Study on action mechanism of reliability influencing factors for space drive mechanism

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Abstract—The action mechanism of influencing factors on the reliability of space drive mechanism was studied. According to the main internal factors that affect the reliability of space drive mechanism, such as material, machining accuracy, assembly error and preload, different failure modes caused by different influencing factors were analyzed. The evolution law of space drive mechanism under different temperature, different speed, and different load were studied. The high and low temperature performance test device of space drive mechanism was used to test driving precision and efficiency of space drive mechanism changing with temperature, speed and load. The test results show that transmission accuracy of space drive mechanism decreases with temperature increasing, and the speed has little effect on transmission accuracy of space drive mechanism. The transmission efficiency of space drives mechanism increases with temperature and load increasing, transmission efficiency decreases with speed increasing.

1. INTRODUCTION
With the continuous development of space technology and the continuous improvement of space mission requirements, space drive mechanism has been applied more and more widely, showing a diversified development trend. The space drive mechanism is a product with high reliability and long life, and its system composition is very complex. Load, working conditions, temperature, vacuum and other operating states will have an impact on its performance, and its performance will gradually degrade with extension of service time, and its reliability and life will also gradually decrease \cite{1,2}.

The space drive mechanism in space environment poor observability, difficult to detect, less accumulation of information, ground test and verification is more difficult, it is the real poor information and small sample products. Therefore, its research space drive mechanism reliability problems must have enough scientific experiment, through the organic combination of experimental data and related theory, the reliability of space drive mechanism are accurately grasp.
Different factors may cause different failure modes, and various factors interact with each other. Therefore, its reliability is a typical multi-factor, strong coupling, high dynamic and time-varying reliability problem. The performance of space drive mechanism can be evaluated by such test indicators as transmission accuracy, efficiency, clearance and start torque. Therefore, it is great significance to study the mechanism of influence factors on the reliability of space drive mechanism for the reliable use and performance prediction of space drive mechanism [3-4].

2. ANALYSIS OF RELIABILITY INFLUENCING FACTORS

The reliability influence factors of space drive mechanism in all stages of life cycle is comprehensive, the various influencing factors acts on space drive mechanism at the same time, it leads to the potential failure factors was activated, the performance degradation or function failure of space drive mechanism. Mutual coupling effects between various influencing factors of space drive mechanism, such as kinematic pair clearance and wear mutual coupling, the collision force of kinematic pair increase with gap enlargement, and the collision force for high frequency oscillation leading to continues increase of gap, so the wear lead to kinematic pair clearance greatens, further lead to motion pair contact collision is more intense, thus deepening sports wear, this is a process of mutual influence and promote each other. Therefore, with the extension of working cycle of space drive mechanism, clearance wear will inevitably cause the performance decline, vibration intensification, motion instability and precision reduction, further affecting the service life of space drive mechanism [5-6].

The elasticity of space drive mechanism and kinematic pair clearance may lead to a sharp drop in system overall performance, it makes deviation between actual and ideal movement of space drive mechanism. It can increase dynamic stress of parts and causing vibration of drive components, produce noise, accelerated wear, lower precision and work efficiency, so the impact factors must be considered. In the mechanism with clearance of motion pair, the collision in motion pair gradually transfers the energy to elastomer of mechanism, arouses the vibration of elastomer aggravates the energy loss and reduces the performance of space drive mechanism [7-8].

The basic idea of reliability analysis of space drive mechanism is shown in Figure 1. Based on the analysis of functional requirements and performance indexes related to reliability, the reliability of product system and its basic components is obtained. Then according to the failure mode and reliability factors analysis study reliability factors of different product [9].

![Diagram](image_url)

Figure 1. Reliability analysis flow of space drive mechanism.
The reliability affecting factors of space drive mechanism are mainly including internal factors such as material, processing error, assembly error and preload force, etc. The main failure modes and mechanisms of space drive mechanism can be obtained by analyzing the mechanism of performance and reliability reduction of space drive mechanism caused by influencing factors, as shown in table 1.

