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A PERSPECTIVE OF SMART MANUFACTURING: A CASE STUDY

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Abstract

Smart technology holds key for future in all sectors. Many interdisciplinary beneficial aspects of smart manufacturing paradigm, research and development in manufacturing field have been increased substantially. However smart manufacturing application for subtractive manufacturing challenging. In this paper, issues smart manufacturing for subtractive manufacturing is studied. Firstly, the concept and current research in smart manufacturing is summarized. Then four layered framework is proposed consisting of physical service layer, virtual layer, web portal layer and user layer. Based on the framework, structure of cloud CNC application is proposed. Case study implementation on cloud based CNC machine validates the proposed method.

KEYWORDS: Smart Manufacturing, Cloud Computing, CNC, Interoperability, CAD/CAM.

1. INTRODUCTION

The term 'smart manufacturing' has inspired from the term 'intelligent manufacturing'. Intelligent manufacturing term was coined around 1990 by Kusiak [1]. In 1995 Japan established Intelligent Manufacturing System (IMS) Programme. USA started Next Generation Manufacturing Systems (NGMS) Programme in 1995. Kurzweil R., Director of Engineering at Google in 2001 predicted that the 21st century may experience 20,000 years of progress.

Manufacturing is a key element in the global economy. Recent progress in computer particularly in cloud computing (CC), Internet of Things (IoT) has taken automation in manufacturing to next level. Smart Manufacturing Leadership Coalition (SMLC) in 2012 has proposed Smart manufacturing (SM) terminology to shape future manufacturing with advanced sensing, platform technologies, control and modeling. Various initiatives like Industry 4.0 by Germany, Factories of Future (FoF) by European Commission, Future of Manufacturing by UK, and Made-in-China 2025 by China are to achieve smart SM systems.

There is no universally accepted definition of SM, various institutes; authors defined it in their own way. According to the National Institute of Standards and Technology (NIST) defined SM as "fully integrated, collaborative manufacturing system that responds in real time to meet changing demands and conditions in the factory, in the supply network and in customer needs" [2]. Davis et al. [3] defined SM as "the use of data-driven manufacturing intelligence in multiple real-time applications deployed throughout all operating layers across the factory and supply chain".

According to Kang et al. [4] SM system is "a collection and a paradigm of various technologies that can promote a strategic innovation of the existing manufacturing industry through the convergence of humans, technology, and information". SM utilises sensor networks, cyber-physical systems (CPS), artificial intelligence (AI), IoT, CC, service-oriented architecture, and data analytics [5].

CC for manufacturing is gaining popularity towards various industrial sectors due to its features like efficiency, flexibility, sustainability, and interoperability [6]. Yu et al. [7] argued that there is commonality between Computer Integrated manufacturing (CIM), CC for manufacturing and Cyber Physical System (CPS) in the ways IT is used and helped different stages of industrial revolution. Use of IoT [8] and big data analytics [9] in SM is helping in advancement of technology but also imposing new challenges. SM is an enabler for new computer aided process and being successfully implemented for processes like additive manufacturing, sheet metal forming, robotic applications etc. However SM applications for machining particularly in subtractive manufacturing are not as popular as additive manufacturing.

All over the world, majority of manufacturers use CNCs and special purpose tooling machines. Direct application of Cloud technology for CNC is little tricky. This same point is the motivation for doing this research. This paper addresses how Cloud technology can be incorporated in subtractive manufacturing and its benefits from manufacturer's point of view.

The objectives of the study are as follows: to study and analyse current trends and issues of subtractive manufacturing and CNC, to access SM application to CNC machine, proposing a feasible solution and validating the proposed method through a case study.

The remainder of this paper is organised as follows: Section II presents literature survey of SM and its applications. Section III describes proposed framework for subtractive manufacturing. Section IV explains about implementation and case study on CNC Lathe machine, followed by discussion in Section V. Conclusions and future directions are presented in Section VI.

2. LITERATURE REVIEW

The literature survey is described in two subsections; firstly enabling technologies to SM are discussed followed by SM and issues in it.

