Designation and Verification of Manned Spacecraft and Cargo Ship Universal Operating Platform for Vacuum Thermal Test Based on Modular Design

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Abstract. Before the spacecraft vacuum thermal test, the spacecraft needs to be hoisted into the space environment simulator. Due to the high altitude of the spacecraft, a dedicated operating platform is required. The size of the manned spacecraft and the cargo spacecraft are inconsistent, so the existing operating platforms cannot satisfy the operating requirements of both types of spacecraft. In addition, the existing operating platform has poor structural strength and needs to be assembled in the space environment simulator. In order to solve these problems a universal platform is proposed. This paper adopts modular design method, using analyzing software for modal analysis, instability analysis and overall lifting analysis. It reduce the maintenance, storage, and transportation costs of the operating platform, improve the assembly efficiency of the operating platform and realize the universal design of the operating platform of the manned spacecraft and the cargo spacecraft.

1. Introduction
Spacecraft vacuum thermal test is an important part of the spacecraft manufacturing process, in order to verify the operational status of the spacecraft in orbit, a thermal vacuum test is required on the ground[1-4]. The manned spacecraft is characterized by a large aspect ratio and can reach a height of more than ten meters. The spacecraft is in an upright state when entering the space environment simulator. Therefore, it is necessary to design an operating platform to meet the operation of the spacecraft in the space environment simulator. The envelope diameters of the manned spacecraft and the cargo spacecraft are different. In previous thermal tests, two operating platforms were designed for these two spacecraft. The transportation and assembly of the two operating platforms were very cumbersome during each use. Maintenance and storage costs are extremely high. Therefore, when the old platform is about to be scrapped, a universal operating platform can be designed to improve the utilization rate of the operating platform and reduce storage and transportation costs. In addition, the universal operating platform can also achieve the purpose of hoisting into the space environment simulator as a whole, which greatly reduces the operation in the space environment simulator and reduces the risk of product bumps.

2. Function and performance requirement analysis
In order to meet the needs of manned spacecraft and cargo spacecraft at the same time, and to ensure the safe distance of the operating platform into and out of the space environment simulator, the dimension of the operating platform must meet the following requirements:

1) The effective height is higher than 13000mm;
2) The maximum envelope circumscribed circle size is less than 8950mm;
3) The inner circle of the inner diameter is greater than 4800mm;
4) The length of the operating platform’s telescopic pedal is not less than 1000mm.

3. Overall structure design
The modular universal operating platform is designed as an octagonal structure and consists of an operating platform base, an operating platform main body and an operating platform lifting sling.

3.1. Base design
The operating platform is designed with 4 modular bases, welded with 80mm×80mm×8mm stainless steel pipes, and the bases are all modular designs. The base is a trapezoidal structure, the base and the space environment simulator guide rail are fastened by locking ring, and the docking plate is welded between the two base modules and fastened by screws. In order to ensure the flatness of the connection surface between the base and the platform and improve the reliability of the butt connection, a 15mm thick stainless steel plate is welded on the top surface of the base and the butt surface of the main platform, and combined processing is performed after welding.

3.2. Main body design of operating platform
In order to improve operability, the main operating platform is designed with 6 layers, each layer is 2200mm high, and each 3 layers is a section. Not only can the effective space of the telescopic pedal be guaranteed, but also the safety of personnel passing and operation. In order to improve the efficiency of processing and post-maintenance, the main body of the operating platform also adopts a modular design. Each layer is designed with 8 sub-modules, and each three-layer sub-module is integrally welded into a sub-assembly. The upper and lower sections of the main platform and the modules are connected by screws. In order to ensure the structural strength and docking accuracy of the screw connection, 15mm stainless steel plates are welded on the butt surfaces of the upper and lower sections. In order to facilitate the installation of the two-stage operating platform, a guide cone pin is welded to the main column of the lower section of the platform. To ensure the connection strength of the cone pin, the cone pin is inserted into the square tube of the main column, the top is welded, and the main column is inserted into the square tube and then tightened again. As shown in Figure 2(a), (b).
The operating platform adjustable pedal adopts the traditional "guide wheel + channel steel" structure, which is composed of an introduction moving device, a first-stage telescopic pedal, and a secondary pedal. The main structure of the adjustable pedal is a bearing frame welded by steel pipes, as shown in Figure 3.

