Eurasian Journal of Analytical Chemistry
ISSN: 1306-3057 OPEN ACCESS 2018 13 (6): 491-497

Industry 4.0 for Advanced Manufacturing and its Implementation

Seung Hyeog Moon*

Received 14 September 2018 ▪ Revised 23 October 2018 ▪ Accepted 24 November 2018

Abstract: Industry 4.0 in many countries related to advanced manufacturing is becoming important. It seems that German government is willing to maintain the high-tech leadership in the new revolutionary stage securing solid technology platform. Many countries recognize that Industry 4.0 developed by Germany is the promising platform with core technologies for the new era, namely 4th Industrial Revolution. It makes sense since Germany is most competitive than any other country in manufacturing industry. However, it is true that it has been challenged severely by followers. In this regard, German government has prepared to deal with the difficulties and rapid changes of the industry. The first key initiative in Industry 4.0 is to integrate interconnected factory systems and Internet of Things (IoT). Cyber-physical systems (CPS) also play a role of major enabler in the integrated environment. There are many variables to prepare advanced manufacturing due to each country's own policy and industry environment. This paper addresses how Industry 4.0 will be implemented for advanced manufacturing enabling smart factories, as well as the role of related technologies and implications for its future perspective.

Keywords: Industry 4.0, Advanced Manufacturing, Smart Factory, Industrial Revolution, Mass Customization.

INTRODUCTION

The industrialized countries have enjoyed the blessing of prosperity since 1st Industrial Revolution. Many people could consume qualified products with low cost thanks to mass production. The customers' needs have been diversified going through 2nd and 3rd Industrial Revolutions. Traditional manufacturing systems have been confronted with severe challenges and competition. Advanced manufacturing is an alternative for overcoming those difficulties and Industry 4.0 is showing the desirable solutions for coming 4th Industrial Revolution. Industry 4.0 goes ahead of other manufacturing technologies. It is part of the "High-Tech Strategy 2020 Action Plan" of the German government. The advanced manufacturing based on Industry 4.0 is the integration of IoT connected with computer networks and big data to intelligently analyze and share production information over all manufacturing facilities [1]. Three countries, Germany, the United States and Japan are leading the smart factories, however each country has a different strategy and perspective on the development of Industry 4.0. It is caused by their own characteristics in manufacturing and other related industries. Nevertheless, they are trying to cooperate for mutual interests. This study investigates how industry 4.0 activates the advanced manufacturing enabling smart factories and its implementation. Also, desirable direction of development is proposed.

CONCEPT OF INDUSTRY 4.0

Industry 4.0 makes manufacturing systems use the sophisticated technologies associated with information and communications. As a result of the advancement, all the processes in smart factory ecosystem are integrated to make production flexible and efficient for high quality and low-cost products. IoT, big data, cloud computing and artificial intelligence (AI) are key enabling technologies implemented for Industry 4.0. It integrates the independent subsystems to transform the existing production lines into the flexible and reconfigurable ones, that is, to implement the key technologies and processes for smart factories. CPS is another critical solution which is a complex engineering system that integrates physical, computation and networking, and communication processes. It can be illustrated as a physical device,

---

Seung Hyeog Moon*, Dept. of Mechanical and Metallic Mold Engineering, Gwangju University, 277, Hyodeok-Ro, Nam-Gu, Gwangju, Korea.

object, equipment that is translated into cyberspace as a virtual. Simply defining, a smart factory is that all the things related to manufacturing are interconnected over IoT and CPS for intelligent operation. Those technologies flexibly and automatically control manufacturing process reflecting production items and equipment conditions to realize best production efficiency. The industrial production of high-tech products is influenced between the satisfaction of various customer needs through individualization and the realization of scale effects along the value chain [2]. By virtue of those technologies mentioned above, the customized production, symbolic characteristic of Industry 4.0 era has come for customer value provision. Further technologies for customization will be developed in this regard continuously. Also, the 4th Industrial Revolution based on Industry 4.0 requires companies to act aggressively without a clear demand for increased productivity from the market-side [3].

STRATEGY DIRECTION

Germany is implementing Industry 4.0 for maintaining manufacturing competitiveness against competitors. Smart factory vitalization is regarded as the core index of transformation towards 4th Industrial Revolution. Although Industry 4.0 is leading 4th Industrial Revolution, each leading country of manufacturing industry pursuing the transformation has its own strategic direction for a smart factory.