2.1. Enabling Technologies for SM

Development in last two decades particularly in information and communication technologies (ICT) has helped to achieve SM in reality. This section briefs about important key technologies as follows.

IoT term was coined by Kevin Ashton in 1999. IoT is a massive network of connected things and it has been estimated that by 2020, almost 20.8 billion devices will be connected using IoT [10]. It is one of the important enabling technologies in Industry 4.0 and SM. IoT is a network of the things like software, sensors, and electricity or physical objects [4]. In 2012 General Electrical introduced the Industrial IoT (IIoT). IIoT applies IoT to manufacturing by incorporating machine learning and big data, harnessing sensor data and automation [11].

CC term was introduced in 2006, which delivers computing service like servers, storage, databases, networking, software, analytics and more over the internet [12]. CC offers benefits such as adaptability, multi-tenancy, reliability, scalability, etc. to companies [13].The term 'Cloud Manufacturing' (CM) was coined in 2009 in China by Professor Bo Hu Li. CM is CC for manufacturing. CM is a customer centric manufacturing process which gives you on demand access to the shared pool of manufacturing resources to enhance the efficiency, decrease the product lifecycle cost in response to the variable demands of the customers [14]. In CM, all the manufacturing resources are sensed and connected to the cloud. For the sharing and exchanging the data automatically, IoT technologies like RFID tags and barcodes can be used [15].

Cyber-physical System (CPS) term was coined by National Science Foundation in 2006 in USA. IoT deals with the internet connected physical objects, CPS is concerned with the nature and system characteristics of the software controlled systems [16]. Most of the studies related to the CPS are linked to SM. Lee et al. [17] has given 5C architecture of CPS for SM with 5 levels: smart connection level, data-to-information conversion level, cyber level, cognition level, and configuration level.

2.2. SM and Related Issues

The SMLC definition states, "Smart Manufacturing is the ability to solve existing and future problems via an open infrastructure that allows solutions to be implemented at the speed of business while creating advantaged value".

Lu et al. [16] discussed the SM Ecosystem, SM capabilities (productivity, agility, quality and sustainability), and standards opportunities for SM. Tao et al. [18] has given a data-driven approach for SM by proposing the framework of four modules (manufacturing module, data driver module, real time monitor module and the problem-solving module). Data driven approach provides full range of services to manufacturing and it increases the efficiency of manufacturing with improvement in products performance [18].

In last decade or so, world has slowly shifted from SM. Because of many interdisciplinary beneficial aspects of SM, research and development in manufacturing field using applications of CC and IoT have been increased substantially. Most of the research work on SM is focused on one particular aspect of manufacturing and development was around it. Some of the researchers created framework, while some of them have put forward architecture of possible SM system. From implementation point of view, many successful ventures were attempted on prototype levels.

Based on literature survey identified research gaps are as follows:

- Industrial application of SM is in initial stage and it needs to be tested large-scale environment.
- The awareness of SM is steadily increased but it is only for SMEs.
- Application range and geographic area are crucial for SM service.
- Interoperability and portability are also concerns of manufacturers.
- Additive manufacturing sector considered to be more suitable for adopting SM than subtractive manufacturing.

To address the issues of SM for subtractive manufacturing author proposed four layer framework. Case study implementation on CNC Lathe machine application used to validate proposed framework.

3. PROPOSED FRAMEWORK

Majority of manufactures around the world still use CNC machines, special purpose machines along with traditional NC machines and lathes. Many researchers around the world have been trying to integrate Cloud technology with manufacturing field. It has been successful venture on additive manufacturing level but not so on subtractive manufacturing. As per discussion in literature survey, reason behind it is interoperability, which is nothing but the ability of computer systems to exchange and make use of information. In manufacturing field, different organisation use different software for their work. To address this problem a generic Cloud based system approach is proposed. The detailed structure of four layered system is given in Figure 1.

In this system information is supposed to be taken in the form of text/numerical format in first layer, i.e. user layer. Based on information feed a CAD file or assembly sequence or Bill of Material etc. for required job will get generated automatically. This application can be operated on virtual level, i.e., on web portal level. This virtual level is operated using Cloud technology. Cloud Based layer is primarily used for virtualization of resources or applications. Then on physical service layer actual operations and controls can happen.

