The Research of Technologies of High Precision & Long Life Space Tracking Mechanism

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Abstract. In the field of space remote sensing technology, this paper researches on the technologies of high precision and long life tracking mechanism. The especial requirements in space for tracking mechanism are presented firstly, and the technologies are studied. Then a tracking mechanism bearing by two flexural pivots and driven by a voice coil motor is designed. Flexural pivot is ideally suited for limited angular rotation. Voice coil motor has a simple structure, without any structure for reversing, and is easy to be controlled. The mechanism's tracking accuracy can reach to 30″, and the life of this tracking mechanism can reach to 3.6E+6 which are all proved by some test in the end.

1 Introduction

For space instrument the demands of light mass, compaction, low power cost, high precision, long life and high reliability are all indispensable. In most instruments tracking mirror is usually needed to swing regularly within a certain range of angles. Then the space instruments can track targets stably when it is working in orbit. Also the life requirement of space instrument is usually 5 years, or even 8 years nowadays. So a high precision and long life tracking mechanism is seen as necessary component for most space optical instruments.

2 Technologies of space tracking mechanism

2.1 Key indicator requirements

For application-specific requirements of space optical instruments, angular rang for tracking is usually ±2°~±6°, and tracking accuracy is usually needed to ±30″~±60″. Besides working angular velocity of space tracking mechanism is very low, usually about 10e-3 rad/s [1].

2.2 Mechanism bearing

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Whether it is space or ground product, rolling element bearings are used usually in lots of traditional rotary devices. But rolling element bearing is only applied to the condition when the mechanism rotates in complete rotations or at least the rolling elements in bearing rotate in complete rotations.

Firstly, the bearings will get deviation when working in a very low velocity, then lead to a low tracking accuracy for mechanism. Secondly, the bearing's life will be seriously reduced when working long term in a small angle range of swing, because the rolling elements in bearing are pressed unevenly. And thirdly, there is metal-to-metal contact in rolling element bearing, which means some treatments have to be done to protect against space cold welding, then some uncertainty and risk come behind[2].

Flexural pivot is used as tracking mechanism bearing in this study. The flexural pivot consists of flat springs crossed at 90° , and supporting cylindrical counter-rotating sleeves, as shown in Figure 1. Friction, stiction (the force required to cause one body in contact with another to move), fretting corrosion, lubrication, space cold welding and lubricant out-gassing in space vacuum applications are all avoided in the flexural pivot because there is no metal-to-metal contact.

Figure 1. Structure of Flexible Pivot

By matching pivot size and spring rate to the application, cyclic stress on the springs may be maintained at a low enough value to assure infinite cyclic life.

2.3 Design of whole structure

The tracking mechanism consists of a base, a scan mirror, two flexural pivots, a voice coil motor, a resolver and other components, as shown in Figure 2. The scan mirror is supported by two flexible pivots, connected to the base; the motor rotor and the resolver rotor are connected to the scan mirror through two adapter structures. Then the mechanism achieves the functions that the motor drives the mirror directly and the resolver feedbacks the angular position.

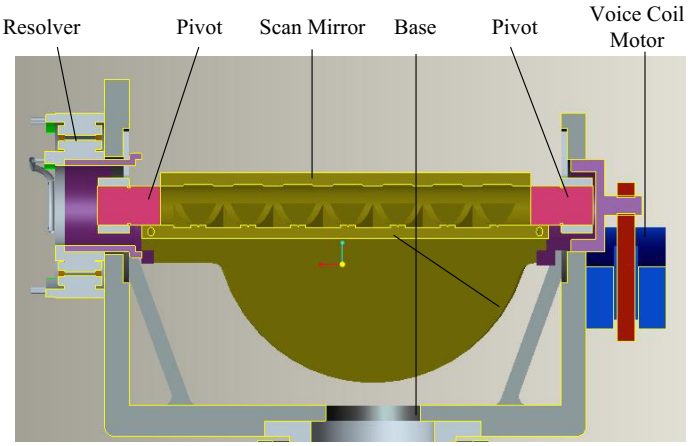

Figure 2. A Design of tracking mechanism

Voice coil motor is a kind of torque motor, and has a special limited angular rotation structure. This can well meet the requirements of this space tracking mechanism.

