Finite Angle Multichannel Space Slip Ring Design

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Abstract. According to the working environment characteristics and technical requirements of the finite angle conductive slip ring, a kind of finite angle slip ring with limited angle is designed by using flexible circuit board to transmit power and control signals between two relative rotating mechanisms. Flexible circuit boards are rotated between the inner and outer ring. The inner and outer rings are designed as wedge-shaped stepped structures, which greatly reduce the friction torque of the finite angle slip rings. This paper focuses on the structural design and performance parameters test of finite angle finite angle slip ring, verifying that the slip ring has the advantages of light, small, low friction torque, high reliability and so on.

1. Introduction

In the space two-dimensional tracking and aiming system, the conductive slip ring is a precise electromechanical device to transmit power and control signals from the fixed mechanism to the rotating mechanism. With the rapid development of satellite, manned spacecraft, space station and other aerospace applications, conductive slip ring, as the key component of space two-dimensional tracking and aiming system, determines the reliability and working life of the tracking and aiming system. Therefore, conductive slip ring is required to develop in the direction of light, small, low friction torque, high reliability and high life.

At present, the structure of conductive slip rings at home and abroad mostly adopts copper ring-brush, which has the disadvantages of large volume, heavy weight and so on. In order to achieve smaller contact resistance, it is necessary to increase the preload between copper ring and brush, which leads to larger friction torque of conductive slip rings and higher requirements for driving torque of tracking and aiming system.

2. Principle of finite angle conductive slip ring

When the conductive sliding ring works, the output point B of the inner ring is fixed, the input point A moves toward A'、A", and the C point on the goose-neck moves toward C', C" with the motion of the flexible circuit board, thus realizing the rotation of the outer ring relative to the inner ring, and ensuring the continuous transmission of power and signal.

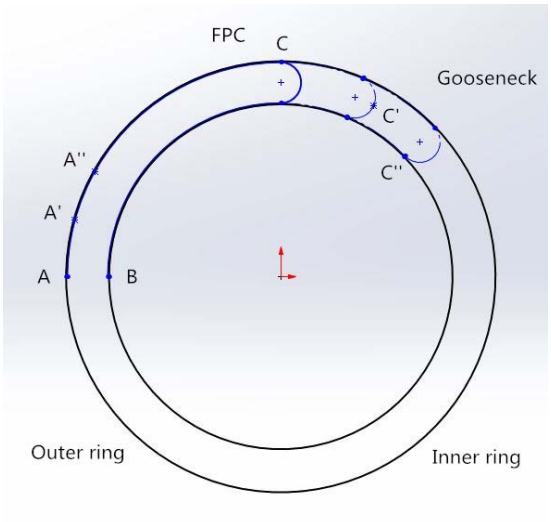

Fig. 1 Schematic diagram of structure

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In the aspect of friction torque, traditional conductive slip rings need to increase the pretightening force between copper rings and brushes, thereby reducing the dynamic contact resistance of conductive slip rings. The friction torque of conductive slip rings is larger. The sliding ring is electrically connected by flexible circuit board. During the working process, the friction coefficient between polyimide and metal of flexible circuit board is small, and the positive pressure between the friction pairs is not increased. Compared with the traditional conductive sliding ring, the friction torque is greatly reduced in principle [1].

When the temperature rises, the hardness of the polymer decreases, the tension of the goose-neck decreases, and the positive pressure between the friction pairs decreases. However, due to the decrease of the hardness of the polymer, the real contact area between the frictions pairs increases, resulting in friction. In the same way, the hardness of the polymer increases, the real contact area between the friction pairs decreases and the friction coefficient decreases, but due to the hardness of the polymer increases. The greater the tension of the goose-neck part, the higher the positive pressure between the friction pairs. By comparing the increase of positive pressure with the decrease of friction coefficient, the torque change of conductive slip ring is judged in the process of temperature decreasing. Through high and low temperature torque test, we can measure the torque change of the conductive slip ring at different temperatures, and get the sensitivity of the influence of positive pressure and friction coefficient on the torque in the process of temperature rising and decreasing through data analysis, and finally get the best working environment temperature of the conductive slip ring [2].