Germany

Technologies for a smart factory has been actively led by the German government and industrial society, and executed by firms, universities and research institutes cooperating each other. Large companies, such as Siemens, Bosch, SAP, etc. are providing platform for the new manufacturing technologies. Besides of them, small and medium-sized enterprises named Festo, Baer, Beckhoff, etc. are also aggressively participating in Industry 4.0. The strategy of the German government is to establish next generation manufacturing system over the country. It has an R&D roadmap planned until 2035.

United States

While Germany has core competency of the new concept and design to manufacture high-tech products in terms of Industry 4.0, the United States has an ability to plan new business model and manufacture with efficient SCM integrating global component and manufacturing resources. Large companies are leading smart factory related business under the name of Industrial Internet. GE proposed the concept first in 2012 and formed Industrial Internet Consortium (IIC) cooperating with Intel, Cisco, etc., and announced cloud platform named Predix.

Japan

Although the manufacturing competitiveness of Japan is not same as before, it has many outstanding players in materials, components and equipment along with sensors and precision measuring instruments. Those are core enablers in smart factories. Large electric, robotic and mechanical companies and related component firms are interested in smart factories and new business model. Japan has moved relatively later than other two countries and Industrial Value Chain Initiative (IVI) was formed with about 60 manufacturing conglomerates led by Mitsubishi, Toyota, Panasonic, etc. It prefers to maximize production efficiency by advanced man-machine interface and edge computing.

INDUSTRIAL REVOLUTIONS

Manufacturing industry pursued a goal to achieve mass production when it was still in its infancy. In the middle of the 18th century, standardization of products and processes was the key issue for managing factories. Many people chose large cities for jobs, but their working conditions were poor. Growing demands for new products with low price triggered to build more factories and created enormous blue color jobs. Mass production influenced on people's life in terms of consumption and expenditure from the beginning of 1st Industrial Revolution.

By virtue of electricity and line production using conveyor belt, the factory size was getting bigger than before and productivity increased in the 2nd Industrial Revolution. Thereafter, development of computer and network systems enabled the automatic production, and controlled man-machine interface for managing manufacturing efficiency and inventory issues. Overproduction and excess capacity caused price reduction and severe competition while scale of economy grew continuously in the 3rd Industrial revolution. Manufacturing industries have had a hard time to resolve these issues and tried to find solutions converging manufacturing systems with advanced technologies such as IoT, Big Data AI, CPS, etc. Needs from each individual are gathered now and production lines are optimized by using those technologies and communicating among products and production systems [4].

MASS CUSTOMIZATION

People have enjoyed material affluence with mass production through industrial revolutions, however their needs have been diversified thanks to economic development. Producers recognized the uniform production systems optimized for identical products are not suitable to win in complex society and competitive industrial environment. Mass customization is defined that it brings advantages of both single piece production (individually and precisely) and mass production (quickly and inexpensively) [5]. For example, Dell was greatly successful on personal computer business when it received orders from each individual and manufactured product by product with different configuration. A smart factory is an alternative to plan, organize and even control the production by themselves. In this regard, Industry 4.0 is the appropriate solutions for fulfilling requirements of customers by mass customization. One of key issues for mass customization is to decrease production complexity, that is, to increase flexibility of a manufacturing system. Producers will create customer value and secure competitiveness according to their implementation capability for ICT convergence mentioned above.

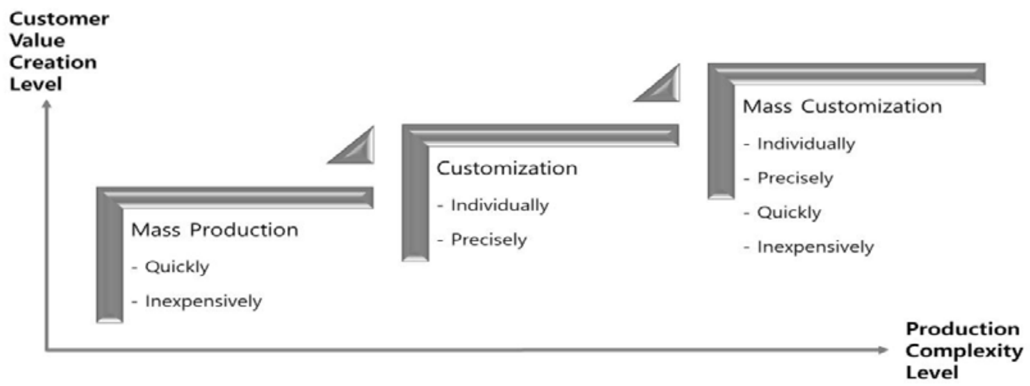

Figure 1: Mass Production vs. Mass Customization

THREE TYPES OF INTEGRATION

Capability of production flexibility is one of key success factors to survive in the upcoming 4th Industrial Revolution era. German government, academic institutions and representatives of manufacturing industries have cooperated to devise a sustainable manufacturing platform optimized for the requirements by industry advancement. Industry 4.0 is the promising solutions for dealing with complexity issues in production and provides customers with the unprecedented values. It is outlined as three dimensional integrations as shown in Figure 2.

