Analysis on The Assembly Technology of Manned Spacecraft and Unmanned Spacecraft

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Abstract. The aerospace machine contains manned spacecrafts and spacecrafts by whether carrying the person. As an important moment, there are several characteristics between manned spacecrafts and spacecrafts in assembly process. The general assembly process is of vital importance in a spacecraft R&D system. It is at the bottom of the technical system of spacecraft manufacturing, and covers quality assurance, integrated scheduling and logistic controlling. First of all, this paper recommends the concept of the spacecraft assembly technology. And then this text introduces six aspects such as system complicated degree, the microorganism control, how to select nonmetal material, craft methods, transport methods, assembly mode to analyze the difference from spacecraft.

1. Introduction

Spacecraft is divided into manned spacecraft and unmanned spacecraft according to whether it is manned. The unmanned spacecraft refers to various types of earth satellites and space probes that are being developed and launched in the world currently. They are generally not recycled except that they have to return to earth for special purposes. After completing a specific space mission, they are burned into the Earth's atmosphere, or continue to "wander" in space to become space junk. The structure of the manned spacecraft is different from that of the unmanned spacecraft. The manned spacecraft must have a large space for people to move, a set of environmental control systems and life support systems. Its structural scaling performance must be good enough and its required equipment must be competent to send people back to the earth. Therefore, the fundamental difference between a manned spacecraft and an unmanned spacecraft is whether it has a closed space suitable for people to live and work, an infrastructure for people to survive, live and work in a space environment and protection measures to ensure people's safety and health. The manned spacecraft includes manned spaceship, cargo spaceship, target air vehicle, space laboratories, space stations and so on. With the development of space technology, the assembly technology of manned spacecraft has more and more characteristics different from unmanned spacecraft, which has gradually emerged [1-3].
2. The spacecraft assembly technology
The mission of the spacecraft assembly technology is to reliably fix the instruments used in each subsystem to the required position of the satellites according to the overall requirements, and connect them through cables and conduits to form satellites whose quality, characteristics, precision and air tightness can meet the overall requirements and ensure that the satellites can function properly under the various conditions of the ground phase, launch phase, flight phase and return phase.

The spacecraft assembly technology includes two parts. When implementing the assembly, the process personnel complete the development of process equipment and the process design according to the requirements of assembly design and then the operating personnel assemble all the parts, components and instruments that have passed the acceptance into the whole satellites (machine) according to the assembly design and process requirements. The spacecraft assembly design determines the difficulty and performance index of the implementation, and the implementation of the assembly directly determines the performance of the spacecraft products [4-6].

3. Analysis of the assembly technology of manned spacecraft and unmanned spacecraft
This paper mainly analyzes and studies the differences between manned spacecraft and unmanned spacecraft in the field of assembly technology from the following six aspects.

3.1. Sub-system category
Manned spacecraft has more sub-systems and higher technical difficulty than unmanned spacecraft. The sub-systems typical manned spacecraft features mainly include ventilation systems, environmental control and life support systems (or ECLSS), and docking sub-systems. The functions of each subsystem are as follows:

   (1) The ventilation system provides the flow field environment and heat dissipation path for the heat dissipation of the instruments and equipment as well as the air temperature control of the human activity area, and controls the humidity in the cabin;

   (2) Environmental control and life support system closely combines environmental control, life support, emergency life support (and life safety repeat or not) with fire safety technology to form a complete engineering system, creates a safe and suitable living environment in the closed cabin. and provides secure material conditions necessary for the astronauts;

   (3) The docking mechanism sub-system is an indispensable device for two aircrafts to perform rendezvous and docking in space, and a device for capturing and rigidly sealing the two aircrafts. It has the functions of capturing, locking, sealing and separating. At the same time, it is equipped with gas, liquid and electric docking interfaces, which can supply propellant and gas to the target aircraft, and realize power supply and information integration.

The increase in the number of subsystems and the technical difficulty results in different assembly processes and tasks. The main differences are shown in Table 1:

3.2. Microbes control
Because manned spacecraft needs to carry astronauts, microbial pollution poses a hazard to astronauts, materials and spacecraft. As the on-orbit time of spacecraft increases, the corresponding microbes will continue to breed and further the hazard to astronauts and spacecraft. Therefore, the strict means of microbes control is one of the important features of manned spacecraft, which is different from unmanned spacecraft. Generally, the assembly time of the manned spacecraft is about two years. At the same time, the spacecraft assembly phase runs through the spacecraft unit’s delivery and launch. Therefore, strict microbial prevention and control management carried out in the assembly phase is extremely important to control the on-orbit pollution of spacecraft.