3. Structural design

According to the finite angle precision conductive slip ring is composed of inner ring, outer ring, retaining ring, flexible circuit board (FPC) and other auxiliary components, conductive slip ring structure as shown in Figure 2.

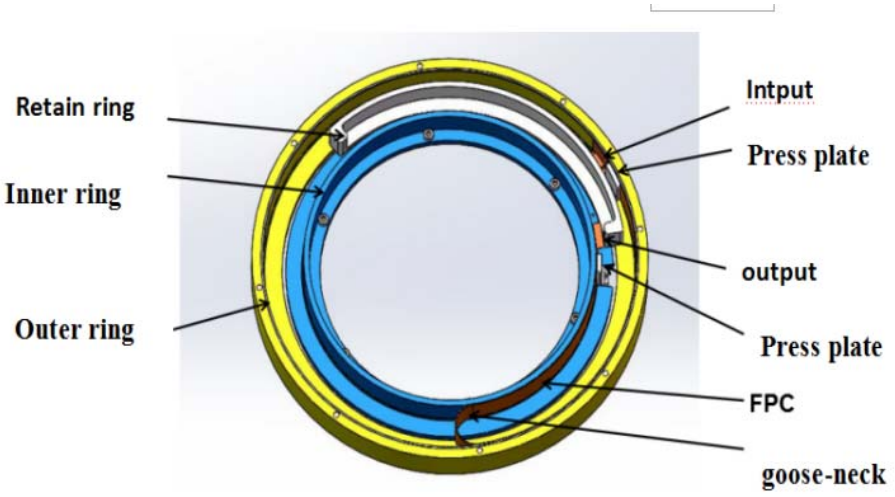

Fig. 2 Structural diagram of rotary finite angle conductive slip ring

4. Dynamic torque test

Disturbance torque is an important parameter of the conductive ring, the size and stability of the conductive ring or even the whole system is essential. In order to test the conductive ring dynamic torque parameters and working stability, the dynamic torque test of the conductive ring.

4.1. Dynamic torque test scheme

Dynamic torque test system includes conductive slip ring prototype, stepping motor, motor drive equipment, J-1AM micro-range dynamic torque sensor, TS3000 torque speed power acquisition instrument, computer and so on.

4.2. Dynamic torque test results

The dynamic torque data of conductive sliding ring and non-conductive sliding ring were obtained at the test speed of 1r/min. The experimental results were shown in Figure 3. The dynamic torque curves of conductive sliding ring were obtained by the difference between conductive sliding ring and non-conductive sliding ring. As shown in Figure 4, the conductive sliding ring torque was obtained by data processing. The root mean square value (RMS) is 0.0324Nm.

