Mobile Manufacturing: Framework, Research Status and Trends

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Abstract. In this paper, the current situation of manufacturing industry is analyzed, and the concept and system structure of mobile manufacturing are derived from the actual needs and theoretical basis of manufacturing enterprises. This paper discusses the framework of mobile manufacturing cell, summarizes the current research status of mobile manufacturing at home and abroad, and then gives the research trends and challenges of mobile manufacturing cell system. Mobile Manufacturing Cell System will solve the large-scale individualized user needs in the future manufacturing industry, as well as the complex sharing, collaboration and interaction among multi-participants. It will also solve the problem of resource optimal allocation in collaborative manufacturing in different places, and improve the flexibility and responsiveness of manufacturing enterprises.

1. Introduction

With a series of major development strategies such as “Big Data”, “Internet of Things”, “Cloud Manufacturing”, “Industry 4.0” and “Made in China 2025”, the Internet is closely linked with manufacturing. The scale of online orders is characterized by multiple varieties and small batches. In order to meet the increasingly personalized needs of customers, it is urgent to change and innovate the manufacturing mode. How to efficiently and reasonably reorganize and dispatch resources in the environment of intelligent manufacturing and cloud intelligent manufacturing to meet the personalized needs of customers and to complete processing tasks is currently a frontier research topic at home and abroad.

2. The Real Demand of Mobile Manufacturing

2.1 Information Technology Driven Demand

Information technology entered the manufacturing industry because of the demand of the manufacturing industry and also promoted the development of the manufacturing industry. Information technology is not simply applied. Instead, a series of new concepts and technologies such as the Internet of Things, the Internet of Services, industrial wireless, industrial Internet and Internet manufacturing have been developed. And promote that development and application of a series of intelligent equipment. Intelligent devices and technologies, such as Internet of Things, Sensor Networks, Industrial Wireless, 3D Printing, Robots and so on, as well as information technologies such as artificial intelligence, cloud computing and big data, have emerged in large numbers. It makes the advanced manufacturing technology driven by information become the key to release the competitiveness of manufacturing industry in the future. Since then, manufacturing industry has entered the era of Intelligent Manufacturing Based on ubiquitous information.

2.2 Policy needs

The promulgation of Made-in-China 2025 clearly points out that “to form a new driving force for economic growth and to shape a new international competitive advantage, the focus is on

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manufacturing, the difficulty is in manufacturing, and the way out is also in manufacturing [1]. Therefore, strengthening manufacturing industry should be the focus of China's future macro-policy and industrial policy. With the rise of mass customization concept and the popularization of digital and information technology represented by 3D printing, technology and business model innovation has come. The entry threshold of manufacturing industry will be lowered to a minimum, and individuals who do not have factories and production equipment can easily participate in the manufacturing industry. The lowering of the threshold for manufacturing industry entry also means that some unexpected enterprises or individuals will participate in the manufacturing industry, thus bringing revolutionary changes to the business model.

Interconnected manufacturing can quickly respond to market changes and rapidly allocate manufacturing resources through rapid reorganization and dynamic coordination of manufacturing enterprises. At the same time of improving the quality of products, reduce the time needed for the products to be put on the market and increase the market share. At the same time, it can also share the costs related to infrastructure construction and equipment investment and reduce operational risks.

With the development of mass customization and network collaboration, manufacturing enterprises also need to receive personalized customization data from many consumers on the Internet in real time. And through the network to coordinate the allocation of resources from all parties, organize production and manage more data of all kinds. The potential value of big data is being recognized by traditional industries. Through the innovation and development of technology, as well as the comprehensive perception, collection, analysis and sharing of data. For business managers and business participants, it presents a new way of thinking about manufacturing value chain.

2.3 External demand

At present, the world is witnessing a new round of technological and industrial revolution, especially in manufacturing. After the economic crisis in 2008, the past “sunset industry” has received renewed attention. Countries all over the world are scrambling to adjust their strategies, conform to the changes of the times, and carry out a forward-looking layout of advanced manufacturing industries.

2.4. Market demand: needs of personalized customization manufacturing

Economic development and social progress make people not only satisfied with the availability of products. It also requires individualization, high quality and continuous renovation. Driven by this demand, the core task of manufacturing industry has changed from the traditional expansion to how to meet the personalized needs of users, how to provide personalized experience of the whole process for users, and how to provide better service for users. Accordingly, manufacturing enterprises are facing pressure to shorten delivery time, improve product quality, reduce costs and improve services, and need to respond quickly to the changing market.