According to the assembly process of manned spacecraft, the microbes in the ground assembly mainly come from two aspects:

   (1) Various materials will be used in the spacecraft assembly process, and the processing, transportation and preservation processes may breed some microorganisms attached to the equipment;
(2) Microorganisms carried by ground operators during operating may cause pollution in the aircraft cabin.

At present, in the assembly process of manned spacecraft, microbes’ control is mainly carried out by the following means:

Personal dressing: The cabin operators should pay strict attention to personal hygiene, especially the hygiene of hands. Sterile gloves and masks should be worn during the operation of the cabin. It is forbidden to expose the fingers, wrists, arms and other parts directly to the product. The operators are required to wear three tights (tight neckline, tight cuffs, tight hem) overalls. They are forbidden to wear accessories and cosmetics when entering the cabin. In addition to the strict control measures for unnecessary materials, they are not allowed bring personal items (such as keys, watches, etc.) that are not related to production in the cabin. At the same time, the movements which may cause body metabolites are forbidden, such as scratching head and skin, etc. In this respect, the ground assembly of Japanese HTV cargo spacecraft has set a good example. Its protective measures in the assembly process are shown in Figure 1.

Equipment cleaning: in the stage of assembly, the single-machine equipment and auxiliary tools for loading should be disinfected before entering the cabin, and the surface should be wiped and cleaned with special disinfectant in the condition that the performance of the equipment is not affected.

(3) Whole machine transport: the spacecraft transport package mainly undertakes the outdoor transportation of the cabin. The package should be cleaned before transportation, and the inner surface of the package should be disinfected with disinfectant. If the package is connected to the outside (the air pressure balancer should be opened to ensure the balance of the air pressure inside and outside the package and make the inside and outside of the package exchange), the pressure balancer can be sealed with filtering cotton to prevent the microbial pollution in the outside air.

(4) Air circulation: in the stage of ground assembly, a hundred-level clean air is conveyed into the cabin by the ventilation equipment to form air circulation in the cabin. During the continuous exchange of air inside and outside the cabin, small suspended pollutants in the air of the cabin should be excluded. The sediment should be removed from the cabin compulsorily and regularly with vacuum cleaners and the like.

In spite of the requirements of personal dressing, equipment cleaning, and whole-machine transportation, the unmanned spacecraft has no requirements for air circulation. Because the unmanned spacecraft does not need to carry astronauts, it has no strict microbial control requirements as manned spacecraft does.

Table 1: Difference of Assembly Process and Mission

| No. | Category       | Manned spacecraft                                                                 | Unmanned spacecraft                                                                 |
|-----|----------------|----------------------------------------------------------------------------------|----------------------------------------------------------------------------------|
| 1   | Leak detection | not only involves the propulsion subsystem, but also carries out the leak detection of multiple cabin and environmental control system in the assembly stage to ensure the sealing performance of the manned spacecraft | only includes the leak detection of propulsion subsystem. Implementing time: single-point leak detection and whole satellite leak detection before the system acceptance test; leak detection of the whole satellite after mechanical experiment |
| 2   | Noise control  | the fixing of the clamp between the hard pipe and the soft pipe in the ventilation pipe system and the noise control technology of the heat control fan | noise-free control technology                                                   |
| 3   | Protective tooling | The manned spacecraft should be equipped with the protection tooling of docking mechanism used for the protection of the active (passive) docking mechanism during the assembly phase | only for the protrusions of the satellite surface                                   |
3.3. Selection of non-metallic materials
Non-metallic materials are light in weight, have certain plasticity and can meet the special requirements for sticking metals, so they have been widely used in the spacecraft assembly process. However, the cabin of manned spacecraft is a sealed environment, which is not conducive to the diffusion of harmful gases and volatiles. Improper material may release harmful gases, or be ignited, or pose potential safety hazards due to aging; in the outside of manned spacecraft cabin, the stuff stripping from non-metallic material is likely to contaminate the optical components like the solar wing, various sensors, etc. Therefore, there are very strict requirements for the selection of non-metallic materials in the assembly process. It is necessary to complete the screening of the following tests: the test of flame retard and combustion product, the test of harmful escaped gas, the test of material quality loss in vacuum, the test of material condensable volatile in vacuum, the test of atomic oxygen, the test of ultraviolet radiation, the test of charged particle irradiation, the test of material antibacterial and mildew proof, etc.