Horizontal Integration

This integration is the interaction among value creation factors, such as human, supplies, product, transport, etc. It includes even water and energy management across internal functions and cross-linking digitized networks throughout the value chain of a product life cycle in ecosystem. Cross linkage is also expanded to other facilities and companies to create customer value for a product through life cycle [6].

Vertical Integration

It makes manufacturing systems networked by integrating various production functions including product design, procurement, production, quality assurance, etc. And it is accompanied by complete digitization and data exchange across equipment, tools, products as well as man-machine interface throughout production process. This integration also includes sales, marketing and services [6].

End-to-End Engineering integration

Vertical integration or horizontal integration works by itself and simultaneously, each integration interacts with one another combining with end-to-end engineering integration by digitized networking from raw materials to product end of life. By end-to-end integration, a sustainable and reusable product model can be available by every stage. The customized goods can be produced thanks to the predictable product design and service enabled by the effective software tools [7]. All the digitized information among cross-company, company-internal functions, customers, suppliers, etc. and data from components, machines, products, factory workers, etc. are networked towards cloud through the entire product life cycle by this integration. It will bring valuable products with reduced cost and flexibility to all the stakeholders in a smart factory ecosystem.

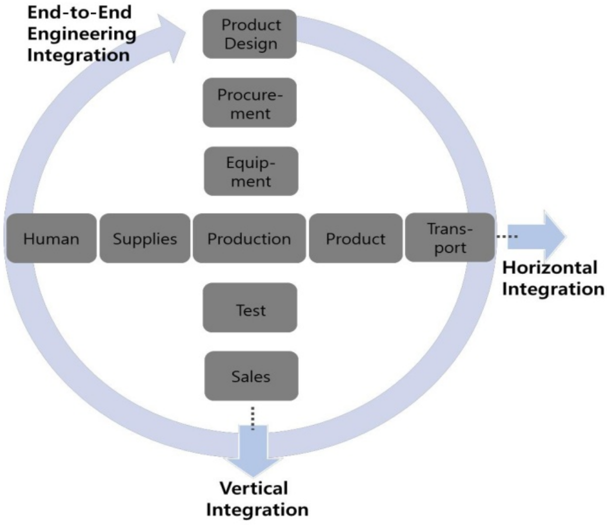

Figure 2: Three Dimensional Integrations

ROLE OF KEY TECHNOLOGIES

It is possible for a producer operating a smart factory in Industry 4.0 environment to secure advanced manufacturing system with related key technologies. There are many product versions in production cells and lines of electronics products. Flexibility level is the most important factor for those industries. For example, Siemens can deal with issues from frequently changing products by implementing Industry 4.0 in its Amberg smart factory. IoT sensors connect and link machines, products and even components closely to IT systems. These connected systems can communicate with one another along the value chain within a manufacturing ecosystem, analyze data obtained and troubleshoot for adjustment autonomously. Embedded computing, sensors and actuators are working for Machine-to-Machine (M2M) communication which make a producer configure predictable and flexible manufacturing facilities. CPS is the technology accompanied by the integrated computational and physical capabilities like sensing, communication and actuation to physical system [8]. In the implementation of CPS, simple connectivity between equipment and sensors is not quite meaningful. To leverage the advanced technology, correct information should be available whenever required for the right purpose [9]. Besides CPS, IoT, Big Data, Cloud Computing and AI are also essential enabling technologies for advanced manufacturing system to complete three dimensional integrations and realize a real smart factory.

CPS

CPS offers higher co-work capabilities between physical and computational units of manufacturing systems [10]. CPS integrates cyber simulation, networking and real world processes. Embedded computers and networks will examine, control and adjust the physical processes which influence on computations and vice versa. CPS in advanced manufacturing industries strongly deals with the two main processes like order fulfillment and product development. The system of the new product design process is going to be adopted increasingly, integrating value stream designing, concurrent and simultaneous engineering.

