Cloud Manufacturing: A New Manufacturing Paradigm for Production

Mundhe Nagnath Digambar[1] Dr. Kallurkar Shrikant Panditrao[2]
[1]Head of Dept. [2]Principal
[1]A.G. Patil Polytechnic Institute, Vijapur Road, Solapur [2]AET‟s Atharva College of Engineering, Malad (West) Mumbai

Abstract— Nowadays, Cloud Computing technology is providing a new way to do business by offering a scalable, flexible service over the internet. It creates new solution & opportunities to modern enterprises, including the manufacturing industries. [6] Cloud manufacturing service oriented customer centric, demand driven manufacturing model explored in both its possible future and current Statues. A unique strategic vision for field is documented, and the current state of technology is presented from both industry and academic viewpoints for benefits in manufacturing. Cloud manufacturing (CM) is an open and service-oriented platform that virtualizes distributed design, manufacturing, and assembling resources together in order to provide a seamless, stable, and high quality transaction of manufacturing procedures. Cloud-based manufacturing (CBM), also referred to as cloud manufacturing, is a form of decentralized and networked manufacturing, evolving from other relevant manufacturing paradigms such as web- and agent-based manufacturing. CBM in the research community revolves around several aspects such as definitions, key characteristics, computing architectures, programming models, file systems, operational processes, information and communication models, as well as new business models pertaining to the CBM paradigm. Presented paper highlights on the (1) Basic concept of cloud manufacturing with comprehensive definition of CM; (2) discuss research progress of cloud manufacturing with key characteristic with key manufacturing technologies (3) relate current research in design and manufacture with CM; and (4) identify key research issues with the CM model with case study.

Key words: Cloud Computing, Cloud Manufacturing, Cloud Manufacturing Model, Cloud Evolution

I. INTRODUCTION

The concept of Cloud manufacturing was initially proposed by the research group led by Prof. Bo Hu Li and Prof. Lin Zhang in China in 2009. [5]

A. Cloud Manufacturing are Defined in Many Ways

It is defined as a Computing and service-oriented manufacturing model developed from existing advanced manufacturing models and enterprise information technologies under the support of cloud computing, Internet of things (IoT), virtualization and service-oriented technologies, and advanced computing technologies. Or

Cloud manufacturing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable manufacturing resources that can be rapidly provisioned and released with minimal management effort or service provider interaction. Or

Cloud manufacturing is a new, networked and intelligent manufacturing model that is service-oriented, knowledge based, high performance, and energy efficient. Cloud manufacturing uses, state-of-the-art technologies such as Informatized manufacturing, Cloud Computing, Internet of Things, Semantic Web, and High-Performance computing are integrated in order to provide secure, reliable, and high quality on-demand services at low prices for those involved in the whole manufacturing lifecycle. The important part of cloud manufacturing is the cloud simulation technology based on the COSIM-CSP platform has primarily been applied in the design of a multidisciplinary virtual prototype for flight vehicle. This lays the foundation for further research into cloud manufacturing.

Cloud manufacturing is a new recent manufacturing paradigm developed from existing advanced manufacturing models and enterprise information technologies under the support of cloud computing, Internet of Things (IoT), virtualization and service-oriented technologies, and advanced computing technologies. It transforms manufacturing resources and manufacturing capabilities into manufacturing services, which can be managed and operated in an intelligent and unified way to enable the full sharing and circulating of manufacturing resources and manufacturing capabilities. Cloud manufacturing can provide safe and reliable, high quality, cheap and on-demand manufacturing services for the whole lifecycle of manufacturing. The concept of manufacturing here refers to big manufacturing that includes the whole lifecycle of a product. Manufacturing is a type of parallel, networked, and distributed system consisting of a integrated and inter-connected virtualized service pool of manufacturing resources and capabilities as well as capabilities of intelligent management and on-demand use of services to provide solutions for all kinds of users involved in the whole lifecycle of manufacturing.

