Friction and wear of self-lubricating composites used in transfer lubrication of ball bearing in space applications

Guillaume Colas [1]* Aurélien Saulot [2] Yann Michel [3] Tobin Filleter [4] Andreas Merstallinger [5]

[1] Univ. Bourgogne Franche-Comté FEMTO-ST Institute CNRS/UFC/ENSMM/UTBM, Department of Applied Mechanics, 24 rue de l'Epitaphe, F-25000 Besançon, France
[2] Université de Lyon, LaMCoS, INSA-Lyon, CNRS UMR 5259, France
[3] Centre National des Etudes Spatiales, 18 avenue Edouard Belin, 314001 Toulouse Cedex 9, France
[4] Department of Mechanical & Industrial Engineering, The University of Toronto, 5 King's College Road, Toronto, ON, Canada, M5S 3G8
[5] Aerospace & Advanced Composites GmbH, Viktor-Kaplan-Strasse 2, 2700 Wiener Neustadt, Austria
*Corresponding author: Guillaume.colas@femto-st.fr

Lubrication of space mechanism must be sustained in different environments, for long period of time, and without any maintenance possible. Transfer lubrication is a way to meet the challenge by lubricating ball/races contacts through transfer of materials from a cage made of composite material. Tribological test have been conducted on four self-lubricating composites (PTFE, MoS_2, fiber) in ultrahigh vacuum and humid air. Additional adhesion measurements have also been performed on the composites before and after friction. Fibers are shown to be critical in trapping mechanically and chemically the transferred material to lubricate and prevent instabilities.

Keywords (from 3 to 5 max): composite; lubrication; adhesion; vacuum; ball bearing

1. Introduction

Numbers of space mechanisms are expected to work multiple years, leading to very long wear life of the tribological components, [1,2]. In numbers of application, solid lubrication using coatings and composites materials is prefered [2,3]. This study focuses on investigating the tribological behavior of four self-lubricating composite materials, two commercially available and used, and two under development. For this study, a dedicated Double Transfer Test Bench (DTTB) has been designed. It fully emulates the cage/ball/race system through a two-contact configuration.

2. Methods

Tribological tests are performed on the DTTB set up. 3 samples are used: a steel disc and a plate to emulate the ball/race contact, and a composite pad (cylindrical shape) put in contact against the disc to emulate the cage/ball contact. Max Hertz contact pressure is 500 MPa at the disc/plate contact, and around 10 MPa at the pad/disc contact. A master/slave control is chosen to drive the disc rotation based on the plate motion. Reciprocating motion is chosen for the plate. Tests gather 3 different phases of 5000 cycles each: (A) running in with only the pad/disc contact to emulate the gentle run in; (B) rolling without sliding with both pad/disc and disc/plate contacts; (C) rolling with 0.5% sliding with both contacts to emulate severe working conditions
Gas analysis (in vacuum only), friction forces, and video (during phase A only) are performed/recorded during the tests. Post-test analysis to study the morphology and composition of the tracks are performed using optical microscopy, SEM, and EDS. Adhesion measurements are performed on the composites before and after friction. Adhesion is measured on AFM using custom made cantilevers with steel and borosilicate microbeads. Interaction between composites components and the steel are studied

3. Results & Discussion

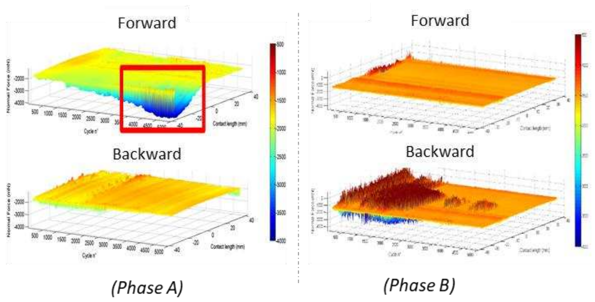

Figure 1: Variation in the normal load at the pad/disc interface, in vacuum. Material: commercial Duroïd 5813

The DTTB allowed to reproduce instabilities and the generation of large particle inside the contact (Fig 1) which induces large variation in the normal force (phase A). 3rd body morphologies similar to those observed on bearing are achieved, which gives confidence in the results. Post-test analysis and adhesion measurements demonstrate the crucial role of fibers in controlling the transfer of material and the success of lubrication.

4. References

[1] J. Sicre, *et al*, PGM-HT as RT/Duroïd 5813 replacement? Lifetime results on STD earth scanning sensor and polder bearing shaft, Proc. 13th ESMATS, ESA SP 670 (2009).
[2] E.W. Roberts, Space Tribology Handbook 5th Edition, European Space Tribology Laboratory, Warrington, U.K, 2013.
[3] J.R. Lince, Effective Application of Solid Lubricants in Space Mechanims, Lubricants. 8 (2020) 74.