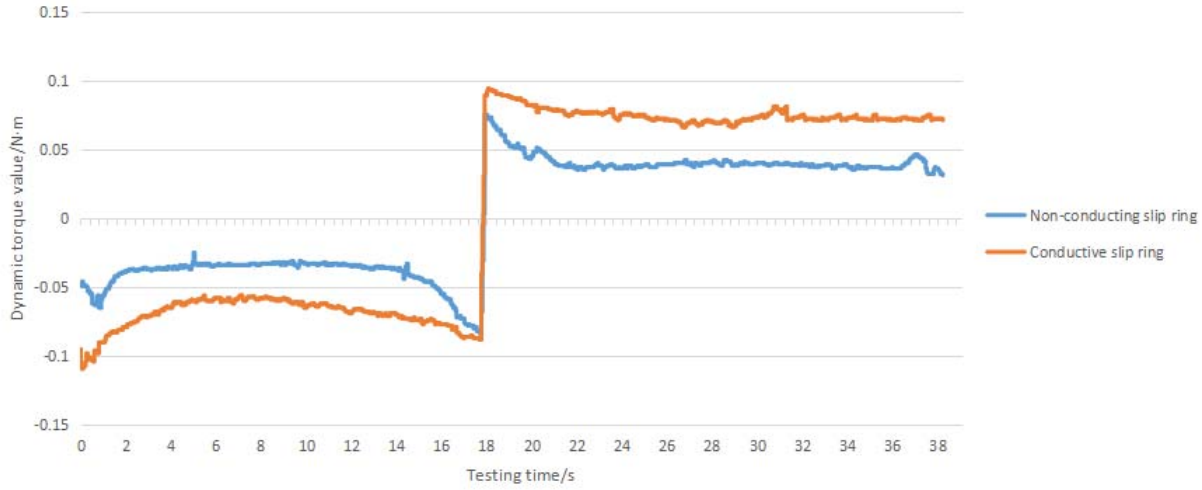

Fig. 3 Under the speed of 1r/min, the test system has the dynamic torque curve of the conductive slip ring condition and the non-conductive slip ring condition

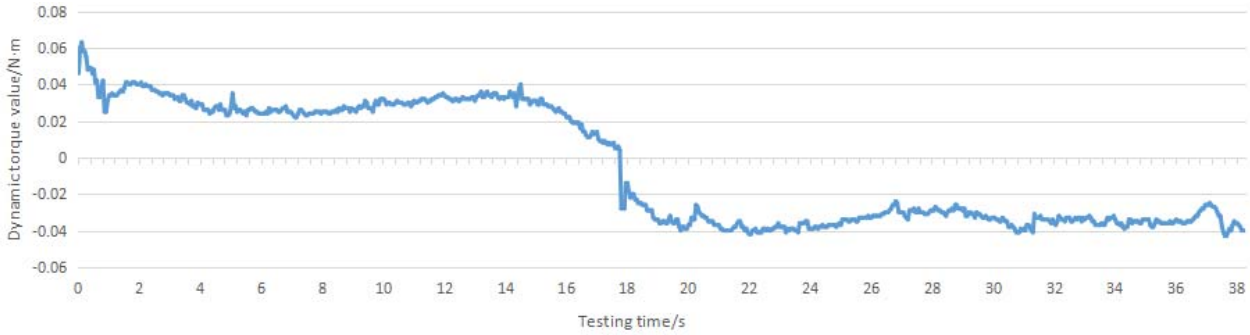

Fig. 4 Torque curve of conductive slip ring at 1r/min speed

To sum up, we can conclude that:

1) At these three speeds, the maximum RMS of the torque of the conductive slip ring is 0.042N M. Compared with the traditional copper ring-brush slip ring, such as a 20-channel conductive slip ring with a copper ring-brush structure, the interference torque of the slip ring is about 0.2N M. The RMS of the torque of the slip ring is much smaller than that of the slip ring, so the slip ring has obvious interference torque. Advantages [4];

2) When the conductive slip ring rotates forward and backward, the torque is basically the same. Only slight torque fluctuation exists when the conductive slip ring rotates forward and backward. Compared with the rotating joints of foreign RUAG companies, the key problem of inconsistent forward and backward torque is solved, and the pressure on the servo control of the whole tracking and aiming system is reduced [5].

5. High and low temperature environmental test

In order to study the influence of high and low temperature environment on the torque of conductive slip ring, find the best working environment temperature of conductive slip ring, and verify the adaptability of conductive slip ring to high and low temperature environment, the high and low temperature environment test of conductive slip ring was carried out.

5.1. High and low temperature test scheme

According to the requirements of GJB 150.3A-2009 military equipment laboratory environment test method, the temperature range depends on the temperature range of the actual working platform, so take the test temperature range of - 40℃ to 60 ℃, in the temperature range, every 10 ℃ as a node, the temperature of the specimen to be heated or cooled, after the temperature reaches a stable temperature, keep the temperature for 2 hours. The above will be tested again [6].

The test system includes: Fuqi C4-340 high and low temperature test box, conductive slip ring prototype, ZJ-1AM micro-range dynamic torque sensor, TS3000 torque speed power acquisition instrument, stepping motor, etc. The prototype of the conductive slip ring is placed in the high and low temperature test box. The conductive slip ring is connected with the torque sensor, stepping motor and other test equipment through the alignment hole on the side of the high and low temperature test box. The test system is shown in Figure 5.