The structure of rotary voice coil motor is shown in Figure 3. Voice coil motor can drive the mirror directly. Its working principle is Ampere force (that's why it's named like a speaker). An electrified coil (conductor) placed in a magnetic field generates a force, and the size of the force is proportional to the coil current. Voice coil motor have a series of advantages like small size, light weight and fast response. Voice coil motor has been widely used in lots of high precision positioning systems and high acceleration devices, such as disk positioning and optic lens positioning on the ground [3-5].

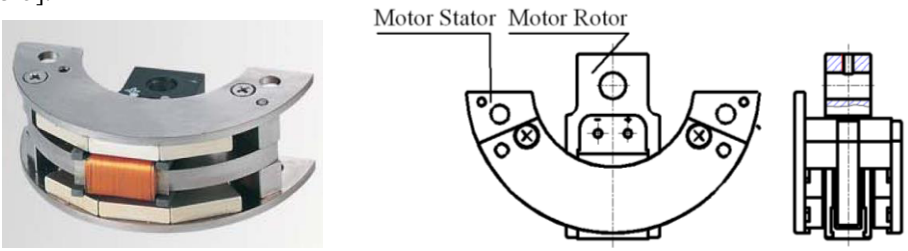

Figure 3. Structure of Rotary Voice Coil Motor

2.4 Control system

The control method is a closed-loop based on position feedback. The high-precision resolver, which electrical error is $\pm 15''$, provides the position feedback information. The control system is digitalized based on DSP servo controller. The detail control scheme is: Instructed by upper lever's parameters, DSP generates a position curve command corresponded, using the angle feedback from resolver, concurrently calculates the angle error. Then according to the control algorithm, adjust the voltage on the motor, through allocating the PWM duty cycle, the closed-loop position servo is achieved [6].

3 Measurement and life test

3.1 Tracking accuracy test

Based on all above researches, we designed and realized a tracking mechanism, which is shown in Figure 4. Then the tracking accuracy of is measured, and key parameters and test result is shown in Table 1. Through the test results we can see the tracking accuracy is better than $30''$.

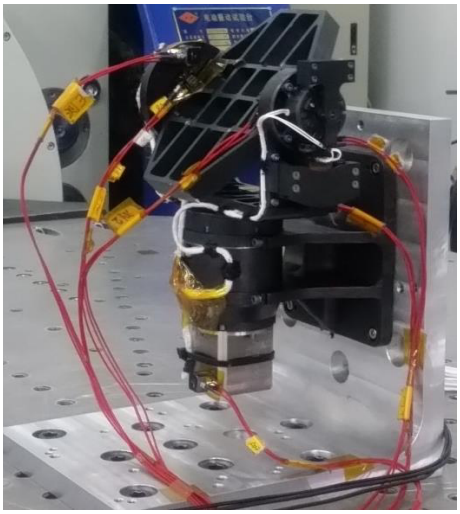

Figure 4. The tracking mechanism

Table 1. Key Parameters and Test Results

Load weight (Kg)	2.2
Load inertia (kgm2)	1.7E-2
Rotation range(º)	±6
Maximum load torque (Nm)	0.08
Torque coefficient of motor(Nm/A)	0.63
Electrical errors of resolver (″)	±15
Tracking accuracy (″)	±26.4

3.2 Lone life test

To demonstrate this tracking mechanism's long life, a life test is prepared. The basic signs of mechanism's long life stability include many features, first it should operate steady through the whole life test, second the tracking accuracy and maximum load torque and maximum output torque of motor should be stable, without any significant changes.

The tracking mechanism above was cycled for over 3.6E+06 cycles over a period of nine months, ±6° for each cycle.

We tested the maximum load torque of this tracking mechanism and maximum output torque of the voice coil motor every 4.0E+05 cycles. The test data is shown in Table 2, the trend of maximum load torque during the entail life test is shown in Figure 5, and the trend of maximum output torque during the entail life test is shown in Figure 6.

