Research on Application of Digital Assembly Technology based on MBD in Spacecraft Field

To cite this article: Xiaohui Song et al 2018 IOP Conf. Ser.: Mater. Sci. Eng. 408 012026

View the article online for updates and enhancements.
Research on Application of Digital Assembly Technology based on MBD in Spacecraft Field

Xiaohui Song¹,²,*, Yi Lu¹, Zhibin Liu¹, Chunsheng Yang¹, Pei Wang¹ and Feng Xue¹

¹Beijing Institute of Spacecraft Environment Engineering, Beijing, China
²Beijing Engineering Research Center of the Intelligent Assembly Technology and Equipment for Aerospace Product, Beijing, China

*songhsiaohui@126.com

Abstract. With the development of technology based on MBD, three-dimensional model has already been the sole basis during spacecraft assembly process, three-dimensional process design technology on MBD has all-around been applied in spacecraft assembly field. On the base of the five key technology which include digital assembly process design, visualization of three-dimensional process, simulation verification of three-dimensional assembly process, three-dimensional work instruction browsing and digital inspection, spacecraft assembly has realized the transformation from two-dimensional process design system to three-dimensional process design system. The digital assembly technology on MBD has thoroughly changed the spacecraft assembly flow. Through the implement of three-dimensional process design technology, the process design results are transferred to the workshop assembly site in the form of three-dimensional assembly instruction, improving the working environment of the production site, the level of spacecraft assembly is improved.

1. Introduction

MBD means a definition based on model, is a kind of method of using integrate three-dimensional entity model to fully express the definitional information of product[1]. Based on the model of three-dimensional product, MBD assembled characters like size marking, tolerance demand, technology information to describe and share the product to fulfill the direct delivering demand of digitization producing information under the situation of cancelling two-dimensional drawing engineering definition. This technology co-defined PMI (3D Product Manufacturing Information) and three-dimensional information into the three-dimensional digital model of product. Also this technology fulfilled the highly integration CAD and CAM (process, assemble, measure and test) by replacing two-dimensional design pattern with three-dimensional dimensioning model as the producing base of product. In the technological system of MBD, MBD data set contains several information from different sections, including design, technology and manufacture[2]. The schematic diagram of MBD data structure is shown in Figure 1.

Three-dimensional digital technology that is based on MBD had applied to many of the general assembly fields of China’s spacecraft with the improvement and perfect of the CAD/CAM technology. It has substantially promoted the development of digital assembly technique, improved the current
production status of manually assemble spacecraft and enhanced productivity, reduced coordination links and developed the assembly technique of spacecraft.

This article illustrates the digital assembly technique and appliance of spacecraft based on the technical background of MBD.

![Diagram of MBD Data Structure](image)

**Figure 1.** MBD data structure.

2. Digital assembly process design

Process design is the bridge that connects design and produce. Within the traditional two-dimensional environment, process design relies on the two-dimensional engineering drawing provided by design, carry out works like process design and matching table, establishing process cards and signing technological process in CAPP system. Then it would be distributed to production unit, combined with files like the standard code of practice onsite and the executional record of the MES system and direct production personnel to carry out operation in the end.

The assembly process technology based on MBD refers to the high-efficient and rational assembly process design system that based on light weight three-dimensional model, utilized MBD data information, digital and structural method to define and present the whole production process[3]. The system established a satisfactory three-dimensional digital spacecraft prototype through setting up the MBD digital definition standard, adopting three-dimensional modelling to define digital products. Under the instruction of MBD process design, technologists would develop their design and establish three-dimensional digital assembly process model directly according to the three-dimensional entity model and conduct digital analogue simulation of the assembly process through digital virtual assembly environment. The virtual assembly verification of the assembly process is conducted to ensure a preciseness of the process the same time as the design process, before the entity assembly process, and the authorized assembly design is issued for field use and entity assemble. The three-dimensional process diagram and multimedia animation data of the assembly operational process is produced during the process of digital analogue simulation of the assembly process, combined with assembly process to establish digital assembly design data and provide evidence for digital assembly process field.

Three-dimensional structural design system of the general assembly of spacecraft is a deep-developed and specialized system with a featured character of the general assembly of spacecraft, which is based on the “Team centre” system of Siemens. Three-dimensional structural process design is the structural combination of process digital prototype, process structure, enclosed piece, technological resources, technological material and enforcement record. The main function of this system includes receiving design data, such as three-dimensional design data, realizing a technological prototype which faces general assembly under three-digital model; realizing a multiple and full connection between model machine, craft, process, step, materials and resources; realizing the fusion of process planning and checking executive logging; realizing the bi-directional, seamless and real-
time integration with MES system; multimediatizing the process; unifying the resource of data of the formal process, temporary process and process planning; breaking through the data link between process and the site; establishing a full life circle data from design, process model machine, three-dimensional technology to AIT site and a data net that connects them all. The logic diagram of aircraft general assemble structural process design system is shown in Figure 2.