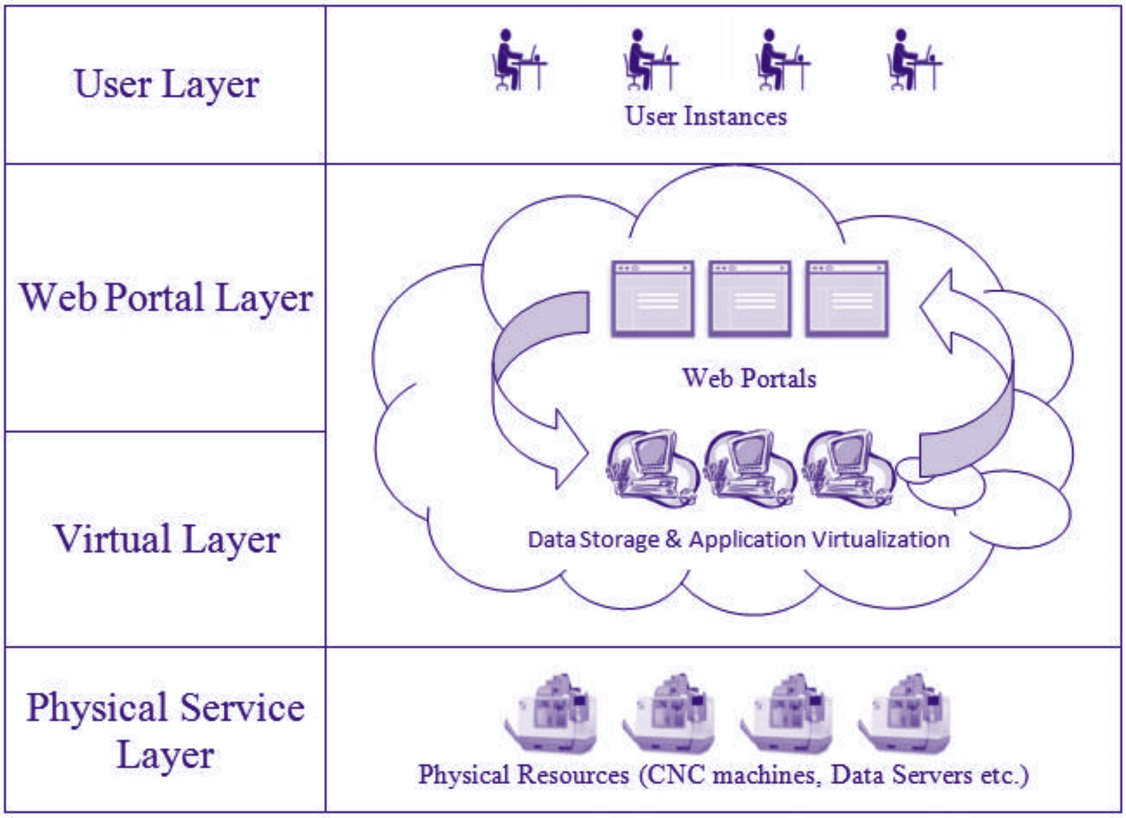

Fig. 1Proposed Framework

4. CASE STUDY ON CNC MACHINE

Cloud based application is developed which generates the CAD file of required job. This application takes information from user in text format and using that information part file gets generated automatically. This CAD will then goes to physical service provider where tool selection and tool-path generation can be done. This system mainly consists of three parts, namely Cloud system, CAD-CAM system and CNC or physical hardware system. Cloud portal is created using 'Microsoft Azure' cloud services. Microsoft Azure is hybrid Cloud platform. Platform as a Service (PaaS) and Infrastructure as a Service (IaaS) features of Cloud technology is utilized.

For automatic CAD file generation 'Solidworks' software and Visual Basic (VB) as scripting language are used. For tool selection and tool-path generation 'Mastercam for Solidworks' is incorporated in system. For actual implementation work an application is created for automatic generation and saving of CAD file using VB coding. In this application a Graphical User Interface (GUI) is given which enables user to input the dimensions, generate the CAD file and save the completed part file on desktop. Different GUIs are shown in Figure 2 and 3.

