Digital Management Systems in Manufacturing Using Industry 5.0 Technologies

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1 Introduction

Industrial revolutions are meant to segregate man's and machine's work and hand over jobs to robots that are difficult and dangerous for the workforce. Due to the significant impact of machines on society, it is crucial to understand their relation [1]. The first industrial revolution can be traced back to 1780s, which started off, with the generation of power from water, steam, and fossil fuels. The second industrial revolution started in the 1870s, which led to electrification and mass production. With the arrival of electronics and information technology, the third industrial revolution started with automation in the 1970s. The development of new technologies paved the way for the fourth industrial revolution, which started in 2011 by the German Federal government but is still unknown and not yet well grown. This utilizes cloud computing and the Internet of Things (IoT) to establish cyber-physical systems (CPS). This CPS will deploy digital twin technologies to increase the level of digitization in every industry [2]. Digital technologies are used during the COVID-19 pandemic to create significant advancements in healthcare. These technologies can digitally store the patient data, which helps for proper monitoring and treatment process [3–12].

With growing technologies, another industrial revolution is bound to happen in the future, which will be the industrial revolution 5.0, better known as Industry

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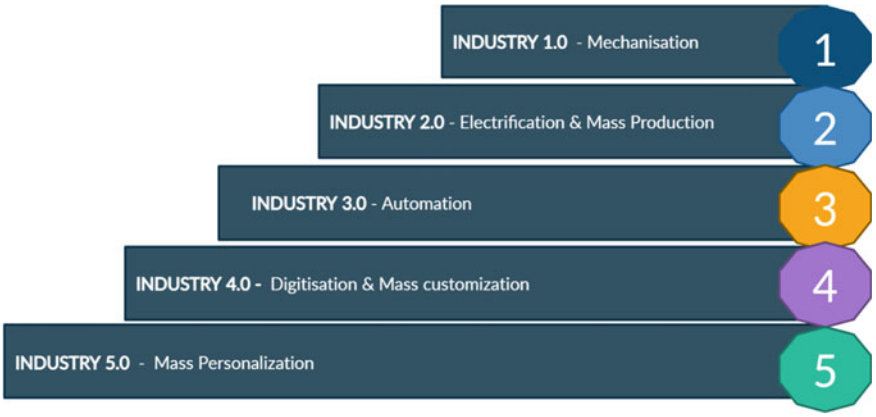

Fig. 1 Summary of Industrial revolutions, their period, and their characteristics

5.0. Researchers have already started talking about industry 5.0, based on learning human behavior with artificial intelligence (AI) [13]. Figure 1 depicts the summary of industrial revolutions, their period, and their characteristics. This paper aims to establish various technological advancements in the upcoming revolution and how these can prove beneficial to the manufacturing industry in solving their problems.

2 Industry 5.0

The term Industry 5.0 was first published in an article on LinkedIn by Michael Rada on December 1, 2015. The implementation of this revolution is meant for solving industrial and social problems related to industrialization [13]. Industry 4.0 is all about increasing the process's efficiency by automating manufacturing processes ignoring all other aspects like employment and environmental pollution. Industry 5.0 will create a smart manufacturing system and smart supply chains which will use data intelligently. Smart factories will provide greater flexibility to communicate among themselves [14]. The transition from Industry 4.0 to Industry 5.0 will create better ideas with humans' brainpower [15]. Industry 4.0 brought mass customization, but Industry 5.0 will bring mass personalization according to the customer's needs. It focuses on continuous development, value-added activities, and less waste generation [16].

3 Need for the Study and Research Objectives

Today, quintillion bytes of data are created every day by technology like IoT. This has imposed many severe challenges. The need to leverage Big Data has become of utmost importance for every manufacturing industry. The unstructured data needs to be structured in order to get useful business insights. Industrial manufacturers can use this data to optimize resources' cost and consumption by creating a digital management system driven by industry 5.0 technologies [17, 18]. These new technologies' help can easily tackle the problem of waste generation and pollution. This paper addresses the following primary research objectives:

- To identify major technologies of Industry 5.0.
- To explore challenges faced by the contemporary manufacturing industries with Industry 4.0.
- To understand the digital connectivity of manufacturing systems by using Industry 5.0 technologies.
- To identify the application of Industry 5.0 technologies in managing manufacturing industries.

