Research on the design of massive weight satellite transfer platform

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Abstract—The new generation of the DFH-5 platform satellite independently developed by China has been successfully launched by CZ-5 launch vehicle in Hainan satellite launch center. Up to now, the satellite has been running smoothly with good functions and services. It is the heaviest satellite launched in China with the highest technical content. In this paper, a kind of transfer platform is designed to meet the transfer requirements of heavy satellites such as the East five platform. The transfer platform is composed of body frame, omni-directional wheel set, console, battery, electric control system, etc. The transfer platform has the functions of independent control, safety detection, accurate positioning, human-computer interaction, etc. through analysis and calculation, the ultimate compression and anti-overturning performance is stable and reliable, meeting the needs of satellite and other tooling during the final assembly test. Then it can reduce the risk of assembly operation and improve the efficiency of assembly test.

1. Introduction
SJ-20 satellite was successfully launched in HAINAN satellite launch center in December 2019. It is the first satellite successfully fixed on the DFH-5 satellite public platform in China, and it is also the satellite with the heaviest launching weight and the highest technical content in China, as shown in Figure 1. DFH-5 satellite platform is a new generation of general geostationary orbit satellite platform, which adopts truss structure style. It has the characteristics of high load, high power, high heat dissipation, high precision, long life and expandability [1]. It can be used for the next generation communication satellite, electronic reconnaissance satellite, ground optical remote sensing, synchronous orbit SAR, missile early warning, regional imaging and other satellites. The total weight of the standard platform is about 8 tons, and it is launched in Hainan with CZ-5 launch vehicle [2].

During the satellite assembly test, considering the large weight of the satellite, a special large weight satellite transfer platform is designed to realize the transfer and positioning of the satellite under various conditions [3]. It avoids the traditional manual transfer operation mode, works stably and reliably, has independent control, safety detection, precise positioning, human-computer interaction and other functions, meets the needs of satellite and other tooling in the final assembly test. Then it can reduce the risk of assembly operation, and improves the efficiency of assembly test [4].
2. Design of large weight satellite transfer platform

2.1 Overall plan
Heavy weight satellite transfer platform is composed of car body frame, omni-directional wheel set, console, battery, electric control system, etc., as shown in Figure 2. According to the requirements of the East five platform satellite, the rated load of the transfer platform is designed as 12 tons, and it has further expansion.

2.2 Structure

2.2.1 Platform framework
The main body of the platform frame is welded with steel plates and vertical bars, which have high strength and stability. In addition, the space between the vertical bars in the middle of the platform frame can be fully used to place the battery pack and the electric control system. By using this structure design, the platform frame itself can have a lower height, at the same time, the platform frame space can be maximized, and the overall structure is compact.

2.2.2 Omnidirectional wheel set
The transfer platform adopts four electric omni-directional wheel groups. The driving and steering of wheel groups are powered by DC servo motor. Through different walking mode control, the turntable has the functions of forward, backward, turning, lateral translation and in-situ rotation. Traveling driving mode: DC motor + synchronous pulley + planetary reducer + driving wheel; steering driving mode: DC motor + planetary reducer + worm and worm rotary drive device.

2.3 Electric control design
The control system of the transfer platform mainly includes the following parts: main control unit, walking drive unit, remote control unit, human-computer interaction unit, safety protection unit, etc. [5].
2.3.1 Main control unit
The main control unit of the transfer platform is a foreign high-performance programmable logic controller (PLC), which is the control core of the transfer platform system and is used for peripheral signal processing and equipment movement control.

After the main power switch is turned on to power on the system, the power on of the servo drive control circuit, the power on of the servo drive main circuit, the state of the drive motor and the input and output of peripheral signals (limit switch, acousto-optic alarm signal, etc.) are detected and controlled by the PLC. At the same time, PLC is also responsible for receiving all kinds of commands and tasks from the touch screen. According to the commands and the detection signals of each sensor, it completes the walking control of the transfer module. The PLC controls the transfer platform through each servo driver to complete the travel related operation, and realizes the forward, backward, turning, lateral translation, in-situ rotation, micro motion control and other functions of the platform. In the process of conversion from forward and backward travel to lateral translation, the "0" turning radius can be realized, and the speed control can be infinitely adjusted according to the requirements of the operator.

2.3.2 Traveling driving unit
Four groups of walking steering driving mechanisms are adopted, each group of driving mechanism adopts the design mode of electric universal wheel, each wheel group is driven by two servo motors respectively. The steering and traveling of wheel set are powered by servo motor, and the universal wheel can realize stepless speed regulation.