Table 2. The test of load and output for life test

Test num.	Total cycles	Operation test	Maximum load torque	Maximum output torque
0.	0	smooth	0.08	0.39
1.	4.0E+05	smooth	0.08	0.38
2.	8.0E+05	smooth	0.075	0.39
3.	1.2E+06	smooth	0.073	0.39
4.	1.6E+06	smooth	0.075	0.38
5.	2.0E+06	smooth	0.073	0.38
6.	2.4E+06	smooth	0.075	0.38
7.	2.80E+06	smooth	0.075	0.39
8.	3.2E+06	smooth	0.075	0.38
9.	3.6E+06	smooth	0.075	0.38

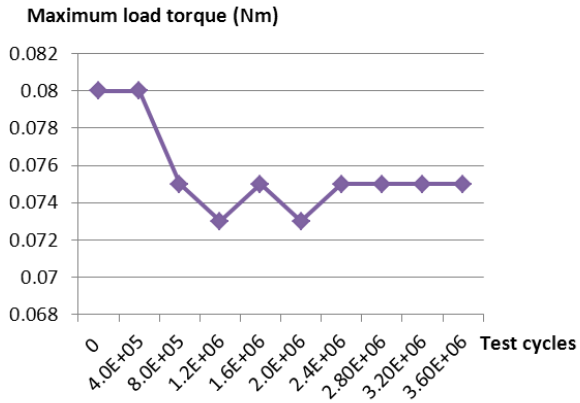

Figure 5. The trend of maximum load torque

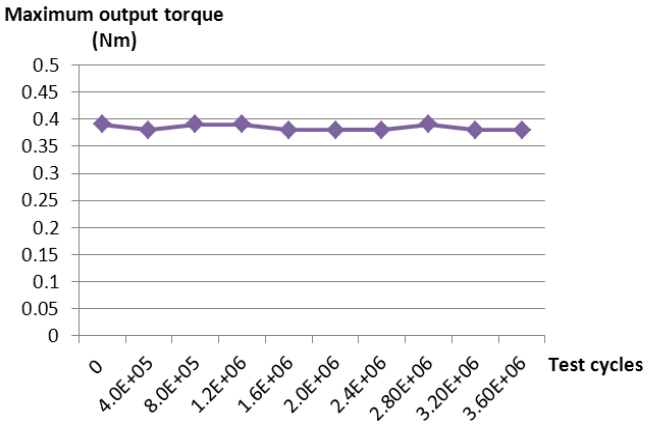

Figure 6. The trend of maximum output torque

Through the test data and trend of maximum load/output torque results we can see that the maximum load torque of mechanism has a slightly fluctuation in the early stages of the life test, after

that stabilized. While the maximum output torque of voice coil motor is stabilized during the entail life test.

Also the tracking accuracy is compared before and after the long life test, and test result is shown in Table 3. Due to the error of measurement system, small fluctuation of accuracy results should be partially ignored. Through the test results we can see that the tracking accuracy is stable after the 3.6E+06 cycles life test.

Table 3. The test of tracking accuracy for life test

Num.	Test items	Before life test	After life test
1.	Operation test	smooth	smooth
2.	Tracking accuracy (″)	±26.4″	±28.8″

Through this 3.6E+06 cycles and all the tests, the high precision and long life stability of this tracking mechanism is proved.

4 Conclusion

In summary, the design of high precision and long life tracking mechanism, which bearing by two flexural pivots and driven by a voice coil motor, got certain superiority on space optical instruments. The tracking accuracy can reach to 30″ , and the life of this mechanism can reach to 3.6E+6. This method is suitable for many similar pointing and scanning mechanisms in space products.

References

1. Y. Shouwang. The Research of Image Scanning Control System of Aerial Camera Based on VCM. FMP. D. (2011)
2. X. Xin-hang, W. Bing, H. Xu-dong, W. Heng-Kun, L. Ting-xia. Design of fast-steering mirror with spherical pair supporting structure driven by voice coil actuators. FMP. J. **19** ,6 : 1320-1324. Jun. (2011)
3. Z. Da-wei, F. Xiao-mei. The Technical Principle of Voice-Coil Actuator. SME. J. **27** ,3 : 224-228. Sum. (2006)
4. X. Lian-guo, Z. Hui-xing, H. Shu-lin, C. Rong-min. Research and Application of Voice Coil Motor. Mic. J. **44**, 8 : 83-88. Aug. (2011)
5. L. En-chao, L. Xin, Z. Yan-na, X. Chun-feng, Z. Xiao-bing. Design of Precise Scanning and Positioning Based on Voice-Coil Actuator. J. **9**, 5 : 384-390, Sep. (2014)
6. W. Chun, X. Nihui, L. Zhe. Application of Delta-Sigma Modulator in Space Pointer Mirror Position Servo System. SRRS. J. **35**, 5 : 54-60. (2014)