Research on the Three-Dimensional Process Design Method of Shipbuilding Based on MBD Technology

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Abstract. From two-dimensional engineering drawings, Computer-aided Design (CAD) technology to today’s three-dimensional process design technology of Model Based Definition (MBD) based on feature representation and control, great changes have taken place in human engineering technology. With the applications of MBD technology in aerospace, machine-tool and other fields, it’s also being actively explored in shipbuilding industry on engineering applications of the whole process of ship design and production under the background of intelligent transformation. After analysing the problems existed in process design of domestic shipbuilding enterprises, this paper firstly introduces a three-dimensional digital model of shipbuilding based on MBD technology. Then, a three-dimensional process design method is proposed in order to provide theoretical basis for the realization of three-dimensional process design of shipbuilding.

1. Introduction
With the great development of human engineering technology, the closely related information control in design process and the production management mode have changed fundamentally. Although three-dimensional (3D) design software have been widely and deeply applied in shipbuilding field, two-dimensional (2D) engineering drawings are still used in its production process [1]. The efficiency of information transmission between design and production personnel is low, which makes the shipbuilding cycle longer. Under the background of intelligent transformation in shipbuilding industry, the 3D process design method based on MBD technology gradually becomes a key research direction.

2. Background

2.1 MBD technology
MBD technology is called 3D annotation technology [2]. It is not only an essential way to develop 3D design, but also the core technology for 3D models replacing 2D engineering drawings to be the unique data source in shipbuilding. MBD technology originated in aerospace field for shortening aircraft production cycle and reducing costs, which was first proposed by Boeing in the 1990s [3]. Now, it is mostly used in aerospace and machine-tool manufacturing industries or other fields. In shipbuilding industry, MBD technology is also applied to change the ship design and production mode. For example, digital simulation assembly based on MBD is applied to the design of a submarine to
solve problems that may occur during the actual assembly process in advance. Hyundai Heavy Industries (HHI) also uses MBD technology to make the 3D model run through all stages of design, production and management, enabling it to be seen by all design and production personnel, administrators and shipowners [4]. What’s more, a MBD-based data structure and a management method for shipbuilding are established to raise shipbuilding efficiency by using the MBD-based 3D model as unique data source. The traditional process is improved based on MBD technology [5].

Ship design and production technology based on MBD uses the 3D digital model as the unique data source to integrate all necessary information during ship design and production, to realize 3D process design of shipbuilding and promote collaborative design, production and management across all departments of an enterprise. Meanwhile, the MBD-based 3D digital model can also be the data source of Enterprise Resource Planning (ERP), Manufacturing Execution System (MES) and other information management systems to support knowledge reasoning, process simulation and assistant decision-making, which will improve the digital and intelligent level of ship design and production.

2.2 Process design of shipbuilding

Process design is the general term of process planning design and process equipment design, it mainly refers to the design for process plans and tools. And process design of shipbuilding refers to the design of process methods and specific process procedures for shipbuilding. At present, the process design of domestic shipbuilding enterprises mostly stays at the stage of "3D designing, 2D drawing". There’s a certain gap compared with foreign advanced shipbuilding enterprises and other fields such as aerospace and machine-tool. 3D and 2D mixed mode makes it necessary for designers to transform a large amount of 3D and 2D information, which easily leads to information deviation and causes problems in every segment. At the same time, the data source of ship design and production under this mode is not unique, information resources among different departments are difficult to share and not uniform. What’s more, it’s hard to achieve data integration management since 3D models cannot run through the whole process of ship design and production, which results in data redundancy and heavy workload to design, production and management personnel.

In summary, it is imperative for domestic shipbuilding enterprises to develop 3D process design of shipbuilding. With the development of Internet and information technology, the emergence of MBD technology makes it possible to realize 3D process design of shipbuilding.

3. Establishment of the 3D digital model of shipbuilding based on MBD

3.1 Classification of ship design and production information

MBD technology is based on the unique data source, it needs to establish a uniform 3D digital model which covers a large amount of information. The information can be classified into design information, production information and management information, as shown in figure 1.

Design information mainly includes 3D entity models, annotated information, material properties, etc; production information mainly refers to process information, tool information and technical requirements involved in the production procedure; management information contains production properties, Bill of Material (BOM), management documents, etc.