Figure 2. Working logic of three-dimensional structured process planning system for spacecraft assembly

3. Digital assembly process design
Assembly process planning is to determine the assembly plan by analyzing the structure and characteristics of the spacecraft. In a three-dimensional environment, the shape and entity model of the product are present in front of the craft, and the technicians can directly measure and analyze the process separation surface, the sequence diagram of the command assembly, the main zero component assembly datum and positioning methods, the main coordination parts and methods, the assembly work position, the assembly sequence and parts of the parts. The docking scheme is carried out and the corresponding process and equipment design work is carried out at the same time. The planning process of assembly process is divided into four modules: resource module input module, assembly process planning module, assembly process simulation module and assembly process file output module[4].

3.1. Resource module input module
The assembly process model is designed and simulated in three-dimensional environment based on the product MBD data set and the product EBOM table extracted from the data information. The product information is extracted from the EBOM form to form a product structure tree. On this basis, the assembly process plan is formulated, the assembly requirements are made and the assembly unit are divided and refined to "work step" level, therefore formed the assembly process structure tree and related to the product and manufacturing resources. The assembly process planning and simulation optimization, the design and assembly process, and the design of the three-dimensional process documents are distributed to the relevant personnel in parallel, and the assembly process model with various information of the product assembly is formed.

3.2. Assembly process planning module
According to the product structure, the assembly process structure and process flow are divided, and the workload of the assembly unit is evenly distributed by taking workload of each unit into consideration.
3.3. Assembly process simulation module
The rationality of the process planning, the parallelism of operation procedures and the correctness of product and tooling design are verified by simulation.

3.4. Assembly process file output module
In the digital process planning environment, using the product structure tree and manufacturing resources, and also using the process template as base, the output of different process documents is carried out on different process nodes through program, and a three-dimensional lightweight model (three-dimensional picture and three-dimensional dynamic painting) is formed through program integration to form a lightweight three-dimensional process file.

4. Visualization of three-dimensional process
The visualization technology of assembly process is to transfer the product design information, manufacturing resource information and process design information to the workshop site in the form of digital quantity, and the method is displayed[5]. Digital product, digital process model and its three-dimensional AO (Assembly Order, that is assembly instruction) has taken the place of traditional two-dimensional engineering drawings, process design and two-dimensional assembly instructions completely, which improved the effect of technical training for workers. It allows the instruction of workers to carry out field production vividly and intuitively, and set up the assembly for field production. It is necessary to visualize an application system facing field production.

Laying network in assembly workshop, setting up digital application terminal equipment at production site, transferring three dimensional data to assembly operation site, using multimedia assembly process information, three-dimensional product data and three dimensional tooling data, and guiding spaceflight assembly work in digital environment.

Because of the large number of spacecraft assembly components, in order to quickly simulate the process of product assembly, so that to make a higher requirement to the performance of computer on the one hand, and to make a requirement of carrying out a lightweight display on the other hand. According to the assembly datum and process of the product, lightweight product MBD model (consistent with the data set designed by the design department) and assembly operation animation made by 3DVIA Composer software to realize the lightweight index of the three-dimensional assembly process regulations. So that to lay a solid foundation for the design of technical specification for lightweight assembly on the one hand. And to enable the surface assembly technology to have an intuitive and vivid characteristics on the other hand, so that workers can operate more directly and improve assembly efficiency. An example of three-dimensional visualization of spacecraft assembly is shown in Figure 3.

Figure 3. Application example of three-dimensional process visualization for spacecraft assembly
5. Simulation verification of three-dimensional assembly process

Assembly process simulation is an interactive method to simulate the assembly process in virtual assembly environment. It is used to analyze the rationality of the design of the assembly process model before the physical assembly, and the assembly process model is continuously optimized through the continuously discovery of the problem. Assembly process simulation verifies the assemblability of structural parts and system parts, and manual assembly simulation verifies the visibility, accessibility and operability of assembly workers, and the automatic assembly simulation verifies the interference between terminal actuator, flexible tooling and fitting parts[6]. After process certification is completed, possible modifications to corresponding process, tooling and even product design are made. The two main directions of assembly simulation are assembly sequence planning and assembly path planning.

Assembly sequence planning (ASP) is the design of assembly sequence in computer based on the product model of design phases. It is one of the key technologies for Design for Assembly (DFA), and is the core content of assembly process design. One correct assembly sequence is selected to verify whether each part is assembled unimpeded by the designed process sequence, and whether assembly time and cost are reduced. A flow diagram of the process design using a three-dimensional model is shown in Figure 4.

![Figure 4](image1.png)

**Figure 4.** Flow chart of process design using three-dimensional models

Assembly path refers to the location of the product from the location of the installed parts until the parts are assembled onto the assembly body to form the trajectory of the product. The assembly path planning is based on the product structure and related technical requirements, and through a certain algorithm to find a space motion path for a part to be installed from the starting position to the designed product. An example of the application of the spacecraft assembly path planning is shown in Figure 5.