3. The foundation and concept of mobile manufacturing

3.1 Theoretical basis

Generally speaking, the development of manufacturing cell includes traditional manufacturing cell, dynamic cell, virtual manufacturing cell and reconfigurable manufacturing cell. Therefore, from the perspective of manufacturing cell development, virtual manufacturing cell and reconfigurable manufacturing cell are advanced forms of manufacturing cell development, which lay a theoretical foundation for mobile manufacturing. In addition, the research of network manufacturing, such as community manufacturing and cloud intelligent manufacturing, provides technology and theoretical basis for the emergence of mobile manufacturing.

Virtual Manufacturing Cell (VMC) is proposed on the basis of expanding traditional manufacturing cell. It chooses the necessary equipment from the alternative equipment resources

according to the production task and forms the logical production unit. The equipment and resources have not changed physically. Rather, logically and conceptually, virtual entities are interconnected, connected through a logistics system, without changing the physical layout of existing systems. Compared to physical manufacturing units, VMCs enable flexible allocation of manufacturing tasks and avoid the cost of reconfiguring physical manufacturing resources due to manufacturing task changes. Thereby increasing the utilization rate of manufacturing resources and effectively reducing manufacturing costs [2].

Reconfigurable manufacturing unit. Reconfigurable manufacturing units are an important part of a reconfigurable manufacturing system. Developed countries first developed the basic and applied research of reconfigurable manufacturing systems from the 1990s. A reconfigurable manufacturing unit is a collection of manufacturing resources that are aggregated according to a certain stage of production tasks. Generally, such aggregation is a rapid reconstruction in production organization and management. The location of the devices physically constituting the manufacturing unit does not change, but logically the devices are combined into different manufacturing units according to the production organization and management needs. Realize the dynamic optimal allocation of manufacturing resources and make timely response to changing tasks. In a fixed manufacturing unit, manufacturing resources (or equipment) are combined according to the needs of specific production tasks to obtain the optimal benefits. At the same time, this also limits that the fixed manufacturing unit cannot adapt to the changes of production tasks in time. When constructing a reconfigurable manufacturing unit, the physical location of the equipment is not emphasized, but the manufacturing resources are organized logically according to the characteristics and needs of the production tasks. In order to meet the comprehensive requirements of production tasks in terms of cost, delivery time and quality, the dynamic combination optimization of manufacturing resources for processing tasks is realized [3].

Reconfigurable manufacturing cell is an important component of reconfigurable manufacturing system, so reconfigurable manufacturing cell has stronger reconfigurability, agility and flexibility than other manufacturing cells.

Networked manufacturing. In the 21st century, the development of manufacturing depends more on the promotion of high-tech applications. The networked manufacturing mode represented by application service provider (ASP), manufacturing grid (MGRID), agile manufacturing, Global Manufacturing and Cloud Manufacturing. It has become an advanced manufacturing mode implemented by manufacturing enterprises to meet the challenges of knowledge economy and manufacturing globalization, with the main objectives of responding to market demand quickly and improving the competitiveness of enterprises (enterprise groups). Networked manufacturing combines advanced network technologies, information technologies, and manufacturing technologies to build a network-based manufacturing system that meets the specific needs of the enterprise. With the support of the system, it breaks through the constraints of the space region on the scope and mode of production and operation of the enterprise, and carries out enterprise business activities (such as product design, manufacturing, sales, procurement, management, etc.) covering all or part of the whole life cycle of the product. To achieve synergy between enterprises and the sharing and integration of various social resources, to provide the products and services required by the market with high efficiency, high quality and low cost [4].

Community manufacturing. The term “social manufacturing” (referred to as SocialM) was first proposed by the Economist magazine in the 2012 special report “The Third Industrial Revolution”. It means that an online community that provides 3D printing and other productive services enables everyone to participate in the production of the product [7]. The current scholars involved in SocialM related research are: Chinese Academy of Sciences Wang Feiyue, Shang, Xiong, etc., Finland Aalto University Mohajeri, South Korea Inha University Park and Kim, Xi'an Jiaotong University Jiang Pingyu team.

Wang Feiyue and others translated social manufacturing into social manufacturing. It is pointed out that driven by 3D printing technology and social computing, social needs and social production capacity will be effectively combined in real time to achieve “from mind to product” [5]. Shang et

al. studied how the consumer participates in the production process of apparel products through the network, intelligent interactive terminals, 3D printers, etc. under the SocialM model [8]. Xiong et al. proposed the framework of the SocialM model and pointed out that everyone's participation in product production is its main feature [9]. Mohajeri and others discussed the difference between SocialM and traditional manufacturing mode in value creation mode from the perspective of value chain model [10]. Park and Kim discussed the technical basis of SocialM, such as Social media, PLM, crowdsourcing, R&D, etc. [11]. Jiang Pingyu and others have been discussing the SocialM model since 2012, and have carried out systematic research in terms of concept discrimination, organizational structure, configuration and operation mechanism, and key technologies [12-13].