II. STAGES OF EVOLUTION OF MANUFACTURING PARADIGMS

Manufacturing industries are going through a period of significant change and uncertainty, with opportunities and challenges to future manufacturing competitiveness driven by a range of factors including: the increasingly complex and globalised nature of industrial systems; the dramatic reduction in manufacturing timescales and acceleration of technological innovation; and the growing need for sustainable, resource-efficient production. Due to which it undergoes different stages of evolution as shown in Fig.1.

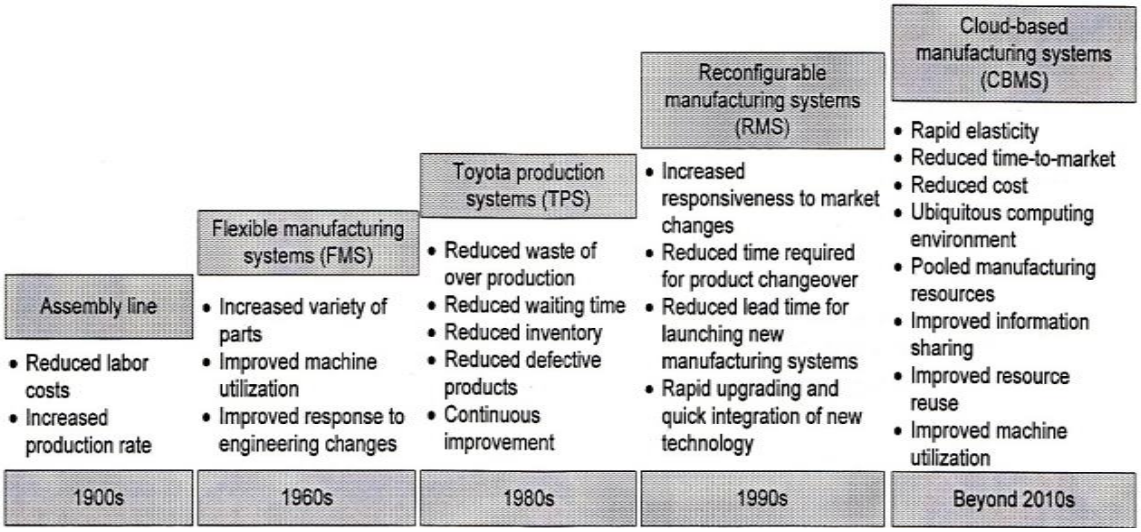

Fig. 1: Evolution of manufacturing paradigms [1]

The evolution of manufacturing paradigms from the assembly line, to flexible manufacturing systems (FMS), to Toyota production systems (TPS), to reconfigurable manufacturing systems (RMS), and to CBM. The, Henry Ford manufactured the first assembly line, in which interchangeable parts can be added to a product in a sequential manner to produce finished products more efficiently and cost-effectively. Then for new product variants, FMS were developed, allowing for high functional flexibility with variation for parts and assemblies but it costly to implement. Then TPS knows as just-in-time production systems are devised for reducing manufacturing costs. It includes different principles like eliminating waste, in terms of waiting time, inventory, and defective products. Then reconfigurable manufacturing systems (RMS) is introduced for ordering to quickly adjust production capacity and for functionality within a part family in response to sudden changes in market or in regulatory requirements with taking the designed advantage of outset for rapid change in structure, as well as in hardware and software components. The RMS include key feature as integrablity, customization, diagnosablityand convertibility. The above manufacturing systems fall into the category of centralized manufacturing with significant changes in machine tools, manufacturing plant layouts, and business models. But with the development of the Internet, distributed manufacturing systems have been increasingly adopted in industry with two major approaches for distributed manufacturing are first web based system and second agent-based manufacturing systems. First web-based systems use the client-server architecture with the Internet to provide a light-weight platform for geographically dispersed teams to access and share manufacturing-related information via a web browser. Likewise, with the increasing structural and functional complexity of web-based manufacturing systems, agent-based manufacturing systems aim at improving computational performance and communication using agents. Second agent- based manufacturing systems consist of agents (e.g., manufacturing cells, machine tools, and robots) exhibiting autonomous and intelligent behavior such as searching, reasoning, and learning. An agent is an independent problem solver that is capable of making decisions by interacting with other agents and its environment.

