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The Importance of STEP-NC in the IR 4.0 Manufacturing Systems

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ABSTRACT

The Fourth Industrial Revolution (IR 4.0) is a massive initiative around the globe. This initiative aims to digitalise industrial manufacturing via the exploitation of innovative technologies. The transformation goal is to enable and enhance the flexibility, individualisation and customisation abilities of the production system. In order to meet the challenges of IR 4.0, the current manufacturing system requires a significant transformation in the information handling between Computer Aided Design (CAD)/ Computer Aided Process Planning (CAPP)/ Computer Aided Manufacturing (CAM) and Computer Numerical Control (CNC). At present, the commercial manufacturing system uses the International Organization of Standardization (ISO) 6983 standard, commonly known as G-code, for the information handling between CAD/CAPP/CAM and CNC. However, this standard has many obstacles, due to which, it has not been able to support the smooth integration between design and manufacturing. In order to tackle this issue, the new data interface model has been introduced, known as Standard for The Exchange of Product Data (STEP) and STEP - Numeric Control (NC). This paper discusses the impact of STEP-NC in the context of IR 4.0. The article also explains how the adoption of STEP-NC will transform the manufacturing system as per the goal of IR 4.0. Consequently, this discussion will also trigger new concepts and ideas for the realisation of IR 4.0.

Key words : Industrial Revolution 4.0, STEP, STEP-NC, CAD/CAPP/CAM/CNC, Manufacturing.

1. HISTORY OF INDUSTRIAL REVOLUTIONS

The Industrial Revolution (IR) has proved itself to be a backbone of the country's economy, growth and development. Till now, there have been four industrial revolutions occurred, as depicted in Figure 1. The first IR was initiated at the end of the 18th century by Britain, which focused on the mechanization and mechanical power generation by water and steam. It is commonly known as the 1st Industrial Revolution (IR 1.0), which transformed the manual work into machine manufacturing process [1]. This revolution commenced the use of new material, energy resources, machines, and organization of work (factory system). Apart from that, the IR 1.0 brought significant developments in the transportation and communication systems such as a steam locomotive, automobile, aero plane, steamship, radio, telegraph and others. This revolution had successfully increased the application of science in the industry and enabled the mass production of manufactured goods [2].

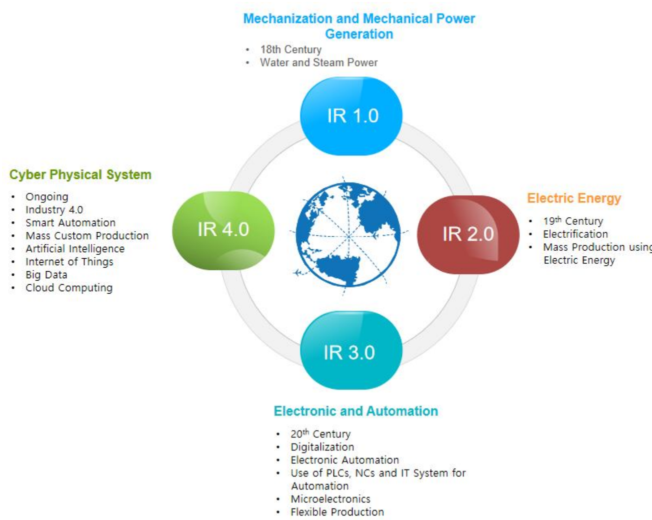

Figure 1: Overview of Industrial Revolutions

Almost a century after IR 1.0, the second Industrial Revolution (IR 2.0) commenced in the late 19th century. In this revolution, the industry began to exploit lighter metals, new alloys, synthetic product and new energy resources like electricity, gas and oil. The principal aim of IR 2.0 was to utilise the electric energy in the industry to enhance the mass production. The development of the combustion engine was a vital milestone of IR 2.0. This industrial revolution had a remarkable impact on the assembly line. It has enhanced the mass production, but there was no room for product customization [1], [2].

In the second half of the 20th century, the third Industrial Revolution (IR 3.0) was introduced, which witnessed the nuclear energy and electronics growth. This revolution was a rise of electronics, which transported the digitalisation and automation to the industry with the utilisation of microelectronics. The third industrial revolution initiated the concept of production flexibility with the help of programmable machines [1]. This revolution brought a high level of automation into the production industry with the creation of Programmable Logic Controller (PLC) and robots [2].

2. FOURTH INDUSTRIAL REVOLUTION (IR 4.0)

Today, the fourth Industrial Revolution (IR 4.0) is underway, which builds upon IR 3.0. The aim of IR 4.0 is to connect all production resources to empower their interaction in real time with the help of Information and Communications Technologies (ICT). Germany introduced the concept of IR 4.0 in the year 2011 [1]. The concept was based on the utilisation of new technologies like Internet of Things (IoT), cloud computing, and cyber-physical systems (CPSs) [3] to construct and open a smart platform for industrial information network applications [4]. Besides that, IR 4.0 aimed to decrease the production costs by 10-30%, logistic costs by 10-30% and quality management costs by 10-20%. The IR 4.0 will also be helpful to speed up the delivery time of the new products to the market, improve customer receptiveness, customise mass production, add flexibility to the work environment and enhance effective use of energy resources [1]. This industrial revolution is the combination of various technologies, as shown in Figure 2. The role of these technologies is discussed in brief by [3], [4].

