Current Research and Prospect of Cloud Application in Manufacturing Equipment Design

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Abstract. Equipment manufacturing industry leads the development of manufacturing industry, which is the pillar industry of the country. Its design process is long-term and complex. This paper summarizes the characteristics of equipment manufacturing industry and its design, summarizes and analyses the mainstream design methods in recent years, describes the key technologies, and preliminarily discusses the development trend of cloud design in equipment manufacturing industry.

1. Introduction
Product design of manufacturing equipment is a long-term and complex process. Lack of R&D funds, lack of technical talents and outdated technology are the common problems of many equipment manufacturing enterprises. Integrating internal and external design resources and strengthening the synergistic cooperation ability of industrial chain, reducing design costs and enhancing comprehensive strength have become the key tasks of equipment manufacturing enterprises [1]. With the leapfrog breakthrough of advanced network technology, information sharing technology, cloud computing and other high-tech [2], cloud manufacturing was born. With the advanced concept of cloud manufacturing or the integration of networked collaborative design, scholars at home and abroad have put forward their understanding of cloud design.

2. Research Status of Manufacturing Equipment Design

2.1. Characteristics of Manufacturing Equipment Design
Manufacturing equipment is the core equipment in the manufacturing industry, with complex structure, large amount of product data, long development time, large size or ultra-fine precision, large load or super sensitive to the external environment, and complex working environment [3], the entire design process needs a large amount of resources including information, design tools, equipment, venues and professional designers [4]. Taken together, the current design issues are mainly reflected in the following points:

1) Design ability is weak, product design depends on employee experience, unable to meet the needs of lean, personalized and lightweight equipment manufacturing market [5];

2) Collaborative and concurrent design capabilities are low. Enterprises can’t easily obtain 3D CAD drawings of non-self-made parts. Different suppliers adopt different design software, and the maintenance and management of self-built standard parts database are not ideal;

3) The design resources of manufacturing equipment in domestic universities are idle, which can’t effectively support the equipment manufacturing industry;
4) Lack of a standardized information platform to realize resource sharing and complementary of advantages.

2.2. Research Status of Networked Design of Manufacturing Equipment
At present, networked design patterns include intelligent optimization-based design methods, reasoning-based design methods, object-oriented design methods, concurrent design methods, collaborative design methods and virtual design methods. Designers can construct dynamic entities in virtual environment through three-dimensional simulation and virtual reality technology in the whole life cycle of products, design around the same product remotely, collaboratively and concurrently, realize resource sharing, and complete product development [6, 7]. In the 1980s, the research on network design began. For example, R. Galli realized the product design of remote three-dimensional virtual environment through the Internet, St. Gallen realized the synchronization and compatibility between Class DAC, Kooperatives, Auto CAD, Netmeeting and other systems.

Due to the continuous expansion of data volume and scale of enterprise information system in equipment manufacturing industry, there are several problems in networked design as follows:
1) The network design resource sharing scope is small, lacks visibility and expansibility, lacks the overall unified resource control management, and the stable operation of the system highly depends on the reliability of the resource itself;
2) Lack of unified integration standards and systems, and lack of a sound security system;
3) Business model is not clear and limited to internal use.

3. Research Status of Cloud Design
3.1. Cloud Design and Cloud Manufacturing
Academician Li Bohu and others defined cloud manufacturing separately [8, 9, 10]. They considered cloud manufacturing as a new service-oriented networked manufacturing mode. They introduced cloud computing into the manufacturing field, based on "manufacturing as a service", covering "design as a service", "experiment as a service" and "simulation as a service" and other service modes. Among them, "Design as Service" refers to the use of cloud service platform to achieve cross-domain and cross-regional product design. The core of network design is parallel, collaborative and remote design. The two are interconnected. Cloud design is a new design pattern developed on this basis.

Domestic scholars have put forward their own opinions on "cloud design" and applied them in practice, mainly from the aspects of conceptual architecture, operation mode and implementation mode of design services: Lu Jixiang et al. put forward that the so-called cloud design should be oriented to cloud manufacturing, integrating modern design, information manufacturing, cloud computing, Internet of Things, intelligent, green and emotional technologies into one product service design [11]; Zheng Mei et al. proposed a resource virtualization method based on Web semantics in view of the characteristics of design resources in cloud design environment [12]; Based on the existing research results of networked design, Wei Yibin et al. combined the technology and thought of cloud computing, designed and implemented a prototype system of cloud design platform based on bus. Foreign countries have also carried out relevant research, such as the US manufacturing service platform MFG.COM, which virtualizes the manufacturing capability so that it can be traded online.

3.2. Infrastructure of Cloud Design Platform
In the cloud design environment, there are many characteristics of design resources, such as distribution, heterogeneity, diversity and dynamics. Based on cloud computing, combined with cloud manufacturing and networked collaborative design, a cloud design platform system for equipment manufacturing industry is proposed. From bottom to top, it is physical resource layer, virtual resource layer, operation control layer and terminal interface layer, as shown in Figure 1.
1) Physical Resource Layer: This layer is composed of computing resources, application software, prototyping equipment and knowledge resources involved in the process of product design. It is the physical basis for the whole cloud platform to provide design cloud services;

2) Virtual resource layer: Transforming physical resources into logical resources to realize the virtualization of design resources;

3) Operation Control Layer: This layer includes task management, intelligent search and matching, resource scheduling and resource monitoring modules. It is a connecting layer, that is, to receive the requests and output results of users on the upper level, to coordinate and organize the needs and design resources of customers on the lower level;

4) Terminal Interface Layer: This layer is a platform-oriented user-human-computer interaction interface, presented in the form of design cloud desktop. It provides services such as design requirement input, resource simulation and design result output for customers, resource description, resource registration and resource publication for resource providers, task management, resource scheduling and resource monitoring interface for administrators.

