Research on a Design and Manufacturing Integration Mode Based on a Full 3D Model

Liang Yan¹·², Zhang Qingdong¹·²·*, Li Shi², Duan Hua², Zhang Yi² and Shao Canxia³

¹ Beijing University of Science and Technology, Beijing 100083, China
² Beijing Aerospace Xinfeng Machinery Equipment Co., LTD., Beijing 100089, China
³ China Institute of Integrated Technical Economics of Shipbuilding Industry, Beijing 100083, China

*zhang_qd@me.ustb.edu.cn

Abstract. In view of issues such as low reuse rate of three-dimensional design model in process and production during product research and design, insufficient ability of 3D process design and optimization application, and urgent needs for a closed-loop design-manufacture-inspection integrated control system based on 3D model, this paper is centered around the digital definition and application technologies based on 3D models and facing full process information of product design-process design-production-inspection, combining the product development process, and studies the design and manufacturing integration framework based on a full 3D model, software architecture and data integration management architecture. This paper too selects products with multi-subject features as verification objects and verifies the feasibility and superiority of the integrated design-production-inspection development mode based on a full 3D model.

Key words: full 3D; design and manufacturing integration mode; integration framework; software architecture; data integration management architecture

1. Introduction
With the continuous development of MBD (macro block design) technology, the design and manufacturing integration mode based on full 3D has been more and more widely applied in actual production and processing[1]. At present, aviation, aerospace, automobile, shipbuilding and other industries have developed the application of full 3D digital design and manufacturing mode, and achieved good results[2-3]. However, the low reuse rate, product and data separation, information isolation and other phenomena of 3D design model in process and production remain, which seriously affect collaborative product development efficiency[4-5]. Aiming at the above issues, this paper studies a design and manufacturing integration framework, software architecture and data integration management framework based on a full 3D model, constructs a product design and manufacturing integration system based on the full 3D model, and realizes full 3D data transmission during product development processes such as product design, tooling, manufacturing and inspection etc.

2. Digital development process
The product digital development process involves product design, machine processing, composite material, assembly etc. The main development process includes digital product design, process design, workshop manufacturing execution and process monitoring, digital detection, etc. The specific development process is shown in Figure 1.

Figure 1. Digital development flow chart

3. Integration framework
Product design and manufacturing mode based on 3D models is mainly composed of a product design system based on 3D models, process design system, manufacturing and testing systems and system structure and system architecture and data based on product design/process design/manufacturing and testing systems, as well as full 3D data channeling mode of EBOM, PBOM and MBOM which is based on uniform data sources, so that a unified data management platform is formed to achieve full 3D design and manufacturing data/technical state management.
Eventually, a full 3D design and manufacturing integration system is established based on a unified data management platform, as shown in Figure 2.

**Figure 2.** Schematic diagram of a product design and manufacturing integration framework based on full 3D models

### 4. Software architecture

The product design and manufacturing integration software system based on full 3D mainly includes product design software, process design software and workshop manufacturing execution and testing software. See Figure 3 for specific software functional architecture. At the design end, cross-unit collaboration, 3D model construction and information extraction are carried out to improve the parallel ability of design process and the ability of full 3D model as the only data source to transfer between design, process, manufacturing and inspection. At the process end, carry out multi-specialty digital process design, tooling design, process model characteristic construction and labeling, assembly process design and simulation, rapid design of composite materials etc., so as to enhance machining, compounding, assembly process design capabilities. Carry out rapid response manufacturing execution and 3D model-based inspection planning and analysis at the workshop end, so as to realize the integration of model-driven production processing, assembly, testing and quality control and shorten the production preparation time.
Product design and manufacturing integrated software system based on full 3D

Product design software
Process design software
Workshop manufacturing execution and testing software

Cross-unit collaboration
3D model construction and information exchange

Completion: pro-release of data, official release of data, rapid design and labeling of products, design and validation of multidisciplinary collaboration, design and manufacturing collaboration, etc.

Completion: process planning based on 3D model, structural process design, testing model parameter design, model library management, model identification and transformation, process information labeling, layer design, inspection feature identification, labeling and extraction, testing process and step design, measurement point planning and layout, testing path simulation and optimization, etc.

Completion: process modeling, visual manufacturing execution process monitoring, 3D process field display, data management, online testing based on inspection procedures, comparative analysis of detection results and simulation results, etc.

Figure 3 Functional architecture diagram

5. Data management architecture
Product data integration management mainly refers to the synchronization, application integration and consolidation of various and relatively independent data, which support the operation of full 3D digital systems, ensures collaborative working of multiple business systems in the development process, digs out valuable information resources, and further provides decision-making basis for product development, and so on. The technical architecture of data integration management is shown in Figure 4.

Figure 4. Data management architecture for the product development process
6. Application verification

A certain product with a design and manufacturing process of machining, compounding and assembly is selected as the verification object. The application flow is shown in Figure 5:

![Application flow chart based on 3D models](image)

**Figure 5.** Application flow chart based on 3D models

In product design phase, parametric design is carried out, and the designer will automatically construct a 3D model of the product after key parameters have been set out. Based on the 3D model, the design, process and manufacturing departments work together in parallel, which will carry out product process review in the initial design phase, improve product quality and shorten the design and manufacturing cycle. Information extraction and reuse based on the 3D model helps improve the transmission efficiency of the model and information between different specialties and departments, significantly improve work efficiency and reduce quality problems.

During the machining process design and production phases of product structural components, apply the unified integration platform and 3D design model, which will realize design data reception, construction and labeling of process models, tooling design, 3D machining design and simulation, online testing, simulation and implementation of structural components, and quality data collation, which will also realize full whole process control during design, manufacturing, and inspection, shortened machining design, inspection planning and manufacturing implementation time.

In product composite material process design and manufacturing phase, through the secondary design based on the 3D model and finite element analysis and optimization of the structure, and according to the corresponding mechanical performance index to determine the prepreg layer angle, sequence etc., proper bearing capacity is guaranteed. Then, according to the specific layer information determined by finite element calculation, the process simulation of the layer is carried out to optimize the shape and position of specific slices, so as to ensure the feasibility and quality of the laying-up process and improve process design efficiency.

In the assembly phase, 3D assembly process design and assembly simulation are carried out to generate simulative animation and assembly process information, which greatly shorten the assembly process design time and improve the rationality and feasibility of the process design.

7. Conclusion

The purpose of design and manufacturing integrated management based on full 3D models is to establish a set of process design and data management methods based on the 3D data sets, through resource sharing and synchronous feedback among design personnel, process personnel, production personnel and inspection personnel in the product manufacturing process. Such management philosophy breaks the walls between design, process, and manufacturing, allowing data flow and information flow moves freely throughout the product life cycle, realizing a cross-specialty design and process, design and manufacturing, design and inspection business system, as well as whole process management and application based on 3D models. The design and manufacturing integration mode based on 3D models can effectively improve product development efficiency and ensure product development quality.
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