4 Advancements in Industry 5.0 as Compared to Industry 4.0

Industry 4.0 focuses on mass customization and provides better coordination between machines and information technology. The main idea of Industry 4.0 is to fulfill individual customer requirements through smart manufacturing. This revolution deals with intelligent devices and systems for creating digital factories [14]. The important drivers of Industry 4.0 are the Internet of Things (IoT), Industrial Internet of Things (IIoT), Cloud computing, Cybersecurity, Big Data, and Smart manufacturing [19]. Industry 5.0 will emerge as the age of augmentation when humans and machines will reconcile and work together. Unlike Industry 4.0, this paradigm will combine both humans' strength and the Cyber-Physical Production System (CPPS) [20]. This efficient relationship will solve all the problems of the economy, ecology, and social world. They will impact the environment in the field of reducing waste materials that may also reduce the material cost, thereby decreasing the social impact of industrial processes [21].

5 Major Technologies of Industry 5.0

5.1 Collaborative Systems and Other Smart Systems

Cobots are different from robots in industries as they are equipped with susceptible smart sensors for assembling products. They work alongside humans in order to enhance personalization in products. This will save time and can be produced in large quantities. Unlike industrial robots, these systems are designed not to harm the workers working along with them [22].

5.2 Digital Twin

In today's world, where everything is now on a virtual platform, manufacturers also need to adopt this concept to reduce the cost of collecting data. Its adoption requires integrating other technologies like Big Data analytics, smart sensors, and other IoT technologies. In manufacturing industries, it becomes necessary to clarify the product's specifications to optimize the final product. The solution provided by the digital twin can be used in this process [23].

5.3 Smart Manufacturing Through Exoskeletons

With increasing social distancing rules and a need for a safer work environment, an advanced robotic technology called exoskeletons can help humans assist them in various manufacturing industries activities. These are a bit different from collaborative robots as humans must be present in the environment while wearing them. Exoskeletons can be an asset to the industry if it incorporates technologies like virtual reality (VR) and machine learning (ML) [24].

5.4 Smart Materials

With the advent of new, advanced materials and structures, smart materials have been recently engineered. Light, reactive smart materials have the potential to be used in the 4D printing method. The use of polymeric composite materials in producing arms of cobots will increase production performance in manufacturing industries. Intelligent materials, on the other side, are more sophisticated and responsible than smart materials. Research is being carried on this topic to employ them in manufacturing industries for smarter production [25].

5.5 Advanced Implementation of AI, IoE, and Cloud Computing

As we proceed to the next industrial revolution, advancements in various technologies like IoT and AI will occur. With time IoT will transform into IoE (Internet of Everything), which will connect the physical assets and various other intangible assets. Advances in intelligent CPS will prove to be an emergent technology in the Fifth industrial revolution [26]. These technologies are also applicable in healthcare during COVID-19 pandemic. The successful implementation of these technologies is helpful to reduce the load of healthcare workers [27–35].

5.6 4D Printing

For manufacturing products that are more creative and personalized, the 4D printing technique will be inaugurated in the fifth industrial revolution, focusing on the design process. 4D printing technology will require different smart materials that are flexible and adaptable in nature, like Shape memory alloys (SMA) and Shape memory polymers (SMP) [36]. 4D printed structures can significantly reduce the volume of storage in industries. These materials can self-adapt and self-repair, which can prove advantageous to the manufacturing industries [37]. Figure 2 shows significant technologies of Industry 5.0 used to create the manufacturing system smarter and intelligent.

6 Personalization in Industry 5.0

The customer's ever-growing demands and the basic human urge cannot be neglected, which has led to personalization. Industry 5.0 will provide technologies that will enhance customers' personalization experience, thereby increasing affordability and comfortability. Such high quality and unique products are possible because of the cyber-physical systems driven by mass customization, making them affordable. This symbiotic relationship between man and machine working together improves efficiency and uniqueness [26]. It is only possible because robots can do repetitive and tedious jobs while humans can have more out of the box thinking.