Direction driving mechanism: install limit switch at two limit positions of its movement to prevent damage to equipment due to movement overrun and ensure product safety. An angle sensor is installed on each driving wheel to detect the current angle of the wheel in real time.

The remote controller sends control instructions to PLC, which is responsible for logic calculation as a controller unit, outputs the calculated control value to the motor controller, and finally the motor performs the required operations. In order to effectively control the steering of the wheel group during the walking process, four angle sensors are respectively installed on the four wheel groups to feedback the steering angle value of the wheel group. The traveling and steering of the wheel set of the equipment are driven by the traveling motor and the direction motor respectively. The traveling motor and the steering motor are both DC servo motors controlled by the servo controller.

2.3.3 Remote control unit
The movement of the whole satellite transfer platform can be controlled by two operation modes, i.e. wired hand-held operation box and wireless remote control, and interlocking control measures can be taken between the two modes.

2.3.4 Human computer interaction unit
The human-computer interaction unit is mainly used for walking micro motion control, system parameter setting and operation status, fault information, communication status display, etc. it is convenient for the operator to observe the operation status of the equipment in real time. The human-computer interface exchanges data with PLC through serial communication.

2.3.5 Safety protection unit
In order to ensure driving safety, the system is equipped with a safety anti-collision unit, which is used to detect the safety distance between the surrounding obstacles and the vehicle body in real time. When the distance is less than the safety distance, the system will send an audible and visual alarm prompt to remind the operator to pay attention to the safety distance, or according to the requirements, when the distance between the obstacles and the vehicle body is less than the safety distance, the system will automatically stop.
An ultrasonic distance meter is installed in the upper left corner, upper right corner, middle left corner and middle right corner of the car body respectively, and a laser distance meter is installed in the middle front end to detect the distance between the car body and the obstacles, so as to ensure the safety of the transport vehicle. In order to facilitate the secondary setting of safety distance for the operator, the operator can set the safety alarm distance on the touch screen, or set the safety stopping distance.

3. Performance analysis of heavy weight satellite transfer platform

3.1 Main performance of platform

The platform frame is the main key component of the transfer platform. Under the normal working condition, the four wheels land at the same time, that is to say, the position of the four corner mounting wheel group is fixed. Load 1.25 times of the rated load, i.e. 15t load to the top surface of the transfer platform, load vertically downward, and analyze the state of the platform after the ultimate stress, as shown in Figure 3, the maximum deformation of the load frame is 0.018mm, the maximum stress value is 70.925mpa, and the safety factor is 4.8, which meets the standard requirements of safe use.

3.2 Calculation of traveling brake

When the transfer platform adopts ordinary brake, the controller controls the motor to brake. The controller can apply braking angular acceleration of magnitude a=300r/s². When the transfer platform is running at the highest speed v=15m/s, the speed of the motor is n=2547rpm=42r/s.

The braking time required for the motor is:
\[ t_b = \frac{n}{a} = 0.14s \]

The braking distance required by the motor is:
\[ s = \pi d_n i / i = 17.3 mm < 25mm \]

Therefore, the ordinary braking distance meets the safe requirements.

3.3 Centroid stability calculation of 5° slope

As the overall mass of the transfer platform is large and the center of gravity of the whole platform is high when it is combined with the satellite, it is necessary to calculate and analyze the stability of the whole platform.

At present, moment method is mainly used to calculate anti overturning stability in China. The basic principle of moment method for checking anti overturning stability is: the algebraic sum of moment
acting on the dangerous overturning edge of various loads including self weight of the bearing body must be greater than or equal to 0, as shown in Figure 4.

\[ M = G \cos \alpha L - G \sin \alpha Z \]  

\( \alpha \) - angle of ramp;  
\( L \) - horizontal distance from the center of gravity of the object to the tipping point (along the direction of the ramp);  
\( Z \) - projection distance from the center of gravity of the object to the tipping point (perpendicular to the direction of the ramp);  
\( G \) - gravity of the object.

Among them, \( G \) is 12t, \( Z \) is 4185mm (the height of the actual centroid position is less than this value), the track width is 1600mm, \( l \) is 800mm, and the slope \( \alpha \) is 5°. Through calculation, \( M > 0 \). Therefore, when the transfer platform and transfer platform are on a 5° ramp, the anti overturning moment is far greater than 0, and the overall center of mass is stable without overturning risk.

4. Summary

This paper proposes a large weight satellite transfer platform to realize the convenient transfer and location of the East five platform satellites. It not only optimizes the traditional operation mode and significantly improves the efficiency of the general assembly operation, but also has high positioning accuracy and multiple coverage conditions, which can be applied to the heavy satellite and tooling of each platform. The research results of this paper can also provide technical reference for the following large spacecraft transfer scheme.

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