FRICTIONAL TORQUE CHARACTERISTICS OF PFPE LUBRICATED BALL BEARINGS UNDER OSCILLATORY MOTION IN VACUUM

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KEYWORDS
Friction; Fluid lubrication; Space tribology; Ball bearing

ABSTRACT
Some pointing mechanisms for earth observation sensors mounted on satellites, such as GOSAT, operate at a relatively narrow oscillation angle due to the characteristics of the observation mode[1]. GOSAT continues to observe CO_2 emission sources on Earth. To monitor these emission sources over a long period, the life of the pointing mechanism must be extended for future missions. In the authors' experience, when the ball bearing that supports the drive shaft oscillates within a small angle range, there are cases where the frictional torque gradually increases as the number of cycles increases, which affects the motor control system and deteriorates the motor positioning accuracy. To address this problem, we investigated the frictional torque characteristics when changing the oscillation angle using the presence or absence of a cage, ball material, and ball diameter as parameters. We then collected data that can be used to design future drive mechanisms.

The test bearings were angular contact ball bearings with an inner diameter of 25.4 mm, an outer diameter of 42 mm, and a width of 9 mm. Test bearings No. 1 to 4 were prepared, as shown in Table 1. Perfluoropolyether (PFPE) was used as the lubricant. The inner and outer rings are made of 440C stainless steel. In contrast to No. 1, Nos. 2 and 3 have load balls that support the load and spacer balls with a smaller diameter than the load balls placed alternately instead of the cage to eliminate the influence of cage contact. The ball material was 440C stainless steel for Nos. 1, 2, and 4, and Si_3N_4 for No. 3. For No. 4, a smaller ball diameter was used, and the effect on frictional torque was evaluated.

Each test bearing was paired and subjected to an oscillation test conducted at a vacuum pressure of 10^{-5} Pa or less, room temperature (approximately 23 °C), and a rotation speed of 5 r/min. The oscillation angle was adjusted in 0.1 deg increments from 0.1 to 2.9 deg. Three pairs of each test bearing were evaluated.

Figure 1 shows the relationship between the peak-to-peak value of frictional torque in clockwise and counterclockwise rotation after approximately 1.5×10^7 cycles and the oscillation angle. For No. 1, the frictional torque increased around the oscillation angle of 1 deg and around 2.5 deg. No. 2 showed almost the same tendency, and it can be assumed that the main cause of the frictional torque increase is contact between the balls and the inner and outer rings rather than contact with the cage. On the other hand, in No. 3 with Si_3N_4 balls, the frictional torque remained low even when the oscillation angle changed, as the wear resistance of the balls improved compared to stainless steel balls. No. 4 tended to have a slightly lower torque than No. 1, but compared to No. 3, the frictional torque increased significantly.

Table 1 Test bearings

Test bearing No.	1	2	3	4
Ball material	440C SS	LB: 440C SS SB: 52100 steel	LB: Si_3N_4 SB: 52100 steel	440C SS
Cage material	resin	none		resin
Ball diameter, mm	ϕ4.762	LB: ϕ4.762 SB: ϕ4.5		ϕ3.175

SS: stainless steel, LB: load ball, SB: spacer ball

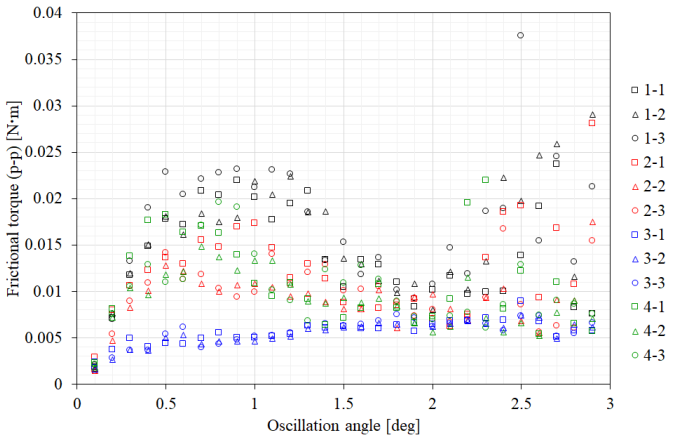

Fig.1 Frictional torque (p-p) vs oscillation angle

REFERENCES
[1] Yoshida, J. et al., "Investigation of the Long-Term Change of the TANSO-FTS Pointing Characteristics for a Future Agile Pointing Mechanism," Trans. JSASS Aerospace Tech. Japan, 17, 3, 2019, 339-343.