must improve their skills and learn new information by acquiring technical and non-technical knowledge throughout their entire careers in intelligent factories (Bishop: https://bluesky-pr.net/industry-4-0-and-the-future-of-work/).

PROFILE OF PROFESSIONAL QUALIFICATION OF ENGINEER 4.0 IN A METALLURGICAL ENTERPRISE

The steel industry, as well as other industries, is preparing to operate in industry 4.0. The implementation of robotization of production processes has already been initiated. Steel mills invest in the digitization of steel products production, and the manufacture of metallurgical products is more and more automated. The production is carried out using modern devices, eg 3D printers, thanks to which new products are created (eg higher precision of products) (Gajdzik, 2018).

The market economy implemented in Poland after 1990 forced a reduction of the surplus of employment. A large number of employees in individual enterprises resulted in low productivity and work efficiency. The standards differ significantly from the European and global standards. State-owned enterprises had high personnel costs (costs of salaries and social benefits). The development of privatized enterprises in the first years of the transformation of economy in Poland was conditioned by the reduction of employment. The largest employment surpluses in Poland occurred in traditional industries: mining and metallurgy. In the steel sector, which is the subject of research, in 1989 there were 144 thousand employed people. After years of rigorous policy of limiting employment and separating activities not directly related to production in the metallurgy industry, there are employed 20.4 thousand people (Gajdzik, 2019, p. 310). After 3 decades from restructuring process in metallurgical sector enterprises create new professional qualification of their workers such as: visionary thinking, assertiveness, problem solving, good communication etc. (Szczepańska-Woszczyna, Gajdzik, 2016).

“A trend noticeable in the industry in the steel sector is multi-skilling. This trend results from shortened production time, shorter production cycles and the need for a company to adapt to changing demand quickly. In the metallurgical industry, changes in the demand for the development of specific skills is observed. Technological change, including automation and computerized production lines, requires a workforce with increased professional qualifications. In addition to technical competencies in one’s area of specialization i.e. knowledge of fundamental principles and theoretical foundations of processes, procedures, and equipment, articulation of professional thoughts and presenting them at professional forums, and creative thinking skills that become a basis for out of the box solutions for significant problems, non-technical content is becoming essential in engineers’ work, for example, communication, teamwork, personal/attitudinal skills and attributes, problem solving and the ability to learn, attitudes and behaviours that support the project-based work model, social and environmental awareness and ethical principles" (Szczepańska-Woszczyna, Gajdzik, 2016, p. 272).

"Engineering competencies that are particularly important include: versatility and flexibility (the ability to go beyond their own narrow specialization areas), independence and problem-solving skills, self-assessment skills and the ability to analyze their own mistakes and those made by co-workers, logical thinking skills and imagination, the ability and courage to make decisions within their competence, intrinsic motivation, the ability to work under stress and cope in a crisis situation, as well as job-related competencies such as the ability to read the documentation, the ability to estimate and price information contained in projects and knowledge of programming basics, as well as practical knowledge of information technology. The optimal profile of engineering competencies should be as follows: openness to new experiences, stress management skills, analytical and conceptual thinking skills at the operational and strategic levels, innovation, creativity, project management skills, decision-making skills, working with a multicultural team, the transfer of knowledge, motivating others, a division and supervision of work and evaluation, change management" (Szczepańska-Woszczyna, Gajdzik, 2016, p. 272-273).

The largest metallurgical enterprise on the Polish market – ArcelorMittal Poland S.A. – has already begun recruiting 4.0 engineers. In the web page: work. pl. Professionals with different skills are sought, including thinking logic, management skills and creativity. "Industry 4.0 Engineer" because such a position was created at ArcelorMittal Poland in Dąbrowa Górnicza should be motivated to implement changes and have knowledge and great interest in all technologies being part of cyber-physical production systems. In the cited enterprise, a team for the implementation of solutions typical for industry 4.0 is created. The team is interdisciplinary and multifunctional. Working in it, members regularly adopt new functions (Gajdzik, 2008; Gajdzik, 2013). The team deals with the design and implementation of innovative solutions in the metallurgical environment. We are looking for employees with experience in the field of design and highly creative. It will be up to the engineer 4.0's responsibilities (www.pracuj.pl):