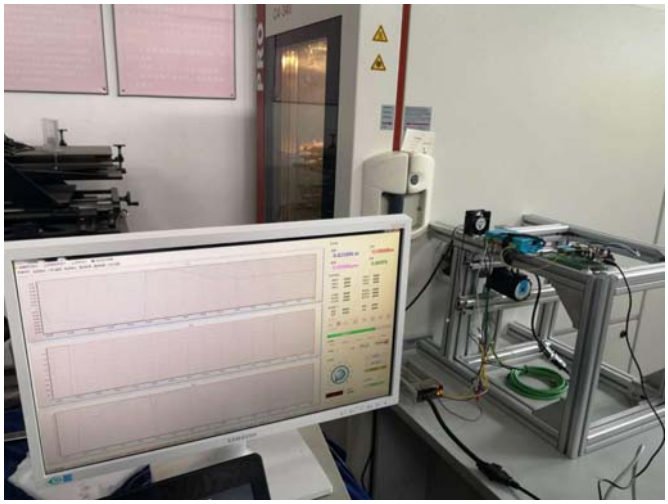

Fig. 5 High and low temperature test physical map

5.2. High and low temperature test results

Conductive slip rings operate at a speed of 3r/min, and the dynamic torque changes of conductive slip rings are measured in the temperature range from - 40 C to + 60 C. As shown in Table 1, the RMS values of conductive slip rings at different temperatures are obtained by data processing.

Tab. 1 Dynamic torque changes in the environment of -40 ℃ to +60 ℃

Temperature / ℃	-40℃	-30℃	-20℃	-10℃	0℃	10℃
Conductive slip ring/N·m	0.32558	0.21816	0.1322	0.05833	0.04139	0.04113
Non-conductive slip ring/N·m	0.30388	0.19784	0.12314	0.0547	0.0384	0.03906
Temperature / ℃	20℃	30℃	40℃	50℃	60℃	
Conductive slip ring/N·m	0.03475	0.04119	0.04964	0.06541	0.08831	
Non-conductive slip ring/N·m	0.03408	0.03115	0.02919	0.0376	0.04199	

As shown in the diagram, we can find that the torque of the conductive slip ring is the smallest and the optimum working environment temperature of the conductive slip ring is 20%. And this phenomenon shows that the flexible circuit board substrate is polyimide, the increase of friction coefficient is higher than the decrease of positive pressure in the process of temperature rising from 20 C to 60 C. At this time, the sensitivity of friction coefficient to torque is higher, so the torque of conductive slip ring increases continuously; the process of temperature decreasing from 20 C to - 40 C. The increase of positive pressure is higher than the decrease of friction coefficient, and the sensitivity of positive pressure to torque is higher, so the torque of conductive slip ring increases continuously.

6. Conclusion

In order to meet the demand of space two-dimensional tracking system for conducting slip-ring, the flexible circuit board is used to realize the transmission of power and control signals between two relatively rotating mechanisms.Through the test, the conductive slip ring is much less than the traditional slip ring in terms of friction torque, and has good stability and significant advantages.In the high and low temperature environment, the effect of temperature on the conductive slip ring is studied, and the best operating temperature of the conductive slip ring is found.

Acknowledgments
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References
[1] Liu zhimin. Failure analysis of printed circuit board under mechanical bending [D]. University of electronic science and technology, 2011.
[2] Cong peihong, li tongsheng, liu xujun, zhang xushou, tao jiang. Effects of temperature on the friction and wear properties of polyimide [J]. Journal of tribology,1997 (03):29-35.
[3] Wang haifeng. Failure mode and experimental study of flexible electronics [D]. University of electronic science and technology, 2011.
[4] Xing lihua, lu jinming, li yaoe, ge fangjun. Development of precision conductive slip rings for space applications [J]. Navigation and control,2015, 14(01):59-64.
[5] Mäusli, P. A, G. Feusier, and V. Gass. "Rotating electrical joints with continuous metallic connections." (2003).
[6] Li Ming, peng wei, zhu yaochang. Analysis of GJB 150.3a medium-high temperature test program (ii): selection of high-temperature daily cycle data and standard application analysis [J]. Spacecraft environmental engineering,2015,32(06):607-611.