For the three types of users (customers, resource providers and managers) of cloud platform, the operation mechanism of cloud platform is as follows:

1) Customer access design cloud desktop: making use of all kinds of services provided by cloud desktop to put forward design requirements. Task management module will process requirements into tasks that need to be executed. Through intelligent search matching and resource scheduling module, appropriate virtual resources are allocated to tasks;

2) Resource providers access design cloud desktop: describing resources according to the resource description template provided by the cloud desktop, registering resources in the cloud platform, and then publishing resource-related information and files on the Internet. The operation control layer accesses the resources to the cloud platform and deploys them to the cloud resource pool according to the information and files provided;

Figure 1. Cloud Platform Structure.
3. Administrators access design cloud desktop: using the task management, resource scheduling and resource monitoring interface provided by the cloud desktop, managing, monitoring and maintaining the design tasks, virtual resources and related hardware and software systems that support the normal operation of the platform.

3.3. Collaborative Design in Cloud Design
Collaborative design comes from CSCW (Computer Supported Cooperation Work). It involves artificial intelligence, cluster technology, advanced manufacturing, distributed heterogeneous processing and key communication network technology [13]. It has the characteristics of interaction, collaborative conflict, scalability, transparency and security. At present, according to the method of product design, collaborative design can be divided into component-based collaborative design, Agent-based collaborative design and network-based collaborative design [14, 15, 16]. According to the way of collaboration, it can be divided into synchronous collaborative design and asynchronous collaborative design. According to the structure, it can be divided into B/S-based collaborative design, C/S-based collaborative design and hybrid-based collaborative design. For a long time, collaborative design has been regarded as the inevitable development of CAD technology. At present, the research on collaborative design mainly focuses on the fourth stage of CAD. For example, Rene C. Malak et al. believe that virtual reality technology should be mainly applied to product design, VR should be applied to collaborative design platform [17]; Georgios Andreadis et al. studied the application of cloud computing in mechanical mapping and design process, and proposed a specific architecture of multi-server collaborative design [18].

Collaborative design based on cloud design platform is actually divided into user management module, query browsing module, remote communication module and design management module according to modular design idea. It organizes data, equipment, CAD software and designers across regions, domains and platforms. In virtual environment, the same product design task is designed, transmitted and communicated in coordination, interaction and concurrency, and the design scheme is discussed and modified in time, so as to improve the defect of traditional collaborative design.

3.4. Key Technologies of Cloud Design
1) Overall Technology
It mainly includes cloud design patterns, platform architecture, related technical standards [19], and privacy protocols and service protocols [20]. Generally, cloud design platforms adopt service-oriented open architecture to provide users with infrastructure as a service, software as a service and platform as a service, in order to build cloud design architecture. From bottom to top, they are divided into physical layer, logical layer, application layer and other different layers.

2) Virtualization technology
It mainly includes the methods of virtualization of design resources and distributed storage and computing technology. It defines, publishes, and encapsulates, invokes and accesses hardware resources, design software resources and design resources.

3) Cloud Service Management Technology
It mainly includes the integrated management of access, publication, composition and scheduling of cloud design services by cloud platform, such as standard definition and dynamic deployment of design resources, access authentication management of cloud services, intelligent search and efficient dynamic matching and scheduling technology of cloud services,[21, 22, 23].

4) Security Technology
It mainly includes security measures of cloud service access, reliability check of design resources, stable operation mechanism and real-time monitoring of cloud platform, and route security guarantee of operation network.

5) Design Business Management Technology
It mainly meets the design needs of users and achieves cross-regional, cross-domain, cross-platform collaborative design efficiently and simply.
6) Interaction Technology
It mainly realizes the convenient communication between users and the visualization of cloud terminal design resources through three-dimensional modeling and rendering technology.

4. Trend of development
1) Informatization of Manufacturing Equipment Design
   Traditional management methods based on paper reports and documents can’t meet the design requirements of modern equipment manufacturing industry, which not only occupies large space, but also is not easy to view and manage. Based on the cloud design platform, the design resources are virtualized and packaged and published to the cloud resource pool for storage, display and management in a digital form.

2) Intelligent Design of Manufacturing Equipment
   Most small and medium-sized equipment manufacturing enterprises still use 2D CAD. Realizing the rapid transformation of 3D and 2D data and solving the problems of using between users. At the same time, because of the universality and particularity of manufacturing equipment, the design will be different in the actual configuration and technical status, with the help of 3D modeling and rendering technology, visualizing the design process.

3) Collaboration of Manufacturing Equipment Design
   The design process involves not only the division of responsibilities of various departments, but also supporting enterprises and users. Considering the decentralization and heterogeneity of regional and design resources, collaborative design is vigorously developed and relevant standard system is established to ensure efficient design.

5. Conclusion
Cloud design is at the stage of conceptual research or prototype system design and development. It integrates advanced concepts of cloud manufacturing and inherits the advantages of networked collaborative design. It is refined from many disciplines such as Internet of Things, cloud computing, computer-aided industrial design, engineering and so on. It will provide a brand-new concept and mode for the design of equipment manufacturing industry. Because it is in an important position in the product life cycle, it will accelerate the development of the entire equipment manufacturing industry in the direction of information, network, intelligence and service.

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