**TABLE 1. FAILURE MODES AND MECHANISMS OF SPACE DRIVE MECHANISM**

| Affecting factors     | Failure mode                  | Failure mechanism       |
|-----------------------|-------------------------------|-------------------------|
| Material              | Structural vibration;         | Precision reduction;    |
|                       | Stiffness reduction;          | Performance degradation.|
|                       | Deformation of parts.         |                         |
| processing error      | Mechanical stress increase;   | Precision reduction;    |
|                       | Aggravating wear;             | Friction growing;       |
|                       | Seal failure.                 | Impact increase.        |
| Assembly error        | Clearance of motion pair;     | Mechanical stress.       |
|                       | Dynamic stress increase.      |                         |
| Preload force         | Increase dynamic resistance;  | Mechanical stress.       |
|                       | Change of mechanism stiffness.|                         |

3. **TEST AND RESULTS OF RELIABILITY INFLUENCING FACTORS**

3.1. **Test conditions**

The high and low temperature performance test device of space drive mechanism was adopted for the test (as shown in Figure 2). The device has a vacuum chamber. It can obtain $5.0 \times 10^{-4}$ Pa vacuum though vacuum extraction system, which can simulate the space environment. The space drive mechanism was lubricated by space lubricating grease, with a transmission ratio of 100, the speed range was 20~1000r/min, the load torque range was 5~15 N·m, and the temperature range was -35~65°C.

![Figure 2. The high and low temperature performance test device.](image)
3.2. Variation characteristics of transmission accuracy
Tests were conducted to test the transmission accuracy of space drive mechanism with different speeds and temperature. When the rotating speeds of space drive mechanism were selected as 20r/min, 40r/min, 50r/min, and 200r/min, respectively, the temperature changed from -35°C to 65°C to test the transmission accuracy of space drive mechanism. The test results are shown in Figure 3.

![Figure 3. Variation curve of transmission accuracy with different temperature and speeds.](image)

It can be found from the curve of transmission accuracy with different temperature and speeds: (1) The transmission accuracy of space drive mechanism decreases with the increase of temperature. When the speed is 20r/min, the transmission accuracy is 91" at -35°C and 77" at 65°C. The transmission accuracy is greatly affected by temperature, mainly because the radial clearance of space drive mechanism is greatly affected by temperature, resulting in a reduction of transmission accuracy. (2) The speed has little influence on the transmission accuracy. At the same temperature, there are some differences in the transmission accuracy of space drive mechanism with different rotating speeds, but the change is not large and there is no rule, which can be considered as the measurement error. Therefore, it can be considered that there is no significant relationship between transmission accuracy and speed of space drive mechanism.

3.3. Variation characteristics of transmission efficiency
Test transmission efficiency of the space drive mechanism with speed, temperature and load were carried out. The load respectively are 5N·m, 8N·m, 10N·m and 15N·m, and the speed respectively are 20r/min, 40r/min, 50r/min and 200r/min, the temperature changed from -35°C to 65°C to test the transmission efficiency of space drive mechanism. The test results are shown in Figure 4.

![Figure 4. Variation curve of transmission efficiency with different temperature and speeds.](image)

a) load 5N·m
b) load 8N·m

c) load 10N·m

d) load 15N·m

Figure 4. Variation curve of transmission efficiency with different speed, temperature and load.

By comparing the transmission efficiency curves under different rotating speeds, loads and temperatures, it can be found that: (1) The transmission efficiency of space drive mechanism increases with increase of temperature. As can be seen from figure 4, under load conditions of 5N·m, 8N·m, 10N·m and 15N·m, the transmission efficiency increases by about 5%, mainly because the radial clearance of space drive mechanism decreases with increase of temperature, it resulting in improvement of transmission efficiency. (2) The transmission efficiency of space drive mechanism decreases with
increase of rotating speed. The transmission efficiency curve shows that the relationship between transmission efficiency and speed presents a certain rule, and the transmission efficiency is significantly affected by speed. Under different temperatures and load conditions, the transmission efficiency decreases with increase of speed, and the transmission efficiency decreases by about 10%. (3) The transmission efficiency of space drive mechanism increases with increase of load. The transmission efficiency curve shows that the relationship between transmission efficiency and load presents a rising law, and the transmission efficiency is significantly affected by load, and the transmission efficiency increases with increase of load at different temperatures.

4. CONCLUSION
(1) Through analyzed action mechanism of reliability influencing factors for space drive mechanism, it found that the machining accuracy, assembly error and preload have great influence on the reliability of space drive mechanism, which can cause the precision of space drive mechanism to decrease, stress increase, wear aggravation, performance degradation and other failure forms.
(2) The transmission accuracy of space drive mechanism decreases with temperature increasing, and the speed has little effect on driving precision of space drive mechanism. The transmission efficiency of space drive mechanism increases with temperature and load increasing, transmission efficiency decreases with speed increasing.

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