IoT

The concept of 'Internet of Thing' has been introduced and developed continuously. RFID and M2M were already adopted as the simple data communication solutions in the early stage of IT revolution. According to glaring development of IT technologies, all the sensors, equipment, products and even components are networked for utilizing embedded computing with standard technologies. IoT makes field devices communicate so that those could interact both with one another and with more centralized controllers, as necessary. Another advantage of the technology is decentralization of analytics and decision for real-time responses.

Big data

A smart factory is featured by an autonomous multi-agent system. It is supported by big data-based algorithm and feedback. Big data is collected from IoT sensors, embedded computers and all of data sources in integrated ecosystem. The Smart factory focuses mostly on self-organized optimization and efficiency. A lot of data usually could be obtained by communicating with different adjacent systems which give a direct effect to equipment performance. It is important for designing cognitive and self-learning functionality to manage and distribute information in three dimensional integrations. Big data improve manufacturing performance, product quality and maintenance efficiency [11].

Cloud Computing

Cloud computing is the most efficient and flexible solution required in end-to-end digitization surroundings by adding, using and exchanging IT service over internet. It offers active, scalable and virtualized resources at anytime and anywhere by using the internet [12]. The advanced manufacturing works require cloud computing and enormous data enabled by virtualization and distributed processing across ecosystems in Industry 4.0. Simultaneously, the performance of cloud technologies will improve in terms of reaction times. Consequently, the role of cloud computing will be more important so that machine data and functionality will be deployed to the cloud increasingly, prompting more data-driven applications for production systems.

AI

The advanced manufacturing method features autonomous sensing, integration, collaboration, self-awareness, automatic analysis, feedback and intelligent adjustment in the production system over product life cycle. AI algorithm is involved in most of those technologies and processes, and will be more increasingly adopted for evolutionary manufacturing stage in Industry 4.0 as enormous data occur and real-time decision-making issues happen in production facilities and ecosystem. Although it will take long time to achieve an ultimate goal, thinking and acting like human, AI will play a reliable role as an intelligent agent and bridge between workers and machines/processes.

Table 1: Key Enabling Technologies of Industry 4.0

	Role	Implementation for Industry 4.0
Cyber Physical System (CPS)	Managing connected systems with one another between their physical assets and computational capabilities in Industry 4.0 ecosystem.	Integrating cyber simulation and physical processes, and examining, controlling and adjusting the real world processes for cost-effective product design,order fulfillment, product development, pre-production simulation pursuing cost reduction.
Internet of Things (IoT)	Creating unified information grid that networks with all the sensors, equipment, products, etc. for utilizing embedded computing	Gathering enormous data fromall the sensors, equipment, products and even components networked over internet and utilizing embedded computing for processing,analyzing and applying for advanced manufacturing.
Big Data	Processing for improving production performance, quality control, maintenance efficiency, etc. with self-organized optimization	Achieving self-aware and self-learning functionality for improving overall performance and maintenance management, optimizing production quality, saving energy and improving equipment service in three dimensional integrations.
Cloud Computing	Exchanging IT service based on the internet which involves providingactive, scalable and virtualized resources at any time.	Managing a lot of virtual computing data, making up distributed processing across ecosystem and providing on-demand service for stakeholders through autonomous and heterogeneous service-oriented computing mode on the internet.
Artificial Intelligence (AI)	Manufacturing by algorithm with big data, intelligent adjustment, innovation of all the system over ubiquitous networks.	Realizing autonomous sensing, integration, collaboration, self-awareness, automatic analysis, feedback, and playing a reliable role as an intelligent agent and bridge between workers and machines/processes over product life cycle.

IMPLICATIONS

People living in industrial society always desire to improve their quality of life. The industrial technologies are advancing to meet the social requirements. Traditional production system is not a sustainable model raising many issues to be resolved. The Industry 4.0 will be implemented as the solutions for those while existing Manufacturing Execution System (MES) is evolving more intelligently for optimized, flexible, customized and cost reduced manufacturing. There are no unique global standards to implement the solutions for advanced manufacturing. The reason is related to various industrial factors and characteristics of each leading manufacturing country such as Germany, United States and Japan. A smart factory is not merely an autonomous facility, but a way of revolutionary cooperation among stakeholders in the manufacturing ecosystem thanks to digital transformation. The leaders in the advanced manufacturing industries will try to develop smart factories with their own strength and competency. Japan is adopting edge computing methodology to advance man-machine interface based intelligence with loose standards whereasGermany and United States are implementing related technologies with strong standards for taking the initiative. It is difficult to assure which strategy and stance are reasonable at this moment because success of smart factory based on Industry 4.0 will be achieved by not only technologies and standards but also operation and management in the ecosystem. Thus, importance of human and organization in autonomous production will increase paradoxically. The answer for the question about the initiative in Industry 4.0 will be the 'customer value creation' executed by the prospective leader.