![Figure 5](image2.png)

**Figure 5.** Application example of spacecraft assembly path planning
6. Three-dimensional work instruction browsing
The traditional AO (Assembly Order), that is the assembly instruction, is a process document used to guide production according to the requirements of engineering design and the requirements of existing technological level and quality assurance. The process instruction under three-dimensional conditions is a combination of structured process information (standard format) and three-dimensional information such as model, view and animation to form a three-dimensional assembly process (instruction) electronic data packet that can guide the work of assembly staff.

With the development of MBD technology, three-dimensional AO has become a digital process document. Which includes product design information, resource information, process design information and process animation. In the MBD manufacturing mode, three-dimensional assembly process field application system for spacecraft assembly is established, and three-dimensional product engineering data, three-dimensional tooling data, operation process graphics and operation animation are organized to complete the three-dimensional AO construction.

In the preparation stage of assembly, by watching the animation of assembly process, assembly workers can have an intuitive understanding of the whole assembly work and master the contents of assembly work, including assembly objects, assembly order and method of the parts positioning. Through digital assembly application terminal, process instructions are described in the way of three-dimensional view and three-dimensional animation, and structured text information is supplemented.

7. Digital inspection
MBD technology defines three-dimensional product manufacturing information (PMI) and three-dimensional design information together in three-dimensional numerical model of the product. Under the MBD technology environment, the inspection of products needs to be protected according to three-dimensional numerical models and relevant quality technical documents.

The spacecraft assembly data model based on MBD technology integrates three-dimensional annotation information needed for product assembly, measurement and inspection. MBD digital terminal users can extract the required data from the digital module according to their needs, and carry out the operation of digital mode measurement, marking and capture.

Three-dimensional annotation information based on MBD technology includes two kinds: geometric and non-geometric information. Geometric information refers to the annotation in addition to three-dimensional entities. Non-geometric information is mainly tagged on feature tree. Three-dimensional labeling of assembly is tagged in a newly built "component" model, and is tagged on assembly structure tree with other models. Due to the large number of spacecraft fittings, size annotation and other information provided in the MBD module do not necessarily conform to the user's needs. This requires users to select and extract useful product information actively from the number mode according to their actual needs[7].

The installation of checkpoints for spacecraft assembly is the crux of spacecraft assembly inspection. Spacecraft assembly is a complex system engineering. Many factors and links need to be coordinated in the assembly process. Therefore, the assembly inspection needs to be divided into different stages. Each stage has different inspection priorities until the whole assembly inspection is completed.

In the inspection stage of spacecraft assembly, inspection methods can be adopted: visual inspection, gauge inspection, fixture inspection and photographic examination. Different technical requirements and inspection states need to be used in different inspection and inspection methods, and the required inspection points are different. Therefore, it is necessary to ensure the scientificness of the inspection points. The scientificness of the test point setting is based on the familiarity and digestion of the MBD number model, the understanding of the relationship between the different parts and the relationship between the different parts and the motion relations and functions. It is a dynamic adjustment process based on the design requirements and technical documents. It may be changed according to the design and process changes at any time. Changes in relevant technical documents are made to make adjustments[8].
8. Conclusion
The general assembly of spacecraft is a comprehensive technology with high technical difficulty, high complexity and complex cooperation. At the same time, due to the high reliability requirements of spacecraft products, the requirements of assembly quality are very strict. MBD technology provides the process information for assembly site application. The process design results are transferred to the workshop assembly site in the form of three-dimensional assembly instruction, improving the working environment of the production site, improving the product quality and production efficiency. Therefore, the application of digital assembly technology in the field of spacecraft assembly will contribute to the long-term development of China's spacecraft business.

References
[1] Qiuzhong Z and Yuqing F 2008 Application of MBD on Airplane Manufacturing AVTION MAINTENANCE & ENGINEERING 2008(3):55-57
[2] Zhongyi M 2010 Digital Aircraft Assembly Technology Based on MBD AERONAUTICAL MANUFACTURING TECHNOLOGY 2010(18):42-45
[3] Jihua Z 2009 Aircraft Digitized Measurement Aided Assembly Technology and Application. AERONAUTICAL MANUFACTURING TECHNOLOGY 2009(24):49-52
[4] Fuzhou D & Haicheng L 2010 Research on Key Technology of MBD-Based Aviation First Article Inspection AERONAUTICAL MANUFACTURING TECHNOLOGY 2010(23):57-59
[5] Junyi N & Xiaofei Y 2012 Expression and Transmission of Engineering Information Under the Pattern of MBD AERONAUTICAL MANUFACTURING TECHNOLOGY 2012(6): 77-79
[6] Yanming Z 2012 Process Design based on MBD Technology CAD/CAM YU ZHIZAOYE XINXIHUA 2012(12):60-63
[7] Yuqing F 2012 Model Based Definition Technology and Its Practices AERONAUTICAL MANUFACTURING TECHNOLOGY 2012(6):42-47
[8] Alemanni M, Destefanis F and Vezzetti E 2011 Model based definition design in the product lifecycle management scenario International Journal of Advanced Manufacturing Technology 2011(1/4):1-14.