In addition, the Institute for the Future, IFTF) released a SocialM research plan to explore the profound impact of SocialM on future development [14]. The University of Aalto in Finland has carried out a research project on SocialM and Intelligent Systems since 2015 [15]. The Global Cleaner Production & Sustainable Consumption International Conference, held in Spain from November 1-4, 2015, set up a special discussion on “Social Manufacturing and Sustainability” [16]. In 2015, the project “A New Socialized Manufacturing Model and Network Configuration Mechanism (No. 71571142)” applied by Jiang Pingyu team was funded by the National Natural Science Foundation of China. SocialM is gradually becoming one of the hotspots of scholars at home and abroad.

Socialized manufacturing can be defined as: a new networked manufacturing model based on decentralized/socialized resources self-organizing configuration, social media-driven interconnection, large-scale collaboration and sharing. Through self-organizing configuration, scattered social resources gather to form various distributed communities. Under the mechanism of interest coordination and business social interaction, decentralized manufacturing services are conducted with the community as the main body. Communitarian manufacturing relies on new information technologies such as cloud computing/service computing and big data analysis integrated in social media to deal with complex collaborative interaction problems such as resource service matching, business process optimization, service process monitoring and so on in social network environment. In addition, information sharing, service planning and control are carried out upstream and downstream of the product life cycle supply chain. The goal of communitarian manufacturing mode is that users do not need to invest in any equipment, only put forward personalized product requirements, and can complete product life cycle activities through collaborative interaction with various resources and communities [17-19].

At present, the research on communitarian manufacturing mode at home and abroad is still in the initial stage, and some problems still need further research. The popularization of mobile Internet enables more social resources and users to participate in communitarian manufacturing and realize extensive, real-time and transparent collaborative interaction through intelligent mobile terminals. (1) How to realize comprehensive and in-depth interconnection of manufacturing from three dimensions of information space, physical space and social space. (2) How to analyze the dynamic evolution mechanism of socialized manufacturing networks, and use big data analysis methods to analyze and predict production disturbances and market trends, and how to personalize manufacturing service portfolios and recommendations based on data analysis results. (3) Complex production planning and operational management issues for equipment manufacturing enterprises when dealing with large-scale personalized user requirements for socialized manufacturing. Consider the issue of production design and manufacturing decision-making when participating in multi-agent collaboration.

3.2 Technical foundation

Information-driven advanced manufacturing technology is the key to unlocking the competitiveness of future manufacturing. Since then, manufacturing has entered an era of intelligent manufacturing based on ubiquitous information. In particular, the research and application of cloud manufacturing technology has further promoted the development of the manufacturing industry in

the direction of “networking, intelligence, and service”, thereby raising the degree of manufacturing informationization to a new level. Especially the in-depth application of artificial intelligence, big data, digital twins, cloud computing and other information technologies in manufacturing product design, production mode, organization system, management mode and other aspects. Realizing the holographic intelligent manufacturing system from product design, virtual simulation to manufacturing execution will form the technical system of mobile manufacturing.

3.3 Environmental basis

The importance of manufacturing environment and conditions has become more and more prominent, becoming a symbol of the progress of manufacturing technology, which is crucial to the development of manufacturing industry. The world is in an era of great transformation from an industrial economy to a digital economy. With the rapid development of information technology and the in-depth development of the integration of the two. In the development of intelligent manufacturing, the intelligent manufacturing environment has an important impact on the development of manufacturing industry, laying an environmental foundation for the emergence of mobile manufacturing.

3.4 Limitations and the concept of mobile manufacturing

At present, the theory and practice of customization to meet the needs of customers are still at the primary stage, and most of them are concentrated in clothing, furniture, automobiles and other industries. Due to the complexity and uncertainty of personalized customization production system, its production mode is often studied by means of “internet plus”, “cloud manufacturing”, “intelligent manufacturing” and “community manufacturing”. However, there is still less research on mass customization. Therefore, the existing research can not meet the market demand of mass customization, and can not adapt to the impact and demand brought by Yunzhi Manufacturing. In order to solve this practical problem, this paper proposes the concepts of mobile manufacturing and mobile manufacturing system.

Mobile manufacturing can be defined as: mobile manufacturing is a dynamic core manufacturing mode of enterprise manufacturing, which is composed of mobile manufacturing units. It can be a collection of manufacturing resources in a factory, workshop or workshop. It is an important way to optimize the allocation of resources in collaborative manufacturing in different places. It is also a unit entity with certain processing capacity. Mainly includes: intermediate task allocation, production scheduling, material scheduling, resource allocation, path selection, task allocation and other functions. At the same time, it can accomplish the manufacturing tasks between virtual enterprises. These small, autonomous core manufacturing units can be shipped to countries and regions to further develop customized content with local labor and resources and cloud resources. Lower labor and other costs can be utilized.

