Satellite Assembly Process Optimization Based on Digital Simulation Technology

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Abstract. In this paper, digital simulation technology is applied to the key link of satellite assembly process. Considering the operating environment, personnel, process equipment and other constraints, the feasibility analysis of the total assembly process scheme oriented to satellite quality control is carried out with the evaluation indexes of the operation space and assembly sequence. Based on the potential risk recognized from the key components of protection, redundancy control, assembly process visible and etc., the assembly process plan is optimized in order to reduce the probability of occurrence of low level of quality problems. The technology proposed in this paper can improve the quality of satellite AIT and provide a solid foundation for the long service life of the satellite in orbit.

1. Introduction
In recent years, digital simulation technology has been widely used in the field of aviation to greatly promote the rapid development of aviation industry, but also gradually applied to the field of space. Digital simulation technology is carried out on the premise of the rapid development of digital [1]. It is based on virtual reality and simulation technology, and it is a unified modeling for product design process. It realizes simulation and simulation from design, processing and assembly, inspection and whole life cycle on computer [2]. It has many advantages, which can not only improve the quality of products, replace physical simulation, shorten the cycle of product development, achieve mass production and design of products, but also reduce the cost of product research and development, and complete the operation and training of complex products [3-5].

The GF-3 satellite is one of the first batch of research projects launched by the national science and technology major project "the major project of high resolution earth observation system" in China. It is also the first C band multi-polarization high resolution microwave remote sensing satellite in China. GF-3 satellite can monitor the all-weather monitoring of global land and ocean information, C band multi-polarization microwave remote sensing information obtained can be used in a number of areas, marine disaster mitigation, water conservancy and meteorological services in China, marine, water conservancy and other meteorological disaster mitigation, industry and business department.

GF-3 satellite is the first 8 years of Leo long-life satellite, whose AIT quality control puts forward higher requirements. There are many difficulties in assembly operation, such as new technology, difficult to implement, operation blind etc. in the SAR antenna planar near field testing and ±Y cabin narrow space intensive products disassembly and assembly operations. This paper focus on the above-mentioned typical key assembly process. Considering the product environment, equipment and tooling,
feasibility evaluation from the operation space and assembly sequence is accomplished. The risk of key parts protection, assembly process visible and operating comfort is found in the assembly before, to reduce the design and product assembly in the process of equipment change, ensure the assembly quality and improve the efficiency of the assembly [6-7].

2. Digital simulation process of typical working conditions

According to the GF-3 satellite SAR antenna planar near field special tests and SAR electronic system in small space, AIT operation with new technology, complex condition, implementation difficulty and risk points, this paper implement the digital simulation technology to simulate different conditions using DELMIA software, PRO/E+SmartReader.

2.1. Expansion of SAR antenna in planar near-field

(1) Simulation process

Firstly, the near field, SAR wall, absorbing materials, scanning frame, two axis turntable, satellite and air bearing table are built using PROE software. And then they are read by SmartReader software to simulate iteratively, in order to identify risk points and take countermeasures.

![Diagram of SAR expansion process](image)

**Fig 1.** Technological process of SAR expansion in planar near-field

(2) Working condition simulation
The layout of the SAR antenna envelope, the air floating platform, the wave absorbing wall and air foot, etc. is simulated in this working condition. The results show that the interference will occur when the satellite’s parking is not reasonable. It is shown in Fig. 2.

(a) +X side of SAR antenna  
(b) -X side of SAR antenna

Fig 2. Interferogram of SAR antenna expansion in planar near-field

The accurate dimensions of all elements in this working condition are analyzed. The displacement of the SAR antenna end surface and wave absorbing wall should be controlled in 450mm-460mm, and the optimal value is 457.5mm. If the distance between the satellite axis and the edge of air floating platform is 710mm, there is no interference along the whole folding process of the SAR antenna. The optimized layout is shown in Fig. 3.

Fig 3. Optimum dimensions of satellite

2.2. Equipment installation in ±Y payload cabin
(1) Simulation environment
1) Operator model
   DELMIA software is used to establish the 3D body model of the operator [8], whose proportion is 50% and height is 1702mm, shown in Fig. 4.
2) Environment model
The Pro/E models of the payload cabin, the rack ladder and the rack car should be transformed into the CATProduct format, which can be recognized by DELMIA software. The optimization variables, such as operation tools, guiding rods, auxiliary support, etc. are also loaded into the simulation program, and then the environment is established. It is shown in Fig. 5.

(2) Interference analysis
It is assumed that the temporary disassembly and disassembly operation of the individual equipment is carried out in the case of the installation of the Y small cabin equipment in the load tank, and the possible interference is analyzed by the simulation, shown in Fig. 6.
Through interference analysis, it is known that:

a) When removing Radar Receiver B, the operator will interfere with Payload Temperature Control, which should be remove firstly.

b) When removing SAR Antenna Distributor B, the distance between operator arm and Payload Temperature Control is 36mm, and there is risk of rubbing cables. So it should pull out the cable firstly.

c) When removing Reference Frequency Source, the minimum distance between operator body and Monitor Timer is 19mm, so it should pull out the cable firstly.

d) When removing FM Signal Source, the minimum distance between operator body and Monitor Timer id 22mm, and there is risk of rubbing cable. So it should remove the cable firstly.

(3) Visibility analysis

The operation visibility of the ±Y payload cabin is simulated, and the ground tools is selected to improve the visibility. The working condition with poor visibility or blind operation can be identified in advance, as shown in Fig.7.
Through the analysis of visibility, we know that:
a) When the fasteners of Reference Frequency Source are installed, the lower position is shielded, and the reflector must be used when operating.
b) When the fasteners of Radar Distributor are installed, the internal position is shielded, and the reflector is required.
c) Operating comfort analysis
   In the DELMIA software, the operator's body color represents the comfort of operation, of which green is comfortable, yellow is better, orange is good, red is discomfort.
   The operation comfort of the ±Y payload cabin is analyzed, and the simulation analysis is carried out through the software simulation and analysis beyond the comfort boundary of the human body. With the help of the auxiliary tools, the simulation analysis of the working condition is improved. The results are shown in Fig. 8.

(a) Operating comfort comparison of Beam Controller (free condition and guiding rod)

(b) Operating comfort comparison of Internal Calibrator (free condition and guiding rod)

Fig 8. Comfort analysis of operations in ±Y cabins

Through the analysis of comfort, we know that:
a) When Beam Controller is installed, the maximum load without auxiliary tool is 5.6kg. Since the weight of Beam Controller is 7.4kg, it is best to use the guiding rod.
b) When Internal Calibrator is installed, the maximum load without auxiliary tool is 5.9kg. Since the weight of Internal Calibrator is 8kg, it best to use the guiding rod.
c) In addition to the above two equipment, other equipment is disassembled, through the operation comfort analysis, can be completed without the use of the equipment.

3. Conclusion
In this paper, digital simulation technology based on Pro/E, DELMIA software was employed to simulate the layout design of SAR antenna unfolding test and equipment installations. The interference, visibility and operating comfort are analyzed during the operation process, and the feasible suggestion is provided. The application results show that the digital simulation technology is very useful in the
initial stage of the development of spacecraft cooperative design for process equipment, process planning, which can be used to discover and correct design defects, shorten the cycle and reduce development costs. Especially in the spacecraft assembly work, it is developed from the model to the stage of mass production mode, which has the reference significance.

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