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Industry 4.0 – A Glimpse

Saurabh Vaidya[a]*, Prashant Ambad[b], Santosh Bhosle[c]

Department of Mechanical Engineering, Maharashtra Institute of Technology, Aurangabad – 431010, India

Abstract

Digitization and intelligentization of manufacturing process is the need for today's industry. The manufacturing industries are currently changing from mass production to customized production. The rapid advancements in manufacturing technologies and applications in the industries help in increasing productivity. The term Industry 4.0 stands for the fourth industrial revolution which is defined as a new level of organization and control over the entire value chain of the life cycle of products; it is geared towards increasingly individualized customer requirements. Industry 4.0 is still visionary but a realistic concept which includes Internet of Things, Industrial Internet, Smart Manufacturing and Cloud based Manufacturing. Industry 4.0 concerns the strict integration of human in the manufacturing process so as to have continuous improvement and focus on value adding activities and avoiding wastes. The objective of this paper is to provide an overview of Industry 4.0 and understanding of the nine pillars of Industry 4.0 with its applications and identifying the challenges and issues occurring with implementation the Industry 4.0 and to study the new trends and streams related to Industry 4.0.

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Keywords: Industry 4.0, Internet of Things, Cyber Physical System, Smart Manufacturing and Cloud based Manufacturing.

1. Introduction

Since the first Industrial Revolution, subsequent revolutions have resulted in manufacturing, from water and steam powered machines to electrical and digital automated production which makes manufacturing process more complicated, automatic and sustainable so that people can operate machines simply, efficiently and persistently [1]. "The term Industry 4.0 stands for the fourth industrial revolution which is defines as a new level of organization and control over the entire value chain of the life cycle of products, it is geared towards increasingly individualized

* Corresponding author. Tel.: +91 9404601624.
E-mail address: saurabhvaidya6@gmail.com

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customer requirements [2]. The central objective of Industry 4.0 is fulfilling individual customer needs which affects areas like order management, research and development, manufacturing commissioning, delivery up to the utilization and recycling of products [3]. The main difference between industry 4.0 and Computer Integrated Manufacturing (CIM) is the concern of the human role in production environment. Industry 4.0 has an important role of human worker in performing the production where as CIM considered workerless production [4]. The Industry 4.0 paradigm promotes the connection of physical items such as sensors, devices and enterprise assets, both to each other and to the Internet [5]. Designing and drafting methods in all disciplines should be reviewed and their suitability be checked for a modern, interdisciplinary approach model for product development and transferred to a common, integrated and interdisciplinary methods, process and IT solution [6]. The production process is divided into small value oriented units which shares information of the consecutive process steps only which helps in increasing flexibility and probably results in reduction of complexity of coordination [7].

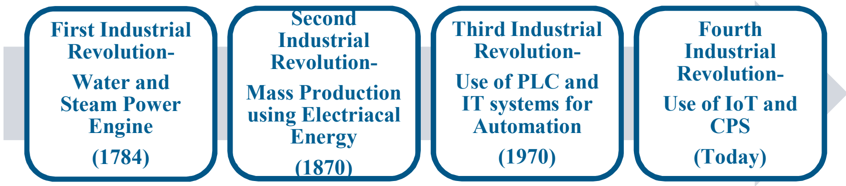

Figure 1. Four Industrial Revolutions

1.1. Need of Industry 4.0

The need of industry 4.0 is to convert the regular machines to self-aware and self-learning machines to improve their overall performance and maintenance management with the surrounding interaction [8]. Industry 4.0 aims at the construction of an open, smart manufacturing platform for industrial-networked information application [9]. Real time data monitoring, tracking the status and positions of product as well as to hold the instructions to control production processes are the main needs of Industry 4.0 [10].

2. Literature Review

The German Federal Government presents Industry 4.0 as, an emerging structure in which manufacturing and logistics systems in the form of Cyber Physical Production System (CPPS) intensively use the globally available information and communications network for an extensively automated exchange of information and in which production and business processes are matched [9]. The four main drivers of Industry 4.0 are Internet of Things (IoT), Industrial Internet of Things (IIoT), Cloud based manufacturing and smart manufacturing which helps in transforming the manufacturing process into fully digitized and intelligent one [11]. The nine pillars of Industry 4.0 will transform isolated and optimized cells production into a fully integrated, automated, and optimized production flow. This leads to greater efficiency and change in traditional production relationships among suppliers, producers, and customers as well as between human and machine [2].

2.1 Big Data and Analytics

The collection and comprehensive evaluation of data from many different sources production equipment and systems as well as enterprise and customer-management systems will become standard to support real-time decision making [2]. According to Forrester's definition, Big Data consists of four dimensions: Volume of data, Variety of Data, Velocity of generation of new data and analysis, Value of Data [12]. The data analysis of previously recorded data is used to find out the threats occurred in different production processes earlier in the industry and also forecast the new issues occurring as well as the various solution to stop that from occurring again and again in industry [13].

