Use of intelligent manufacturing systems in industries in the era of industry

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Abstract

The last stop of societies in the history of industrial revolutions is defined as the fourth industrial revolution, namely Industry 4.0. Businesses that want to be ahead of the global competition in the world of the future make their production systems intelligent manufacturing by taking the help of the technologies used in Industry 4.0 in order to optimize their organization, production and distribution processes. In this way, they increase the efficiency of their processes and make faster, more efficient, higher quality and more flexible production.In this study, it is aimed to examine the intelligent manufacturing systems that started to be used in various industries with the industry 4.0 revolution. In this context, firstly, the relationship of intelligent manufacturing systems with Industry 4.0 and the technologies used in these systems are examined. Then, the advantages of using intelligent manufacturing systems in enterprises are explained. At the end of the study, results and evaluations are made and information about the future of intelligent manufacturing systems is presented.

Keywords: Industry 4.0, Industry 4.0 technologies, intelligent manufacturing systems.

1. Introduction

Since the first industrial revolution that introduced steam power and mechanized manufacturing, the manufacturing industry has always undergone significant changes. After the first industrial revolution, the use of electricity and assembly lines in factories brought the second industrial revolution. Then, the advent of automation led to a third industrial revolution in the 1970s. With the inclusion of digital technologies in the manufacturing environment, the fourth industrial revolution emerged and was named Industry 4.0. The digital technologies used here are central to the realization of intelligence in the manufacturing industry of the future. Examples of digital technologies include augmented reality (AR), virtual reality, predictive maintenance, cloud computing, internet of things (IoT), big data, autonomous robots, simulation, and digital twins [1, 2] but not limited to these. With the adoption of these digital technologies, data collection and knowledge creation reach unprecedented levels. The vision of Industry 4.0, in which these digital technologies are used, is to create cyber-physical production systems (CPPS) that seamlessly connect the physical and digital worlds to make production increasingly intelligence, thereby increasing autonomous autonomy and flexibility [2, 3]. It is clearly known that production is very important for the economic development of countries. Therefore, production is seen as a critical factor for growth all over the world. With Industry 4.0 introduced by Germany at the Hannover Fair in 2011, all countries attach great importance to production technologies. Therefore, various countries have developed strategic roadmaps to transform/change manufacturing. For example, the USA has created an advanced framework for implementing smart manufacturing. Similarly, in 2015, China revealed its "Made in China 2025" plan [4].

Industry 4.0 aims to transform manufacturing technologies using cyber-physical systems (CPSs), IoT and cloud computing technologies. Thus, by creating intelligent factories, it aims to monitor the processes in manufacturing, to create the digital twin of these processes and to make intelligent decisions by providing real-time communication. It also transforms traditional production systems into intelligent production systems by changing production and business models [5].

Intelligent manufacturing is a concept introduced with the industry 4.0 paradigm. It means that management, design and production processes are carried out with the help of advanced technologies,

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together with information and communication technology. It encompasses the process of production activities, which includes self-perception, self-learning, self-decision, self-actualization and self-adaptation. Intelligent manufacturing is seen as a strategy to develop industries and technological innovation in various developed countries. [6]. Therefore, it is supported by the complementary efforts of information technology and industrialization [7].

In this study, the use of intelligent manufacturing systems in industries has been examined. In the next section of the study, intelligent manufacturing systems are explained, in the third section, the technologies used in intelligent manufacturing systems are included, in the fourth section, the benefits of intelligent manufacturing systems for businesses are focused on, and in the last section, the results and evaluations obtained from the study are given.

2. Intelligent manufacturing systems

Since the first industrial revolution, the revolutions started with the use of water and steam machines and turned to automation with electricity and electronics, and the use of computers has been shaped as a reflection of digitalization on production. Production processes have also become increasingly complex, automated and sustainable. This has revealed the need for simple, efficient and stable operation of machines [8]. Advances in information and communication technology have led to the use of machines used in production processes by computers instead of humans. Depending on these advances, since the 1980s, production systems have been named in different ways as flexible production cells, flexible production systems, computerized production and intelligent manufacturing [9].

Intelligent manufacturing is considered a new manufacturing model based on intelligent science and technology that greatly improves the design, manufacture, management and integration of the entire life cycle of a typical product [5]. An intelligent manufacturing system is defined as a production system that can respond in real time to the changing needs of production processes, supply chain networks and customers [10, 11]. This means