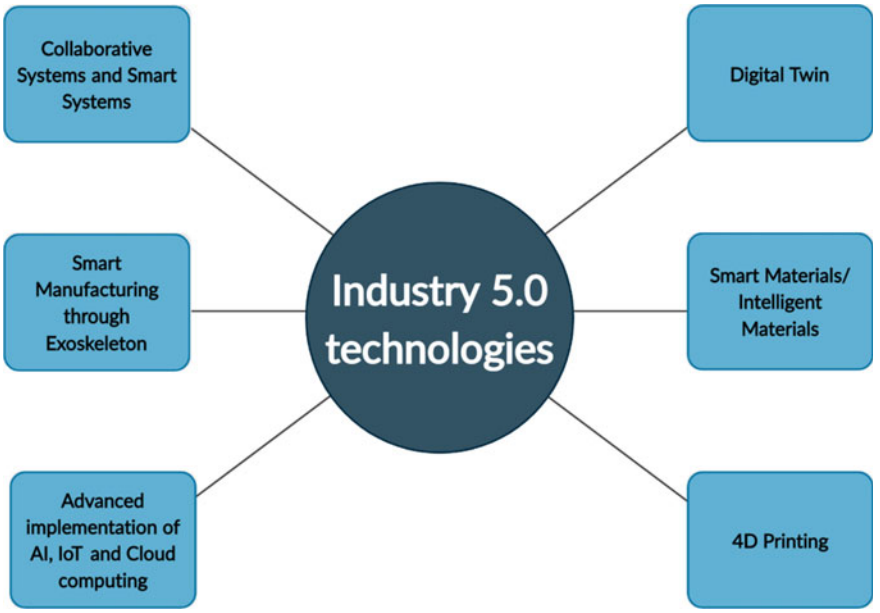

Fig. 2 Significant technologies of the fifth industrial revolution to create the manufacturing system smarter and intelligent

7 Digital Management System

A digital management system benefits from leveraging digital technologies to improve a physical operation's efficiency and performance. With the increase in technologies and resources, manufacturers need to optimize their production, logistics, supply chain, and various other domains. Digital transformation will lead to disruption, which is a necessary disruption. So, the manufacturers need to automate and digitalize their management system for the upcoming changes in technology.

8 Challenges to Contemporary Manufacturing Industries

Manufacturers need to identify the technical, social, and environmental barriers which can hamper their productivity and profitability. The future of manufacturing industries depends on the decisions and actions and is thus required to provide a solution. Table 1 discusses major challenges to manufacturing Industries which are to be taken care of by Industry 5.0 technologies. These challenges need to be addressed in order to find effective ways to solve a manufacturer's problem. Reducing the quality of the manufactured product will not help increase the manufacturing industry's

Table 1 Challenges to contemporary manufacturing industries

Sr. No.	Challenges	Description	References
1	COVID-19 Pandemic	COVID-19 pandemic has severely impacted the manufacturing industries and is causing disruptions to economic activity. Most of the manufacturers must revamp their raw material stock and production capacity. This pandemic has slowed down trade between different countries, thereby disrupting the supply chain	[38–43]
2	Globalization	Globalization is the worldwide exchange of technologies or trade. However, along with these come great challenges. This has led to the concentration of capital in the developed countries or countries which are developing at a high pace	[44]
3	Automation	Automation is considered one of the biggest challenges for the manufacturing industries. With an increased demand for customization and personalization of products, manufacturers need flexible automation tools. Manufacturers need to shift quickly to modular, flexible, and collaborative automation system	[45]
4	Manufacturing skills	These days most of the manufacturing sector is transforming itself according to the technologies. Lack of digital skills and less software knowledge hampers the firm's growth. As the industries are becoming data-driven, a highly skilled workforce is essential	[46]
5	Supply chain	The manufacturing sector generates a massive amount of real-time Big Data from sensors, machines, and digital devices. Good supply chain management must be carried out in order to enhance visibility throughout the process. Also, this will reduce the wastage of resources during the procedure	[47]
6	Environmental challenges	Due to industrialization, a major part of climate change can be attributed to the manufacturing industries. Global warming is one of the most critical issues that need to be taken seriously. There is considerable pressure on the government and the manufacturing sectors to ensure that the environment is protected. Combining robust green products and clean production will help the manufacturers attain sustainable growth	[48]

(continued)

Table 1 (continued)

Sr. No.	Challenges	Description	References
7	Digital transformation	In today's competitive landscape, manufacturers need to gear up for the changing industrial environment. For a smooth transition, every industry must ensure that they are technically intellectually, and strategically available. Manufacturers have to adapt their business to the digital world. For this ample number of resources are required	[49]

production or profit. Therefore, technologies associated with the fifth industrial revolution will help them cope with the challenges, further increase profit and production, and maintain their quality.