III. COMPONENTS OF CLOUD MANUFACTURING

Informatized manufacturing - This platform includes, integration framework, integration platform and computer-aided collaborative work platform multidisciplinary virtual prototype, Web design, Intelligent design, Project Management, Quality management, complex system modeling and simulation technology.

IV. TYPES OF CLOUD MANUFACTURING MODELS

Cloud Manufacturing can be divided into two categories. The first category concerns with deploying manufacturing software on the Cloud, i.e. a **"**manufacturing version**"** of CComputing. CAx software can be supplied as a service on the Manufacturing Cloud (MCloud). The second category has a broader scope, cutting across production, management, design and engineering abilities in a manufacturing business. Unlike with computing and data storage, manufacturing involves physical equipment, monitors, and materials and so on. In this kind of Cloud Manufacturing system, both material and non-material facilities are implemented on the Manufacturing Cloud to support the whole supply chain. Costly resources are shared on the network. This means that the utilization rate of rarely used equipment rises and the cost of expensive equipment is reduced. According to the concept of Cloud technology, there will not be direct interaction between Cloud Users and Service Providers. The Cloud User should neither manage nor control the infrastructure and manufacturing applications. As a matter of fact, the former can be considered part of the latter. In Cloud manufacturing system, various manufacturing resources and abilities can be intelligently sensed and connected into wider Internet, and automatically managed and controlled using IoT technologies (e.g., RFID, wired

and wireless sensor network, embedded system).Then manufacturing resources and abilities are virtualized and encapsulated into different manufacturing cloud services (MCSs), that can be accessed, invoked, and deployed based on knowledge by using virtualization technologies, service-oriented technologies, and cloud computing technologies.

V. TECHNOLOGICAL BASIS OF CLOUD MANUFACTURING

The Cloud computing is a new recent service-oriented computing technology that has emerged in recent years. In cloud computing, mass, highly virtualized computing resources are organized using a cloud computing platform, and a large-scale resource pool is formed to provide unified services. Individuals and enterprises can access computing resources on-demand through heterogeneous, self-governing Internet services. Professional IT and networking companies third-party service operators—build computing repositories and service centers in which "clouds" of virtualized resources are stored and offered as services. When cloud computing resources are replaced with cloud manufacturing resources, cloud computing operation models may offer new ways of achieving networked and informatized manufacturing systems with high efficiency, service-oriented and low energy consumption. The manufacturing resources include machines, processing centers, and computing equipment used during the whole manufacturing lifecycle. With the use of data, software, and professional knowledge used during production. With the use of cloud computing technology, semantic Web, embedded system technology, Internet of Things, and high-performance computing may be used for virtualization, optimization and scheduling, and collaboration of manufacturing resources.

VI. RESEARCH PROGRESS OF CLOUD MANUFACTURING

The cloud manufacturing is a service-oriented, knowledge-based smart manufacturing system with high efficiency and low energy consumption. In a cloud manufacturing system, state-of-the-art technologies such as informatized manufacturing technology, cloud computing, Internet of Things, semantic Web, high-performance computing, and cloud manufacturing are integrated. By extending and shifting existing manufacturing and service systems manufacturing resources and capabilities are virtualized and oriented towards service provision. In cloud manufacturing, pervasive and efficient sharing and coordination of resources and capabilities can be achieved by their unified and centralized intelligent management and operation. Cloud manufacturing provides the whole manufacturing lifecycle with secure, reliable, high quality, and on-demand services at low prices through networked system. The manufacturing lifecycle includes pre-manufacturing (argumentation, design, production and sale), manufacturing (product usage, management and maintenance), and post-manufacturing (dismantling, scrap, and recycling).