that the production technology and system can respond in real time to the complex and variable situation of the production area [10]. It is defined by the Leadership Coalition (SMLC) as having the right data, the right information, the right technology and the right operations always and wherever needed throughout the production [12]. Intelligent manufacturing refers to a new manufacturing paradigm in which production machines are fully connected via wireless networks, monitored by sensors and controlled by advanced computational intelligence to reduce costs while increasing product quality, system productivity and sustainability [4]. Intelligent manufacturing systems try to maximize these capabilities by using advanced technologies that support the rapid flow of digital information within production systems [8, 11]. The concept of intelligent manufacturing, which started to emerge in the 1980s, is closely related to the fourth industrial revolution and its related technologies [13]. Intelligent manufacturing is a general concept that is constantly being developed and can be categorized into three basic paradigms as shown in Fig. 1: digital manufacturing, digital networked manufacturing, and new-generation intelligent manufacturing [14].
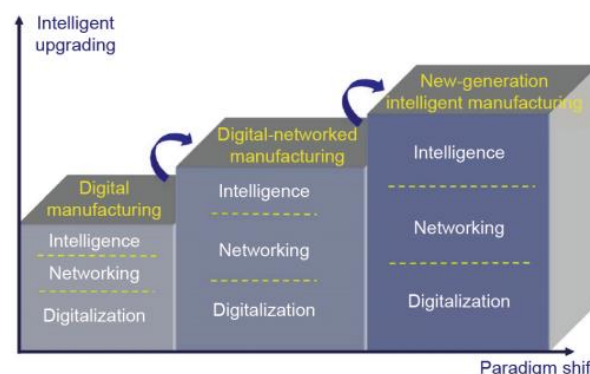

Figure 1. The evolution of three basic paradigms in intelligent manufacturing [14]

Digital manufacturing, which is the first basic paradigm of intelligent manufacturing, can also be

defined as first generation intelligent manufacturing. In digital manufacturing, digital identification of

product information, process information, and source information is made. Thereby, significantly reducing the time required to design and manufacture products, providing benefits in meeting specific customer requirements. Digital networked production, the second fundamental paradigm of intelligent manufacturing, can be called "Internet + production". Internet+ is reshaping the manufacturing industry and transforming it into digital networked manufacturing through business-to-business collaborations and all kinds of information sharing and integration. The new generation intelligent manufacturing, which acts as the main driving force of the new industrial revolution, refers to the integration of new generation artificial intelligence technology and advanced production technology [14].

3. Technologies used in intelligent manufacturing systems

Intelligent manufacturing leverages advanced information and manufacturing technologies to achieve flexible, intelligent and reconfigurable manufacturing processes to cater to a dynamic and global market. Intelligent manufacturing requires certain supporting technologies to enable devices or machines to change their behavior in response to different situations and requirements based on past experiences and learning capacities. These technologies allow direct communication with production systems. Thus, it allows for problem solving and timely adaptive decisions to be made. Some technologies have artificial intelligence that enables to learn from experience of manufacturing systems to eventually realize a connected, intelligent and ubiquitous industrial application [5].

Due to the complexity of advanced production systems, the use of intelligent processes has become a necessity to use the obtained data in processes. Because the decisions to be made in order to eliminate the complexity in the processes should be made by intelligent systems with minimum human intervention at the right time and at the right place. In this context, technologies such as artificial intelligence, IoT, cloud computing, big data simplify the process by meeting these needs [15].

Of these technologies, artificial intelligence is used as an infrastructure to gradually integrate with various industries, accelerate the optimization and upgrading of the economic structure, and have a profound impact on people's production and lifestyle. The manufacturing sector is the main area of artificial intelligence applications [6].

Information and communication technology plays an important role in production systems. The continued development of cyber systems and intelligence technologies has led to big data, IoT, cloud computing, CPSs, digital twin and further developments. Intelligent manufacturing [11], one of several advanced manufacturing paradigms that uses these concepts to improve manufacturing processes and systems with some degree of intelligence or intelligence, is a new revolution and paradigm of the manufacturing industry. Technologies related to intelligent manufacturing have also been developed individually or in combination with other technologies.

In the past, IoT technology was mostly about working with machines or processes. This was mainly due to the lack of networks, data processing systems and methodologies that support rapid data exchange in a complex environment where the entire production system must be under full control in real time. However, the gradual development of hardware and software technologies has allowed for real-time processing of diverse and complex information [16]. Real-time production with IoT brings new opportunities to streamline production and operations management. Therefore, IoT is used to improve production performance in production time, critical machine workload and energy consumption [17].

Sensors used in intelligent manufacturing will play a key role in the future development of intelligent manufacturing with their low-cost structure. These sensors provide a wide range of advanced capabilities by realizing intelligent sensing, real-time process analysis. When the information from the sensors is properly integrated into the manufacturing process, it provides efficiency in both time and quality in processes such as quality control tests. From this point of view, the data obtained from the sensors is seen as the key to making improvements in the production process [12]. Moreover, In addition, the process can be digitized by generating large amounts of data by industrial sensors in almost every part of the manufacturing process [6].

CPS and cloud technologies, which develop depending on IoT and sensor technologies, develop together with existing production systems or IT technologies. With the development of modeling and

simulation technologies, the CPS creates a digital twin that connects production areas to cyber models [10]. When the applications are examined, it is seen that 40% energy savings and 30% efficiency increase in a real-life industrial experiment with CPS and big

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4. Advantages of intelligent manufacturing systems

Intelligent manufacturing systems create significant gains in the agility, quality and efficiency parameters of production enterprises, and this increases long-term competition. In addition, intelligent manufacturing, unlike other technology-based production paradigms, defines the vision of new generation production with advanced capabilities and is based on developing information and communication technologies [8].