According to the various stages of ship design and production, BOM can be specifically divided into Engineering BOM (EBOM), Plan BOM (PBOM) and Manufacturing BOM (MBOM). EBOM refers to the detailed list of parts and materials required in the process of ship design and production. Based on the process design level of shipbuilding enterprises, PBOM is a list that describes the manufacturing relationship of parts and components, such as the manufacturing location, manufacturers, material suppliers and so on. MBOM represents the specific processing method and procedure of parts and components.
3.2 Data management for ship design and production

Shipbuilding is a typical discrete production mode. The types of 3D models, the number of drawings and documents involved in its design and production process are enormous, and the information used at different stages is also various.

Based on the principles of digitalization and integration, the MBD-based data management mode for ship design and production is established, as shown in figure 2. Design department, process department, production department and management department import design information, production information and management information into MBD data management system respectively, thus, a 3D digital model based on MBD technology has been generated. Information transmission and sharing among departments can be carried out through the MBD data management system.
3.3 Representation of the 3D digital model of shipbuilding based on MBD

MBD technology realizes 3D model design and real-time transmission of digital information by taking design, production and management information of the model as the core of organization and analysing constraint relationships between various types of information. Technicians can acquire information at every stage of ship design and production by means of the 3D digital model, as shown in figure 3. The 3D digital model truly becomes the only information carrier for ship design and production, which lays the foundation for realization of the 3D shipbuilding process design method based on MBD technology.

![3D entity model](image)

4. The 3D process design method of shipbuilding based on MBD

As shown in figure 4, the traditional design and production procedure contains a lot of 2D information which greatly increases the difficulty of information conversion, storage and management, and
seriously affects the progress of ship design and production. In order to improve the efficiency of design and production, a 3D process design method of shipbuilding based on MBD technology is proposed, which is shown in figure 5.

ERP system is a management platform to provide decision schemes for enterprises with systematic management thought based on information technology. For shipbuilding enterprises, it can cover all kinds of design and management software in ship design and production, and optimize the sharing and utilization of enterprise resources from the supply chain. MES is a kind of monitoring and feedback of ERP system in the field production stage, which can promptly report the problems in the production process and quickly respond through information transmission, and guide the production management with accurate data. The MBD data management system integrated with ERP and MES covers all information in the whole life cycle of ship design and production. It can promote the coordination and unification of design, production and management platforms and make information transmission more timely and accurate.

Meanwhile, the MBD-based 3D process design method of shipbuilding incorporates Knowledge Engineering, which is a new subject that acquires knowledge and information through modern science and technology with high efficiency and large capacity. It studies how to use computer to represent knowledge and solve problems automatically, which is the development of artificial intelligence in conducting knowledge and information. For a long time, due to the lack of information carrier and effective representation mode throughout the whole life cycle of ship design and production in domestic shipbuilding enterprises, knowledge engineering has been difficult to apply to the actual production process. MBD technology is characterized by the unique data source and 3D representation mode, which will make it possible to integrate Knowledge Engineering into ship design and production. Knowledge Engineering acquires knowledge from the inside and outside of systems, verifies its accuracy, and forms a solid knowledge base. Based on professional software, it enables computers to do knowledge reasoning, process simulation and assistant decision-making for specific problems, making the research of shipbuilding process design method more intelligent.

![Figure 4. Traditional design and production procedure](image-url)
5. Conclusion
MBD technology is a key technology for manufacturing industry to realize intelligent transformation. However, nowadays, MBD technology is in the stage of theoretical research in shipbuilding industry which needs continuous development to break through the traditional method and to be applied in the actual design and production of shipbuilding enterprises. And it’s worth mentioning that the technical
advantages of MBD technology in ship design, production and management have been initially reflected. Based on the existing problems of process design in domestic shipbuilding enterprises, this paper discusses the applications of MBD technology in ship design and production. The 3D digital model and process design method of shipbuilding based on MBD technology are proposed to provide theoretical basis for the realization of 3D process design of shipbuilding. In the future, the research of Model Based Systems Engineering (MBSE) will be carried out for the whole life cycle of ship design and production.

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