- development of new solutions for Industry 4.0 by initiating new organizational ideas and technological solutions,
- constant search, initiation and management of innovations as well as provision of relevant data for process design and optimization in the field of industry 4.0,
- developed innovative solutions in selected pilot projects conducted by the company at the stage of preparation for functioning in Industry 4.0,
- close cooperation with various plants throughout the company, while maintaining architectural standards and business rules, supporting the overall data strategy,
- cooperation with product visionaries to provide innovative VR experience,
- communicating with other engineers from Industrial Digitalization Cell from other countries in Europe.

Table 1
Profile of professional qualifications of the Engineer 4.0 for a metallurgical enterprise

Knowledge	**understanding of the Industry 4.0 concept, knowledge about IoT solutions and the specificity of the metallurgical industry, experience in creating Augmented Reality applications and / or Virtual Reality, experience in creating image processing, computer vision algorithms, 3D scanning applications, strong knowledge of the development of mobile applications, solid knowledge of data structures, object-oriented programming and engineering principles of steel production software, experience in 2d / 3d traffic tracking, knowledge of artificial intelligence, machine learning, neural networks, interest in Big Data / BI / Data tools and data analytics**
Skills	visionary thinking, assertiveness, problem solving, the ability to transform industrial needs into projects confirming the concept of industrial development 4.0, the ability to initiate and implement industrial innovations, including technical and non-technical ones, strong communication skills, including the ability to convince users to technical discussions, the ability to learn and adapt to new technologies and programming, passion for learning new things and advanced technology.
Eduation	a master's degree or a doctorate degree in the field of computer science or a related field, e.g. production engineering, Master's degree in technical universities with the following majors: Industrial Information Technology, Production Engineering, specialized post-graduate studies in the field of industry 4.0.
Knowledge of a foreign language	fluent use of English

Source: developed based on: https://www.pracuj.pl/praca/industry-4-0-engineer-dabrowa-gornicza, oferta,6279108.

SUMMARY

The main technologies of industry 4.0 include artificial intelligence, large data sets, the Internet of Things and robotics. These technologies are increasingly used in the manufacturing sector to create cyber-physical production systems (CPPS). New cyber-physical solutions in enterprises result in changes in employment. The full impact of Industry 4.0 on changes in employment is not yet known, because many of the technologies cited function at the earliest stages of their development. In available scientific publications and research reports, different change scenarios are created, both optimistic, eg an increase in demand for highly qualified jobs, as well as pessimistic ones, eg reduction of employment. On the basis of the literature stage, it can be assumed that changes are inevitable and new employees must demonstrate a variety of skills, including knowledge of IT, analytical skills, creativity and visionary thinking, the ability to initiate and change, the ability to adapt to new solutions and passion for learning new things within the cyber-physical business space. The profile of professional qualifications of engineer 4.0 quoted in this publication, being a job offer prepared by the largest steel producer in Poland (ArcelorMittal Poland S.A.) indicates that the steel sector is already looking for workers for industry 4.0.

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Abstract. Along with the growing dynamics of technological changes in production in the perspective of the development of 4.0 industry, there are changes in the structure of employment and professional qualifications of employees. The development of cyber-physical production systems (CPPS) entails an increase in the demand for engineers. Industry 4.0 is a new megatrend in production. In the second decade of this century, the concept of Industry 4.0 gained importance thanks to the policy of the German government and gradually penetrated into other countries. Enterprises, in addition to traditional production organization, started realizing of cyberphysical production lines as well as smart factories. New production solutions based on IT and robotics technologies using IoT the need for new employee competencies. On the market there is still a growing demand for IT specialists, and there is a demand for engineers 4.0, that is employees with new technical competences, able to control and service CPPS.This publication attempts to present the scope of changes in employment and presents the profile of professional qualifications of engineer 4.0 in a metallurgical enterprise. The list of new skills for an engineer 4.0 employed in an metallurgical enterprise is presented in this article by authors.

Keywords: industry 4.0, engineer 4.0, metallurgical enterprise