Ball Bearing Lubrication Regime Transitions in Vacuum – Bridging Test Rig Monitoring and Bearing Modelling

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The considerations involved in correctly estimating fluid film thickness through axial shaft displacement are described. Lubrication regime transitions are identified and correlated with contact resistance, axial vibration, and torque measurements. The effects of operation under boundary/mixed, EHD, HD regimes and of starvation on traction and bearing torque are explored. Experimental results obtained in the Advanced Bearing test Rig in vacuum are correlated to bearing model estimations using CABARET.

Keywords (from 3 to 5 max): vacuum, ball bearings, EHL, starvation, modelling

1. Introduction

The special requirements of space applications highlight the need for detailed complementary measurements of lubrication regime changes within bearings through life or variations with speed. The recently developed Advanced Bearing Test Rig (ABTR) allows concurrent measurement of bearing torque, axial shaft displacement, preload, contact resistance, and temperature, for a pair of angular contact ball bearings operating in vacuum [1]. Fluid film thickness estimation by interpretation of axial shaft displacement measurements is presented. The effects of regime transition(boundary/mixed/EHL) and starvation on torque and vibration are presented. Torque and film thickness are compared to modelling with CABARET, a quasi-static bearing analysis software developed at ESTL on behalf of the European Space Agency.

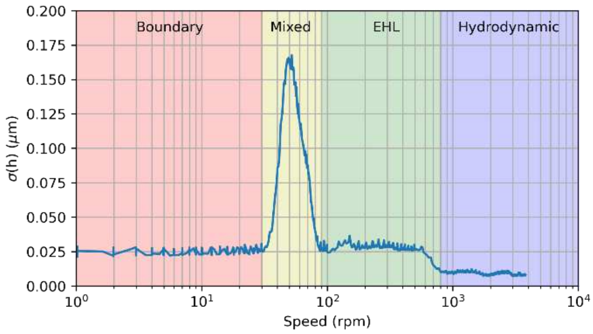

Fig.2 Identifying lubrication regimes using standard deviation of film thickness measurement from ABTR.

2. Observed Phenomena

Characterisation tests have been conducted on two space lubricants (a PFPE grease and its base oil) with varying temperature and preload. Observed effects include:

1. **Boundary lubrication and transition to EHL**: a shift of the apparent film thickness by a constant amount during the transition through mixed lubrication, requiring adjustment of film thickness calculation.
2. **Axial vibration modulated by the lubrication regime:** vibration amplitude peaks during passage through mixed regime and has discrete pleateaus in EHD and HD, attributed to the film effect on bearing stiffness (Fig.1).
3. **Starvation induced by oil fill** and **entrainment velocity:** its characteristic is an exponential decay with speed, which appears linear with a negative slope in log-log scale.
4. **Low-speed grease effect:** higher film thickness in the boundary regime for grease compared to oil, attributed to the effect of the thickener.

3. Modelling

As space bearings often operate under starvation and have strict torque restrictions, a method to estimate the resultant bearing torque using current state-of-the art regressions [2] of meniscus dimensions is being evaluated for inclusion in CABARET. With extension of the regressions to the conditions of the tested bearings, starvation corrected estimations may match the experimental results (Fig.2).

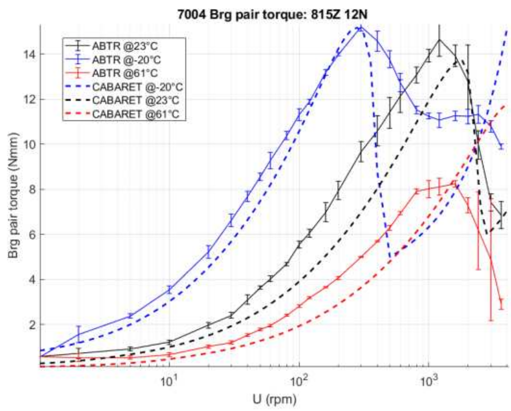

Fig.2 ABTR (measured) and CABARET (estimated) bearing pair torque vs speed and temperature.

4. References

[1] Vortselas, A. K., et al., 2019, “A Study Of The In-Vacuum Performance Of Space Lubricants In A Compliantly Preloaded Pair Of Angular Contact Ball Bearings Using The Advanced Bearing Test Rig,” Proc. 18. ESMATS 2019, Munich, Germany.

[2] Nogi, T., et al., 2017, “Starved Elastohydrodynamic Lubrication With Reflow in Elliptical Contacts,” J. Tribol, 140(1), pp. 501–509.