VII. OPERATION MODEL AND KEY TECHNOLOGIES OF CLOUD MANUFACTURING

The Cloud manufacturing system consists of manufacturing resources and capabilities, manufacturing cloud, and the whole manufacturing lifecycle applications. It also includes core support (knowledge), two processes (import and export), and three user types—resource providers, cloud operators and resource users. Fig.2 illustrates the operational principle of cloud manufacturing. Manufacturing resources and capabilities are encapsulated as cloud services. This process is called manufacturing resource "import". Depending on different manufacturing requirements, cloud services are combined to form a manufacturing cloud. The cloud provides the whole manufacturing lifecycle applications with diverse services. This process is called "export". Knowledge plays a central role in supporting the entire operating process of cloud manufacturing. It is necessary for intelligent embedding and virtualized encapsulation during import; it assists functions such as intelligent search of cloud services; and it facilitates smart cooperation of cloud services over the whole manufacturing lifecycle. In a cloud manufacturing system, knowledge-based integration across the whole lifecycle is possible.

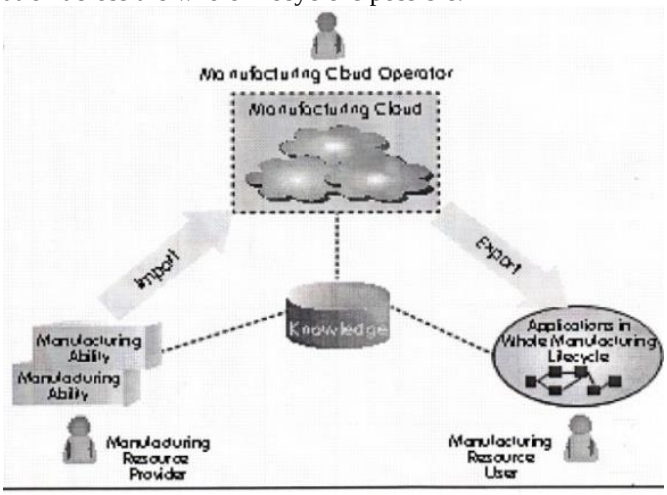

Fig. 2: Operational principal of cloud manufacturing [3]

A cloud manufacturing application model is shown in Fig.3 Users send specific requests to the cloud manufacturing platform. This platform is responsible for the management, operation, and maintenance of manufacturing clouds and service tasks such as import and export. It analyzes and divides service requests, and automatically searches the cloud for best-matched services. By a series of processes including scheduling, optimization and combination, a solution is generated and then sent

back to the client. A user does not need to communicate directly with every service node, nor find the specific locations and situations of service nodes. Through the cloud manufacturing platform, manufacturing resources and capabilities can be used in the same way as water, gas, electricity, etc. Cloud manufacturing architecture has five layers: physical layer, virtualized resource layer, service layer, application layer, and user layer.

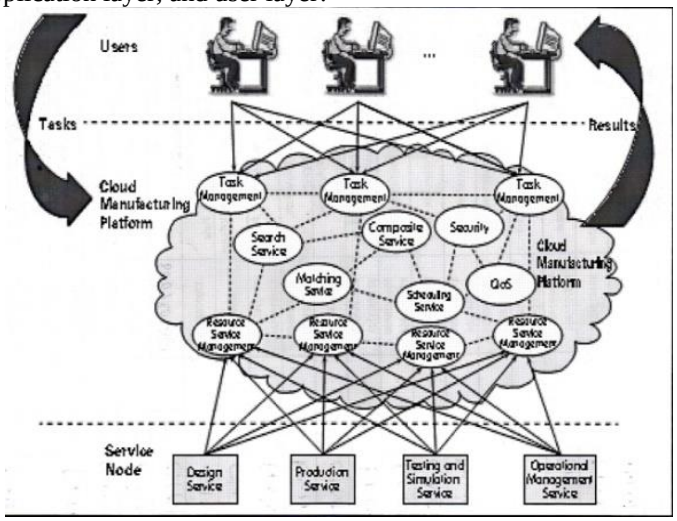

Fig. 3: Application model of cloud manufacturing [3]