9 Significant Management Areas in Manufacturing Industries Using Industry 5.0 Technologies

The technologies associated with the fifth industrial revolution can solve various contemporary manufacturing industries' problems in different domains [22, 50]. Figure 3 shows the interconnection of a different area where Industry 5.0 technologies are helpful in manufacturing. With proper implementation, these are used to improve the efficiency and productivity of the industry.

Table 2 discusses the significant management areas in manufacturing industries that would be extensively using Industry 5.0 technologies.

10 Limitation and Future Scope of the Study

This study is purely theoretical, and the ideas proposed by this paper have not been practically implemented. Any reliable statistics or surveys are not available. As Industry 5.0 is yet to arrive, it is in the conceptual state; not much research is available on this topic, and manufacturing industries are trying to find solutions to their problems with the implementation of Industry 3.0 and Industry 4.0. Extensive research needs to be done on developing the right set of skills among the workforce for the upcoming transition.

The paper mainly focused on the components and technologies associated with Industry 5.0, challenges and issues associated with the manufacturing industries, and its application in manufacturing industries by creating an efficient digital management system. As the implementation of Industry 5.0 increases, new research streams should be discovered. Differences and disputes can appear between man

Fig. 3 Areas in the manufacturing industry where Industry 5.0 technologies can be applied

and machines. It must be minimized in the future. Risks and challenges that may come with this new revolution have to be determined as technology comes with great power.

11 Conclusion

The Fifth Industrial revolution is supposed to bring mass personalization along with smoother production and higher efficiency. It is also expected to positively impact our environment, which is being gradually declining due to industrialization. This revolution uses smart machines with intelligence to automate manufacturing processes. The new technologies in Industry 5.0 enhance not only efficiency but also the interaction between humans and robots. Contrary to the assumption that people would lose

Table 2 Significant management areas in manufacturing industries need Industry 5.0 technologies

S. No.	Management areas	Description
1	Manufacturing	On the whole, manufacturing becomes less sophisticated with introducing technologies like AI, IoE, Cobots, etc. Products manufactured are less defective, more personalized, as well as cost-effective. Repetitive and arduous tasks can be performed by exoskeletons and robots, while humans can do the intellectual and creative part [51, 52]
2	Finance	For transparency in transactions and exchanging data securely, manufacturers can leverage IoT and Blockchain concepts. These can help secure transactions within the manufacturing sector. With the help of a digital assistant, invoices and expenditures can be calculated intelligently saving time [53, 54]
3	Processes	With the help of more advancement in collaborative robots, automation in the industry will indeed occur. With the help of IoT and AI, manufacturing processes can be interlinked with each other so that real-time data can be transferred, leading to higher efficiency in production and more outstanding quality [55, 56]
4	Quality	Industry 5.0 technologies not improve the quality of life but also maintain the quality of the product. By the use of the concept of smart manufacturing, they can optimize the workflow and other processes. Mass personalization is achievable by employing the correct business strategy in these industries. This revolution puts much focus on the design and manufacturing of products [57]
5	Supply	Technologies like cobots, AI, wearable exoskeletons can transform the traditional supply chain into a smart supply chain leading to robust logistics. This will reduce supply risks and increase customization, which in turn lead to customer satisfaction. It will help us gain business insights which will help in gaining enormous profits [58]
6	Inventory	By using correct techniques and technology in the manufacturing industry, a vast amount of resources can be saved in inventory management. There is a need to balance the right amount of inventory in the warehouse for a smooth supply chain. This kind of inventory management software is available like warehouse management software and RFID and barcode scanners for orders [59]
7	Transportation	Intermodal transportation can help save time in the supply chain process also save much money. Manufacturers can pool their resources and use sophisticated Transport Management Systems (TMS) for reducing their costs. It will effectively manage the massive amount of data generated from the supply chain and take care of how much resources are being spent anywhere [60, 61]

(continued)

Table 2 (continued)

S. No.	Management areas	Description
8	Workforce	Collaborative robots will work along with humans to perform hazardous and repetitive jobs in order to improve efficiency. Cobots are installed with GPS, AI, and smart sensors to learn behavior, while humans can use their innovative ideas for smart production. Industry 5.0 will produce different roles like Chief Robotics Officer (CRO) in the manufacturing industry, which will require new skills to learn in the coming future [62]

jobs, we see that this revolution will create different roles that will indeed differ from today's workforce. The government, industry, and researchers will have to make sure that they are relevant in the future by investing in them.

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