Mobile manufacturing system definition: With mobile manufacturing as the core, through the network platform and information technology, through the self-organizing configuration, the scattered social resources are gathered to form various distributed communities. These communities form a mobile manufacturing system by conducting decentralized manufacturing services under the interests of coordination and business social mechanisms. With the support of the mobile manufacturing system, we will break through the constraints of the space area on the scope and methods of production and operation of the enterprise, and carry out enterprise business activities (such as product design, manufacturing, sales, procurement, management, etc.) covering all or part of the product life cycle. To achieve network collaboration between enterprises and the sharing and integration of various social resources, to provide the products and services required by the market with high efficiency, high quality and low cost.

3.5 The formation of mobile manufacturing

The essence of manufacturing cell formation is the optimal selection and combination of manufacturing resources. In terms of type, mobile manufacturing can be either physical manufacturing unit or virtual manufacturing unit. Structurally speaking, mobile manufacturing

system is a multi-level networked manufacturing system with heterogeneous characteristics.

There are two main ways to form and form mobile manufacturing systems:

(1)Manufacturing system with key manufacturing units as the core and remote resources and cloud resources as the auxiliary.

The manufacturing unit itself is the core part of the whole manufacturing system. According to the requirements of personalized customization in different places, the core manufacturing unit builds a manufacturing system in different places for manufacturing with the help of cloud intelligence manufacturing platform and resources or multiple manufacturing communities. (not moving the entire manufacturing system)

For a country or region, it can provide customized products or services, use its own key technologies and key equipment to control, and the rest of the resources use local resources and cloud resources for manufacturing.

(2)A complete manufacturing system consisting of independent core manufacturing units.

The manufacturing unit itself is a complete manufacturing system, such as a manufacturing unit responsible for a core component, component, product family or personalized key parts, which moves to other places to meet the customized production needs.

Regardless of the way of organization, the mobile manufacturing system is aimed at mass customization production, which decomposes the production process into value-oriented manufacturing units. By moving the core manufacturing unit to a different location, online trading of manufacturing capabilities can be achieved through a cloud platform or an industrial Internet platform. The use of social manufacturing resources to reconstitute a new manufacturing system that can meet the individual needs of customers, and the new manufacturing system is automatically disbanded after the manufacturing task is completed.

4. Research Status at Home and Abroad

The concept of Mobile Manufacturing Cell (MMC) was first put forward in March 2017 in the White Paper Shaping the Future of Manufacturing: Four Contrasting Perspectives in 2030 jointly issued by the World Economic Forum, the World Economic Forum (WEF) and the consulting firm Korni. The report points out that another major evolution in manufacturing in the future is the arrival of mobile urban manufacturing units. These small, self-manufacturing units are shipped to various countries to further develop customized content with local labor. This is different from large-scale suburban factories, and can use the lower labor and other costs to paint a distinctive future for industrial manufacturing [1].

Academician Wang Zhu, from the Shenyang Institute of Automation, Chinese Academy of Sciences, proposed a new model for intelligent manufacturing space. He believes that the trend of large-scale personalized custom production and service-oriented manufacturing has led to the development of the manufacturing model from the current centralized to the distributed direction. The production chain will be flexibly organized by more specialized units to form a distributed manufacturing model [19]. Furthermore, it is pointed out that the intelligent manufacturing space will break the traditional physical area restrictions, and the continuous emergence of a large number of information technologies will promote the rapid development of distributed manufacturing capabilities in order to meet the urgent needs of mass customization of products. The production organization system will undergo rapid changes, making the manufacturing industry itself form a new manufacturing mode and information environment, and further promoting the change of production mode. This is a preliminary exploration of mobile city manufacturing units in China.

Therefore, the research on mobile manufacturing at home and abroad is still in its infancy. The concept of mobile manufacturing has not been clearly put forward and clearly defined, and no relevant theoretical system has been formed. Therefore, it is under the general trend of mass customized production and rapid development of information technology. As a new manufacturing mode to meet the needs of the globalization of manufacturing industry, the research on related issues is an important direction that we need to further study in the future.

5. Research Trend of Mobile Manufacturing

At present, the research on mobile manufacturing mode at home and abroad is still in the initial stage. After analyzing the current research status, this paper lists three research trends of mobile manufacturing mode.

Looking at the development process of the entire manufacturing industry, the research on manufacturing cells and cell manufacturing systems is an important part of the technological development of manufacturing industry and has been paid close attention to by people. With the rapid development of information technology and the in-depth development of integration of informationization and industrialization, in the era of Intelligent Manufacturing Based on ubiquitous information under the demand of mass customization, mobile manufacturing research judges and predicts the future change and development of manufacturing information environment and mode. It is necessary for China to study the optimization of manufacturing resources, site selection, scheduling and operation of mobile manufacturing, and to construct the theoretical framework and application system of mobile manufacturing.

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