Fig. 2 User Input Window

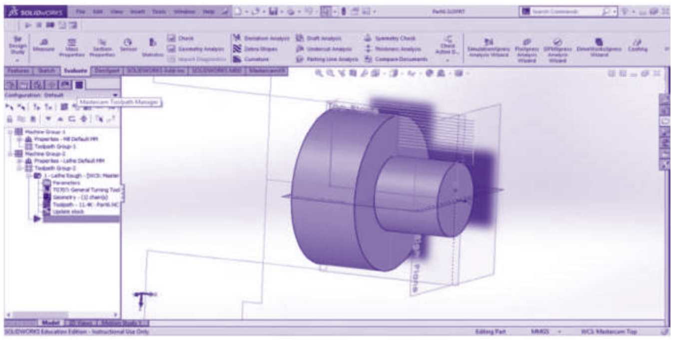

Fig. 3 Tool Path Simulation

Generate button is associated with following processes: Opening of Solidworks, generation of new part file, plane orientation selection, generation of basic profile of object based on input dimensions, and generationof part file. For machining purpose, standard CNC Jobber XL machine with Fanuc series controller is used. .

5. DISCUSSION

At this time, Engineer-To-Order manufacturing companies are under high pressure due to global competition, also facing new challenges due to increasing complexity of products and processes [19]. CC for manufacturing is beneficial to both customer and producer. Consumers to enjoy a variety of customized products also they can design and make their own products, while producer can save by creating on-demand, agile, green, and intelligent production solutions [20].

Proposed case study proves how cloud technology application is beneficial for manufacturing purpose.

Based on results got in this case study, those aspects are given in Table 1.

Table 1 Comparison between
'SM approach' and 'Traditional manufacturing approach'

Comparing Factor	SM approach	Traditional approach
Generation of CAD file	12-15 sec.	120-150 sec.
Tool path generation and checking of code	10-15 min.	15-20 min.
Remote access of work	Possible	Not possible
Flexibility with hardware constraints	Available	Not available
Data storage and processing	Easily available with Cloud factor	Requires extra Infrastructures
Pay as you go Option	Available	Not Available

Concerning last point mentioned in Table 1, Pay as you go mode option stands for paying money only as per usage of service. That service could be of any nature, infrastructure, platform or application. This is highly beneficial for aspect subtractive manufacturing industry. Manufacturers with limited monetary options or those who want to focus on their core competencies only can get benefit from this. They can get any service from service provider and can pay as per their usage only.

Azure Platform used for this case study costs around INR 40 per hour and only as per usage, which is cheaper than actual setup. Major limitation observed during this case study is that unlike Solidworks, Mastercam has not provided information regarding standard API. Hence tool path generation in Mastercam does simplify the process but creating standalone application for automating it is not possible yet, but in future it may. As technology is changing rapidly with huge research and development going on in this field, further development in this approach can be expected.

6. CONCLUSION AND FUTURE DIRECTIONS

The research work is taken so as to understand the basic concept of Smart technology application in manufacturing paradigm. Based on literature work done, SM is in its early stage of development. Even though good amount of research and development has been going on; its principle focus remained to additive manufacturing sector and seldom in other sectors like subtractive manufacturing. Also amount of research work happening in India in this area is far lesser as compared to other countries like China or USA. Hence its widespread application is not made available yet.

The main advantage of proposed system is that user can directly generate and transfer required files on virtual level itself with the help of web-based application. This solves the problem of interoperability of files up to some extent. Since in Cloud technology everything is treated as a service, even small manufactures or those who want to focus on core work only can use it by taking Cloud or Infrastructure as a service from third party service providers. The system architecture proposed here is generic in nature and can customize or modify.

There is tremendous future scope is available in this field, many of the SM platforms developed are still in embryonic stages. With using IoT technologies, framework proposed for Cloud based subtractive manufacturing system can be further improved. One may integrate new technologies like IoT along with CC to make it more automated. Its future variations and possible applications are huge.

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