Research on Anti-Vibration based on Screw Fixation and Friction-Assisted Fixation Method for the Space Payloads

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Abstract. Rack is kind of the experimental platform that used in the space station for performing scientific experiment. Many payloads are mounted on Rack with limited operating space. The shipment of a Rack to its final destination in orbit is far more complicated than for all other commercial products. The launch vehicle-induced vibration and shock environment can be a payload killer. Based on the limited operating space, this paper proposes a screw fixation and friction-assisted fixation method. Through establishing the force and the parameters of the screw fixation and friction-assisted fixation based on the payload, deriving the mathematical model and carrying out the dynamic environment test. Test results match theoretical results quite well. The screw fixation and friction-assisted fixation method can effectively resist excessive dynamic and shock loads.

1. Introduction

As the development of Chinese space technology, many space loads with various mission are investigated a lot. Rack is kind of the experimental platform that used in the space station for performing scientific experiment. Like satellites, the Rack undergoes design, fabrication, test, and shipment. However, the shipment of a Rack to its final destination in orbit is far more complicated than for all other commercial products. Excessive dynamic and shock loads can be a satellite killer causing permanent damage to electronics, optics, and other sensitive equipment. To compensate for the harsh dynamic environment, payloads must be designed and tested to very high dynamic levels [1–5].

![Removable maintenance platform and installation method](image)
In this paper, an installation method is introduced to fix the payload (removable maintenance platform) on the rack with limited operating space. Through screw fixation and friction-assisted fixation method, as shown in figure 1, the safety and reliability of removable maintenance platform during the launching process can be guaranteed.

2. Model and Theoretical Analysis

2.1. Model

The parameterized model and the force of the removable maintenance platform are shown in figure 2, and figure 2a) is the top view, figure 2b) is the side view. The force of the wedge locking strip is shown in figure 3. And the force of the friction-assisted fixation is shown in figure 4.

![Figure 2](image)

**Figure 2.** The parameterized model and the force of the removable maintenance platform

![Figure 3](image)

**Figure 3.** The force of the wedge locking strip

![Figure 4](image)

**Figure 4.** The force of the friction-assisted fixation

2.2. Force Analysis

According to the figure 2, we can get the impact force of removable maintenance platform

\[ F_1 = ma \]  

where, \( m \) is the mass of removable maintenance platform; \( a \) is the impact acceleration.

And the following force balance equation can be obtained

\[ F_1 \times h = F_2 \times L \]  

where, \( L \) is the distance between the friction force and the fixed point; \( h \) is the distance between the center of mass and the fixed point; \( F_2 \) is the force which can withstand the impact load.

So

\[ F_2 = \frac{mah}{L} \]  

According to the Fig. 3, we can get the force produced by the torque applied to the screw

\[ F_t = \frac{T}{D} \]  

where, \( T \) is the torque applied to the screw; \( D \) is the diameter of the screw.

And the following equations can be obtained
\[
\begin{align*}
F_{N1} &= F_i \cot \beta \\
F_{N2} &= F_i \cot \beta \\
F_{N3} &= F_i \cot \beta \\
F_{N4} &= F_i \cot \beta \\
F_1 &= F_2 = F_3 = F_4 = F_i
\end{align*}
\]  
(5)

where, \( \beta \) is the angle of wedge block; \( F_{N1}, F_{N2}, F_{N3}, F_{N4} \) are the pressure component of the wedge block at different positions on the removable maintenance platform.

According to figure 4, the force of friction generated by a single wedge locking strip can be obtained

\[
\begin{align*}
F_f &= \mu F_N \\
F_N &= F_{N1} + F_{N2} + F_{N3} + F_{N4}
\end{align*}
\]  
(6)

So

\[
F_f = \frac{4\mu T \cot \beta}{D}
\]  
(7)

According to the current design, the values of the above variables are shown in the table 1.

**Table 1. The values of the different variables**

| Variables | \( m \) (kg) | \( a \) (m/s²) | \( h \) (m) | \( L \) (m) | \( \mu \) | \( T \) (N.m) | \( \beta \) (°) | \( D \) (m) |
|----------|-------------|--------------|---------|--------|------|-------|---------|--------|
| Value    | 12          | 300          | 0.25    | 0.4    | 0.3  | 7     | 45      | 6 \times 10^{-3} |

According to the above formula and table, we can get

\[
\begin{align*}
F_2 &= 2250N \\
F_f &= 1400N
\end{align*}
\]  
(8)

So

\[2F_f > F_2\]  
(9)

Therefore, the design can meet the requirements of safety and reliability.

**3. Fabrication and Assembling**

The wedge locking strip is manufactured and assembled as shown in figure 5. In order to increase the friction force, the friction contact part is knurled.

Removable maintenance platform and slider guides are manufactured and assembled, which integration with the Rack, as shown in figure 6.
4. Test
The acceleration measurement points are pasted in the corresponding position of removable maintenance platform as shown in figure 7.

![Figure 7](image7.png)

**Figure 7.** The acceleration measurement points of the removable maintenance platform

The dynamic environment testing was carried out on the Rack, as shown in figure 8. And the conditions of the dynamic environment testing conditions are shown in table 2.

![Figure 8](image8.png)

**Figure 8.** The dynamic environment testing platform

| Parameter Name       | Parameter Values |
|----------------------|------------------|
| Value of Amplitude   | 7.5mm 3g 5g 3g  |
| Sweep Frequency      | 2 oct/min        |
| Loading Direction    | Three axial directions |

The mechanical conditions shown in table 2 are applied to the Rack. The acceleration curve of the acceleration measurement points as shown in figure 7 can be obtained, as shown in figure 9. It can be seen from figure 9 that the maximum acceleration is 300 m/s² at the acceleration measurement point 15.

![The Rack](image10.png)

After the above test conditions, the output curve at 15 measurement points before and after the 0.2g characteristic scanning can be obtained, as shown in figure 10. The above test results show that the frequency sweep results before and after the test are consistent. The installation state has not changed to meet the design requirements.
5. Conclusions
In this paper, the screw fixation and friction-assisted fixation Method has been proposed. The mathematical model was established and the dynamic environment test were carried out. Test results match theoretical results quite well. The results show that the screw fixation and friction-assisted fixation method can ensure the safety and reliability of the payload.

6. References
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