With the rapid development of information technology, companies carry out their production according to the changing demands of their customers. As a result, they reduce their costs by improving their production processes and increasing their efficiency [18]. Intelligent manufacturing systems enable flexible production processes as well as high efficiency in production thanks to their advanced automation. The robot, cyber-physical production systems and intelligent transport systems in the intelligent production system will maximize the capacity utilization rate. The cost benefit of intelligent manufacturing systems automation is not only in the labor cost, but also in the preparation,

production and inventory costs due to the elimination of the human factor. Unlike traditional production systems, in intelligent manufacturing systems, strategic, tactical and operational decisions regarding production processes will be made by intelligent machines that are in constant communication without human factor [19].

As production processes are made more and more intelligent by information communication and sensor technologies, downtime in the production process is reduced and product quality is improved [4]. Statistics show that 82% of companies using intelligent manufacturing technologies experience increased productivity, 15-20% achieved quality gains, and 45% experienced increased customer satisfaction [4, 20].

Recent advances in IoT, big data, cloud computing, CPS and artificial intelligence provide unlimited data for intelligent manufacturing. With these data they provide, they provide very important advantages as summarized in Fig. 2. [4].
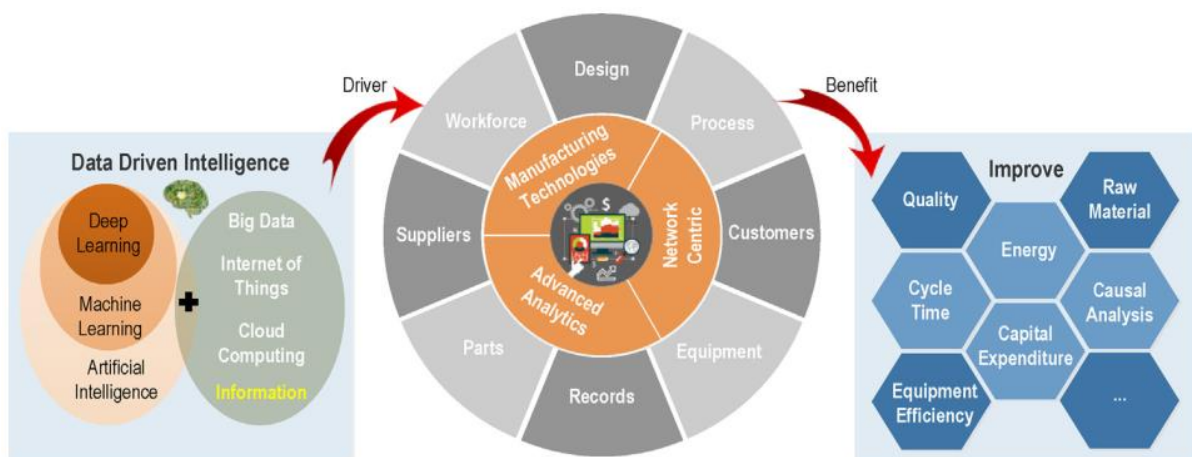

Figure 2. The role of data in intelligent manufacturing [4]

According to research, it is predicted that intelligent manufacturing will provide a gain of 500 billion to 1.5 trillion dollars to the global economy by 2023 [20].
Despite the above advantages, it is necessary to overcome several challenges to create an intelligent

manufacturing system. For example, the amount of investment required for the installation of highly automated intelligent manufacturing systems is quite high. Another challenge is the possibility of reduced capacity flexibility in highly automated production systems as the human factor is eliminated [4].

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5. Conclusion and evaluation

Over the centuries, the industrial environment has changed and the manufacturing sector has evolved through various paradigms such as flexible manufacturing, reconfigurable manufacturing, lean manufacturing, wireless manufacturing, triggered by the developing technologies and changing market in parallel. In addition, major countries have emphasized the importance of the transformation of their manufacturing sectors.

Intelligent manufacturing is a broad manufacturing concept aimed at optimizing production and product processes by taking full advantage of advanced information and manufacturing technologies. The vigorous development of intelligent manufacturing has tremendously spurred many advanced business models and new industries and this has constantly added vitality to the manufacturing industry.

In this study, it is aimed to examine the use of intelligent manufacturing systems in production, which started to be used in the industry 4.0 industry age. In this context, the technologies used in intelligent manufacturing are examined and the advantages of these technologies to the industry are explained.

According to the study, it has been seen that intelligent manufacturing systems increase production efficiency, increase product quality, improve the performance of processes, and provide significant gains. It is predicted that if intelligent manufacturing is applied not only to some processes, but also to all processes of the enterprise, including the supply chain, it will be more beneficial to the enterprise. Despite these advantages of intelligent manufacturing systems, the amount of investment required for their initial setup is quite high. However, considering that the gains to be made in the following years will be greater, it will be important for enterprises to invest in intelligent manufacturing systems in order to compete.

In addition, it is a clear fact that competent human resources are as important as intelligent devices and systems for intelligent manufacturing systems. It will be very important for the continuity of the system to have qualified employees and managers in the development, establishment, use and management of these systems. For this reason, necessary training should be given to qualified personnel in advance.

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