Taking non-metallic rubber materials as an example, the room-temperature fast-curing epoxy adhesive--HY-914 is commonly used on unmanned spacecraft, mainly used in the working conditions such as sticking the precision reference mirror, preventing the lose of electrical high-frequency connector and others, mainly owing to its advantages of high strength to resist shearing(≥19.7MPa), good toughness, oil resistance, water resistance, aging resistance, good sealing, etc. But it is not used in manned spacecraft due to its poor heat resistance and volatilization similar to the smelly volatilization of hydrogen sulfide.

3.4. On-orbit maintenance
The life of an unmanned spacecraft is generally 8-15 years, and the life of a communication satellite can be as long as 15 years, but it is not maintainable. If failing to work, it cannot be repaired on orbit, but the manned spacecraft is different. The on-orbit maintenance technology is a necessary condition to extend the life of the spacecraft. The designed life of the space station "Мир" was 5 years, and it was actually extended to 15 years through maintenance. The astronauts spent 75% time carrying out maintenance in the final mission of the space station "Мир". The International Space Station has a designed life of 15 years and is currently at the end of its life. It has been evaluated to extend its life to 20 years through maintenance. It can be seen that on-orbit maintenance is an indispensable means for manned spacecraft such as space stations to achieve long-term on-orbit working. For the needs of on-orbit maintenance, to ensure the good on-orbit maintainability of manned spacecraft, a suitable process method in the assembly process is needed to facilitate the astronauts to perform the reverse on-orbit process.

Taking glue as an example, the structural room-temperature curing adhesive--Redux 420 has good shear strength (≥25MPa), so it is widely used as an excellent stuff to prevent fastener losing in unmanned spacecraft. But it is very hard to remove. Once the fasteners are sealed with adhesive, they are unable to be unscrewed. Therefore, for the requirements of the on-orbit maintenance of the astronauts, the threaded anti-loose adhesive is chosen for the dismantled parts (such as instruments and various types of direct parts) during the assembly process of the manned spacecraft.

Taking the cable network as an example, the thermistor is commonly used as a unit to measure and control temperature in the spacecraft assembly process. On the unmanned spacecraft, weld is generally...
used for reliability. In the manned spacecraft, the pin jack CX-1B-5 is generally used for connection on the purpose of easily replacing the single equipment. When the equipment is replaced, it will be OK to disconnect the pin jack.

3.5. Transport method
The size of the unmanned spacecraft is small, so is the weight. For example, Dongfanghong 4 platform satellite is the unmanned spacecraft with largest weight under research currently. Its transport weight is less than 3t, and the weight does not exceed 6t after the filling. The transshipment is generally based on the bracket car of the whole machine, two-axis turntable, and the packing box of the whole machine. All of these adopt the wheeled transport method.

Compared with unmanned spacecraft, manned spacecraft is large not only in dimensions, but also in weight. Taking the Shenzhou spacecraft as an example, the transport weight of its plants is as high as 8.3t, and it is impossible to adopt the wheeled transport mode. Therefore, the air-floating transport platform is more suitable for special working conditions such as large shape, heavy weight and small turning radius, as shown in Figure 2. The air-floating transport supports the weight of the transported product through the air cushion, which has large carrying capacity, and small turning radius almost reaching zero. The air-floating transport can be realized without a tractor. It only needs a gas source along the transport route.

![Fig. 2 Sketch Map of Air-floating Transport Platform](image)

3.6. Operation openness
Unmanned spacecraft generally adopts the main bearing structure of “central bearing cylinder + outer wall panel” or “truss + outer wall panel”. The operating space is very open. After the cabin end is folded in the assembly, the operator can penetrate into the cabin for operation using the method of installing process board. Photographs of a satellite in Figure 3.

![Fig. 3 Photographs of A Satellite](image)
Manned spacecraft generally uses a rotating metal structure. Due to the poor openness and visibility of the assembly, the work carried out in the cabin requires to design corresponding tooling. To reduce the operational risk and difficulty, higher requirements are put forward to the tooling design. For example, when the front-cone instrument panel of the target aircraft Tiangong-1 is installed, the working space is narrow. In extreme cases, the operator needs to insert and remove the electrical connector under invisible conditions. Model picture of Tiangong 1 in Figure 4.

Fig.4 Model picture of Tiangong 1

Conclusion
The assembly of spacecraft is an important part of the spacecraft development. According to the statistics of the Russian space department, the workload of the assembly accounts for 35% of the total, and the assembly cycle accounts for 30% of the total. Therefore, studying the difference of the assembly technology between the manned spacecraft and the unmanned spacecraft will help to further improve the design level and implementation effect of the assembly, and comprehensively improve the final assembly level of the spacecraft.

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