2.2 Autonomous Robots

Robots are becoming more autonomous, flexible, and cooperative day by day and at certain they will interact with one another and work safely side by side with humans and learn from them [2]. An autonomous robot is used to perform autonomous production method more precisely and also work in the places where human workers are restricted to work. Autonomous robots can complete given task precisely and intelligently within the given time limit and also focus on safety, flexibility, versatility and collaboratively [9].

Table 1. Autonomous robots used in different industries [5]

Sr.no.	Name of Robot	Company	Function of Robot
1	Kuka LBR iiwa	Kuka	Lightweight robot for sensitive industrial tasks
2	Baxter	Rethink Robotics	Interactive production robot for packaging purpose
3	BioRob Arm	Bionic robotics	Use in close proximity with humans
4	Roberta	Gomtec	6-Axis industrial robot used for flexible and efficient automation

2.3 Simulation

Simulations will be used more extensively in plant operations to leverage real-time data to mirror the physical world in a virtual model, which can include machines, products, and humans, thereby driving down machine setup times and increasing quality [2]. 2D and 3D simulations can be created for virtual commissioning and for simulation of cycle times, energy consumption or ergonomic aspects of a production facility. Uses of simulations of production processes can not only shorten the down times and changes it but also reduce the production failures during the start-up phase [14]. Decision making quality can possibly be improved by easy and fast way with the help of simulations [15].

2.4 System Integration: Horizontal and Vertical System Integration

Integration and self-optimization are the two major mechanisms used in industrial organization [15]. The paradigm of Industry 4.0 is essentially outlined by three dimensions of integration: (a) horizontal integration across the entire value creation network, (b) vertical integration and networked manufacturing systems (c) end-to-end engineering across the entire product life cycle [16]. The full digital integration and automation of manufacturing processes in the vertical and horizontal dimension implies as well an automation of communication and cooperation especially along standardized processes [11]. Figure 2 shows the short description of system integration.

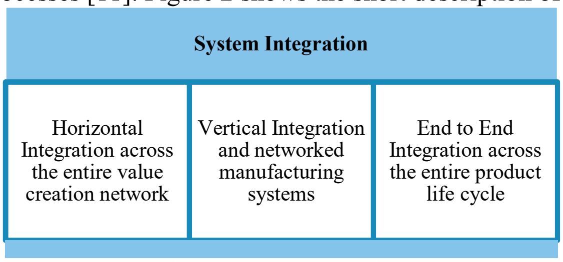

Figure 2. System Integration

2.5 The Industrial Internet of Things

The Internet of Things means a worldwide network of interconnected and uniform addressed objects that communicate via standard protocols [17]. Internet of Things (IoT) should also known as Internet of Everything (IoE) which consists of Internet of Service (IoS), Internet of Manufacturing Services (IoMs), Internet of People (IoP), an embedded system and Integration of Information and Communication technology (IICT) [3]. Context, omnipresence and optimization are the three key features of IoT in which context refers the possibility of advanced object interaction with an existing environment and immediate response if anything changes, omnipresence provide information of location, physical or atmospheric conditions of an object and optimization illustrates the facts that

today's objects are more than just connection to network of human operators at human-machine interface [12]. The value chain should be intelligent, agile and networked by integrating physical objects, human factors, intelligent machines, smart sensors, production process and production lines together across the boundaries of organization [18]. Software and data are key elements for intelligent planning and control of machines and factories of the future [19].
E.g. In the case of storage in warehouses, intelligent shelving and pallets will become the driving force of modern inventory management. In respect of the carriage of goods – tracking and tracing becomes faster, more precise and safe [20].

2.6 Cyber security and Cyber Physical Systems (CPS)

With the increased connectivity and use of standard communications protocols that come with Industry 4.0, the need to protect critical industrial systems and manufacturing lines from cyber security threats increases dramatically. As a result, secure, reliable communications as well as sophisticated identity and access management of machines and users are essential [2]. The strong connection of the physical, the service and the digital world can improve the quality of information required for planning, optimization and operation of manufacturing systems [21]. The term CPS has been defined as the systems in which natural and human made systems (physical space) are tightly integrated with computation, communication and control systems (cyber space) [13]. Decentralization and autonomous behavior of the production process are main characteristics of CPS. The evolution of CPS mainly depend on the adoption and reconfiguration of product structures Supply Networks considered as Collaborative Cyber physical systems which are used in Manufacturing systems as well as different cyber physical systems like city traffic control and control systems [22]. The continuous interchanging of data is carried out by linking cyber physical systems intelligently with the help of cloud systems in real time [16]. Digital Shadow of Production is defined as the representation of physical object in virtual or information world. The basic requirement of real time oriented manufacturing operation and optimization of actual production system is achieved by massive considerations of cyber physical systems [3]. Use of proper sensors in CPS should find out the failure occurring in machines and automatically prepare for fault repair actions on CPS. Also finds the optimum utilization of each work station with the help of cycle time required for the operation performed on that station [23]. The 5C structure uses cloud computing to communicate with the machines (machine with machine or human with machine) [20].
E.g.. The smart vehicle is a typical Cyber-Physical System combined production to represent the development of Industry 4.0. With this production, a data mining method is used for the route prediction, which achieves 80% prediction accuracy [1]

2.7 The Cloud

Cloud-based IT-platform serves as a technical backbone for the connection and communication of manifold elements of the Application Centre Industry 4.0 [21]. With industry 4.0, organization needs increased data sharing across the sites and companies i.e. achieving the reaction times in milliseconds or even faster [2]. "Digital production" is a concept of having the connections of different devices to same cloud to share information to one another and can be extended to set of machines from a shop floor as well as the entire plant [24].