CONCLUSION

Industry 4.0 has been instrumental in accelerating 4th Industrial Revolution. An outstanding aspect in the revolution is the increasing demand of customized goods in combination with decreasing life cycle of products. Mass customization is what many industrialized countries are interested in and focusing on. It needs further transformation of organizational structure and value chains across a company, which will cope with increased complexity. It will take some time for Industry 4.0 to proliferate over the manufacturing industries because of differences of their cost structure, customer needs, value proposition, etc. The standards issue will be resolved by cooperating among related countries in the mean while. Companies implementing Industry 4.0 for smart factories need to elaborately develop their strategies for stakeholders; customers, employees and partners in ecosystems. Also, three dimensional integrations based on Industry 4.0 over the entire product life cycle and digitized networks will provide manufacturing industries with reasonable solutions in 4th Industrial Revolution era eventually.

ACKNOWLEDGMENT

This Study was conducted by research funds from Gwangju University in 2019.

References

[1] Jay Lee, "Smart Factory System", Informatik Spektrum, vol. 38, no. 3, pp. 230-231, 2015

[2] Malte Brettel, NiklasFriederichsen, Michael Keller, Marius Rosenberg, "How Virtualization, Decentralization and Network Building Change the Manufacturing Landscape: An Industry 4.0 Perspective", International Journal of Information and Communication Engineering, vol. 8, no. 1, pp. 37-44, 2014

[3] G. Schuh, T. Potente, C. Wesch-Potente, A. R. Weber, and J.-P. Prote, "Collaboration Mechanisms to Increase Productivity in the Context of Industrie 4.0," Procedia CIRP, vol. 19, pp. 51–56, 2014

[4] Uwe Dombrowski, Tobias Wagner, "Mental strain as field of action in the 4th industrial revolution", Science Direct, Procedia CIRP vol. 17, pp.100-105, 2014

[5] PrzemystawZawadzki, Krzysztof Zywicki, "Smart Product Design and Production Control for Effective Mass Customization In the Industry 4.0 Concept", Management and Production Engineering Review, vol. 7, no. 3, pp. 105-112

[6] Janani, F., Kohan, S., Taleghani, F., Ghafarzadeh, M.Effective strategies in promoting evidence-based maternity practice from theperspective of midwives in Iran: An opportunity for change,(2018) International Journal of Pharmaceutical Research, 10 (3), pp. 55-62. DOI: 10.31838/ijpr/2018.10.03.050

[7] Shiyong Wang, Jiafu Wan, Di Li, Chunhua, Zhang, "Implementing Smart Factory of Industrie 4.0: An Outlook", International

[8] Journal of Distributed Sensor Networks, Volume 2016, Article ID 3159805, 10 pages

[9] Jay Lee, Behrad Bagheri, Hung-An Hao, "Recent Advances and Trends of Cyber-Physical Systems and Big Data Analytics in Industrial Informatics, Proceeding of Int. Conference on Industrial In formatics (INDIN) 2014

[10] Ushasi Das, Gopa Roy Biswas And Sutapa Biswas Majee (2013) Fabrication of a Disintegration-Accelerated Matrix Tablet of Carvedilol. International Journal of Pharmacy Research & Technology, 3 (2), 22-28.

[11] Radu. C, Ioana. A, Olteanu, Gheorghe. "Smart Monitoring of Potato Crop: A Cyber-Physical System Architecture Model in the Field of Precision", International Conference on Agriculture for Life, Life for Agriculture, Agriculture and Agricultural Science, Procedia CIRP vol. 6, pp. 73–79, 2015

[12] Jay Lee, Hung-An Kao, Shanhu Yang, "Service innovation and smart analytics for Industry 4.0 and big data environment", Proceedings of the 6th CIRP Conference on Industrial Product-Service Systems, Procedia CIRP vol. 16, pp.3-8, 2014

[13] Gu Pingli, Shang Yanlei, Chen Junliang, Deng Miaoting, Lin Bojia, Enterprise-oriented Communication.