VIII. CASE STUDY FOR CLOSED-LOOP EVALUATION WITH A PROTOTYPE MANUFACTURING CLOUD USED FOR RAMP

The system is develop for workforce training pipeline for mission critical operations including advanced manufacturing and smart power grid and developed by Charlotte to establish RAMP (Remote Automated Management Program) system which includes all software and hardware resources to be expanded to a manufacturing cloud. The architecture used for RAMP and he proposed manufacturing cloud are illustrated in Fig.4.The system uses NetLab+ manufacturing cloud for managing the front side. It allows remote users to login from any position. NetLab+ will create a virtual machine for every user, through which the user could reserve hardware resources. And he proposed security enforcement mechanisms will be implemented and integrated into the cloud administration software for required result. The newly implemented component will be in charge of reservation of resources, detection of side channel attacks, and aggregation and management of the sensing data. The cloud administration software will be real equipments located in two different buildings. Due to this the platform allows to connect any equipment with an Ethernet interface to the system from one place to another place. The Clouds include components like programmable logic controller (PLC), Siemens controllers, hydraulic trainer, and robotic arms, as shown in Fig.4.

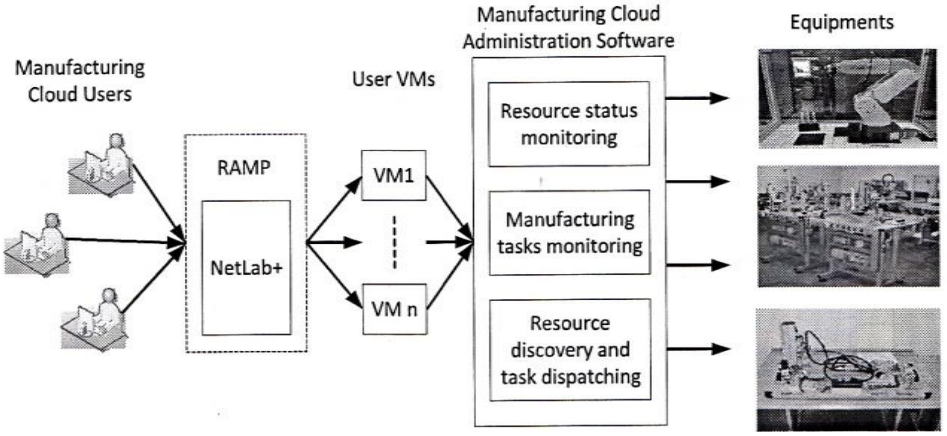

Fig. 4: Platform for RAMP System [2]

IX. CONCLUSION

The Cloud manufacturing is a recent developed new model to manufacturing Informatization and has huge development potential in manufacturing. The application of cloud manufacturing will be a gradual, long-term process. For the implementation of cloud manufacturing, companies or manufacturing unit should have good resource on internal integration of information and processes. Therefore, there is a relative high entrance standard to implement cloud manufacturing for the majority of manufacturing unit. The future development of cloud manufacturing will face many challenges in key technologies. But the integration technologies of cloud computing, Internet of things, semantic web high performance computing, and embedded systems, and several important technical issues must be solved such as knowledge based resource clouding, cloud management engines, collaboration between cloud manufacturing applications, and visualization and user interface in cloud environment. By using this concept of cloud manufacturing the manufacturing unit can take the advantage for production. The cloud manufacturing gives benefits for long term with implementation to take the advantage of the technology for production.

ACKNOWLEDGMENT

I am thankful to Dr. Kallurkar S.P.for giving me opportunity for presenting this paper under his guidance.

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