3.3. Operating platform lifting sling design
In order to meet the overall lifting conditions of the operating platform, the special lifting sling is designed as an 8-point lifting beam made of Q460 steel, and the pin shaft is made of 30CrMnSi forgings. This structure is an assembled structure, which is convenient for transportation and storage.
4. Mechanical analysis

After the design of the modular operating platform is completed, Pro/e Mechanica is used to perform a static analysis on the operating platform to verify whether it meets the load-bearing capacity. Firstly, the static analysis of the base is carried out. The boundary conditions are: the weight of operating platform is about 23000Kg, the platform bears 3375Kg when fully loaded, and the 4 bases are calculated according to the local load, and each base should bear 6500Kg. A uniformly distributed load of 65000N is applied to the bearing surface of the top of the base, and the calculation result is shown in Figure 5. The maximum stress is 47Mpa, and the maximum deformation is 0.32mm.

Next, analyse the load application of the entire operating platform: the operating platform's own weight is about 23000Kg, the platform carries 3375Kg when fully loaded, and the load is evenly distributed to each platform at 675Kg. A uniform load of 6750N is applied to the bearing surface of each platform. The calculation result is shown in Figure 6. The maximum stress is 34Mpa, the maximum deformation is 3.55mm, and the stress is far less than the yield limit of Q235 steel. The maximum is that it occurs at the gap at the bottom of the operating platform, so the supporting structure should be appropriately added in actual use.

The static analysis of the adjustable pedal is then carried out: the operating platform has a weight of about 80Kg, and the first and second stages of each adjustable pedal are designed to carry two people at the same time, that is, 270Kg. A uniform load of 2700N is applied to the bearing surface of each adjustable pedal. The calculation result is shown in Figure 7. The maximum stress of the two-stage adjustable pedal is 36.5Mpa, and the maximum deformation is 1.1mm.
Finally, the mechanical analysis of the spreader is carried out, the contact surface of the cantilever beam and the disc is selected to apply a fixed constraint, and a load of 100000N is applied to the lower circular surface of the connecting circular hole under the lower lifting point ear plate, as shown in Figure 8. The maximum deformation of the cantilever beam is 2.5mm; the maximum stress is 400MPa, which is a local stress concentration, and the overall stress is less than the yield limit of 20 steel, 245MPa.
5. Test and verification

After the modular operating platform is designed and processed, in order to ensure its safety and reliability, it needs to go through overall lifting and load testing before it can be formally used in the spacecraft vacuum thermal test. After loading, lifting, turning and other tests, the overall deformation of the measuring operating platform is not more than 5mm. The weak parts of the opening structure in the simulation process have been strengthened, and the rigidity has also been greatly improved. The lifting test is shown in Figure 9. Shown.

![Figure 9. Lifting sling.](image)

6. Conclusion

Compared with the previous operating platform, the operating platform structure of this solution is a closed modular structure. The closed structure can greatly improve the structural rigidity of the operating platform and effectively reduce the deformation during use.

In order to reduce the welding deformation of the platform structure, each section of the platform and the base is divided into 8 modular units for welding processing. The modular welding method can effectively reduce the welding size and facilitate the control of welding deformation.

In order to reduce the lifting deformation of the operating platform, this scheme designs an octagonal sling, and the sling is lifted vertically. Disperse the stress concentration and lateral force generation during the overall hoisting process of the platform, and evenly distribute the force to the connection position of each main bearing column and beam through eight lifting points, effectively reducing the deformation of the hoisting process.

Considering the versatility of manned spacecraft and cargo spacecraft, reducing the processing, storage and transportation costs of the operating platform, and improving the efficiency of the operating platform

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