Figure 2: Technologies of IR 4.0

In the IR 4.0 manufacturing system, the interoperability and connectivity are the significant components which will help to enable seamless integration between Machine-To-Machine (M2M) and Human-To-Machine (H2M) [1]. This integration is a compulsory requirement in smart manufacturing systems. As the CNC and NC are among the commonly used elements of today's manufacturing system; therefore, the interoperability and connectivity among CAD/CAM/CAPP/CNC is a crucial issue to address. There are many other issues, and challenges present in the implementation of the IR 4.0 and some of them are discussed by [5]. However, this paper addresses the issues of interoperability and connectivity among today's manufacturing system in light of IR 4.0.

3. INTEROPERABILITY IN THE MANUFACTURING SYSTEM

Manufacturing is one of the critical divisions of IR 4.0 that is expected to be intelligent, adaptable, open, flexible and interoperable [6]. At present, most of the manufacturing industries are using NC and CNC technologies, which are based on the five decades old data interface model, commonly known as G-Code (ISO6983). This data model has major drawbacks like no access to the internal code engine (act like a black box), one-directional data flow, limited bandwidth, loss of information between CAD/CAM/CNC, no shop floor data modification and others [7]. In the presence of these weaknesses, this data interface model is unbearable to achieve the aim of IR 4.0 manufacturing system.
However, Standard for the Exchange of Product Model Data Compliant Numeric Control (STEP-NC) guarantees the transparency among design and manufacturing, which will resolve the information loss issue of G code and will enable the bidirectional informational flow. This transparency of data between design and manufacturing has built an enormous platform to facilitate the interoperability in the manufacturing system [8].

4. MANUFACTURING SYSTEM OF IR 4.0

The manufacturing systems of IR 4.0 are meant to cover design, machining, monitoring, control, and scheduling activities altogether. In order to perform the aforementioned activities, the system is required to be smart, intelligent, flexible, real-time and interoperable. This empowering will be the composition of various technologies and techniques; some of them are stated in Figure 3. The integration of these technologies and techniques will require a high level of interoperability, which is one of the critical issues in the commercial manufacturing systems, especially in the CNCs, as discussed earlier.

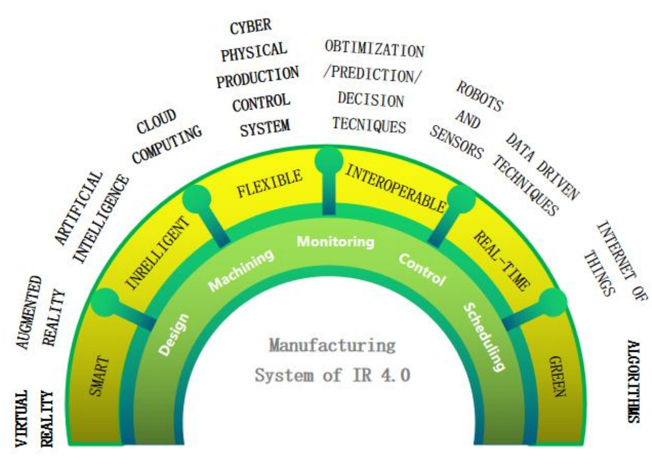

Figure 3: Route, Technologies and Techniques of IR 4.0 Manufacturing System

However, thanks to STEP and STEP-NC, which reconstructed the manufacturing numerical chain and enabled the high-level data exchange within the entire manufacturing system. The feature-based structure of STEP-NC makes the machine independent and scalable. This standard also provides an easy excess to the entire data of the product, which makes designing, simulation, machining, monitoring, optimisation and inspection possible in the entire chain of the manufacturing system. These powerful features of STEP and STEP-NC make them a more appropriate data interface model for IR 4.0 manufacturing systems.

5. CONCLUSION

Intelligent/smart manufacturing is one of the significant goals of IR 4.0, and it is considered to be one of the significant potential areas of the research. Plenty of research has been carried out on that ([1], [2], [11], [12], [3]–[10]) to enable the intelligence, flexibility and interoperability into the current manufacturing environment. It has been substantiated that the G code is not strong enough to tackle the entire concept of manufacturing in IR 4.0 because of its black box nature and limitation. Therefore, there is a sheer need to adopt STEP-NC as it can achieve the target of IR 4.0 manufacturing system.

STEP-NC had effectively overcome the drawbacks of the G code, and it has been broadly used by the various scholars all around the world such as USA, China, Germany, France, Japan, Malaysia, United Kingdom, Switzerland, New Zealand and others [3], [12].

This paper has presented the history and concept of industrial revolutions. Moreover, the paper also highlighted the expectations of the manufacturing system in the IR 4.0, why G code is not able to meet these expectations, and why STEP-NC is suitable to replace the G code and have potential to fulfil the desired expectations of the next generation manufacturing systems.

It is evident that the future needs the intelligent, flexible and interoperable manufacturing systems. On such regard, the authors believe that the needs of the future manufacturing system are possible to achieve with the utilisation of the STEP-NC data interface model because it has the capability and success ratio. Therefore, this field of study needs to be researched together with the latest technologies and techniques of IR 4.0.

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