2.8 Additive Manufacturing

With Industry 4.0, additive-manufacturing methods will be widely used to produce small batches of customized products that offer construction advantages, such as complex, lightweight designs. High-performance, decentralized additive manufacturing systems will reduce transport distances and stock on hand [2]. The production should be faster and cheaper with the use of additive manufacturing technologies like fused deposition method (FDM), selective laser melting (SLM), and selective laser sintering (SLS) [21]. As the needs of customer is changing continuously the challenge of increasing individualization of products and reducing time to market are faced by many companies. These challenges they encounter in particular with increasing digitization, IT penetration and networking of products, manufacturing resources and processes [6]. Decreasing product life cycles in combination with the growing demand of customized products asks for the further transformation towards organization structures which lead to increased complexity [7].

E.g. Cars of the same model are offered with many variations in engine, bodywork and equipment; all this in order to better meet the needs of increasingly informed and demanding customers [12].

2.9 Augmented Reality

Augmented-reality-based systems support a variety of services, such as selecting parts in a warehouse and sending repair instructions over mobile devices. Industry can use of augmented reality to provide workers with real-time information to improve decision making and work procedures. Workers may receive repair instructions on how to replace a particular part as they are looking at the actual system needing repair [2].
E.g. A helicopter stuck in remote place in Africa need to deliver food. The next mechanic is some 17 flight hours away and need helicopter back in air within 2 hours. With the help of augmented reality glass on the pilot's head connected to central computer that would know every details about chopper. The repair action is performed with the help of augmented reality glass [2].

3 Issues and Challenges in Industry 4.0

The discovery of new technologies has made industry development from the early adoption of mechanical systems, to today's highly automated assembly lines, in order to be responsive and adaptive to current dynamic market requirements and demands. Challenges like embedment, predictability, flexibility and robustness to unexpected conditions [25]. There are some challenges and fundamental issues occurs during the implementation of industry 4.0 in the current manufacturing industries are given as

- Intelligent Decision-Making and Negotiation Mechanism: In smart manufacturing system needs more autonomy and sociality capabilities as key factors of self organized systems whereas the today's system have 3C Capabilities i.e. lack of autonomy in the systems [25].
- High Speed IWN Protocols: The IWN network used today can't provide enough bandwidth for heavy communication and transfer of high volume of data but it is superior to the weird network in manufacturing environment [25].
- Manufacturing Specific Big Data and Analytics: It is a challenge to ensure high quality and integrity of the data recorded from manufacturing system. The annotations of the data entities are very diverse and it is an increasing challenge to incorporate diverse data repositories with different semantics for advanced data analytics [4].
- System Modeling and Analysis: In system modeling, to reduce dynamical equations and conclude appropriate control model, systems should be modelled as self-organized manufacturing system. The research is still going on for complex system [25].
- Cyber Security: With the increased connectivity and use of standard communications protocols that come with Industry 4.0, the need to protect critical industrial systems and manufacturing lines and system data from cyber security threats increases dramatically [2].
- Modularized and Flexible Physical Artifacts: When processing a product, Equipment for machining or testing should be grouped and worked together for distributed decision making. So there is a need of creating modularized and smart conveying unit that can dynamically reconfigure the production routes [25].
- Investment Issues: Investment issue is rather general issue for most of new technology based initiatives in manufacturing. The significant investment is required for implementing industry 4.0 is an SME initially. The implementation of all the pillar of industry 4.0 requires huge amount of investment for an industry [19].

4 Conclusion and Future Work

The paper mainly focused on the concept of fourth industrial revolution, called Industry 4.0 which allows smart, efficient, effective, individualized and customized production at reasonable cost. With the help of faster computers, smarter machines, smaller sensors, cheaper data storage and transmission could make machines and products smarter to communicate with each and learn from each other. The nine pillars of industry 4.0 explained with the examples to understand the application of Industry 4.0 as well as used to identify the challenges and issues with the implementation of Industry 4.0. As the implementation of the industry 4.0 increases new research streams should be discovered like transparent and organized supply chain and industrial management, Data collection from the production lines and optimization of that data for the use of effective machines, Energy Saving and Optimized maintenance scheduling. The term Industry 5.0 has been introduced to the research areas which are considered as next industrial revolution, but it is more systematic transformation that includes impact on civil society, governance and structures, and human identity in addition to solely economic/ manufacturing ramifications.

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