7th World Tribology Congress, WTC 2022
July 10-15, 2022, Lyon, France

Tribofilms on Turbine Engine Bearing Steels and Lubricants Part 2 – WTC 2021, Lyon

Mathew Kirsch[1)] *, Daulton Isaac[1)], Patrick Hellman[1)], Daesung Chong [2)],

[1)] Engine Mechanical Systems Branch, United States Air Force Research Laboratory, WPAFB, OH, USA
[2)] University of Dayton Research Institute, Dayton, OH, USA.
*Corresponding author: mathew.kirsch@us.af.mil

Aerospace bearings operating at high speeds while lightly loaded have an increased likelihood of experiencing scuffing and subsequent catastrophic failure. In previous testing, aerospace bearing steels have exhibited varying resistance to scuffing under similar test conditions. It is believed that these variations are due to the formation of beneficial tribofilms on some steels. Some research has been performed to understand tribofilms on aerospace bearing steels, but extensive characterization has not been attempted. In this work, a multi-technique approach is used to characterize the morphology, thickness, composition, and mechanical properties of tribofilms formed on various bearing steels.

Keywords: scuffing, tribofilms, Pyrowear 675, M50, microscopy

1. Introduction

Much research has focused on fully characterizing the phosphate tribofilms formed due to the reaction of anti-wear additives found in automotive lubricants, namely ZDDP, and traditional automotive bearing steels like AISI 52100. By comparison, relatively little literature exists regarding the tribofilms formed on aerospace bearing steels by the anti-wear additives found in MIL-PRF-23699 lubricants. Using previous investigations of ZDDP characterization as a template [1,2], a series of characterization tools including Scanning Electron Microscopy (SEM), Focused Ion Beam (FIB) and X-ray Photoelectron Spectroscopy (XPS) will be utilized to investigate the morphology, thickness, composition and interfacial mechanical properties of the tribofilms generated in Part 1 of this paper.

2. Methods

2.1. Materials

A selection of common bearing steels of various types are investigated including a through-hardened tool steel (M50), a carburizing stainless (Pyrowear 675) in two tempering conditions with differing surface hardness, a high nitrogen stainless (Cronidur 30), as well as nitrided, and carbonitrided variants of those above listed steels.

2.2. Electron Microscopy

SEM analysis reveals high resolution morphological information of the surface within the tested areas and coupled with Energy Dispersive Spectroscopy (EDS), large areas can be chemically characterized in the near surface. Additionally, the use of Dual Beam FIB-SEM can be utilized to create cross-sections within the tested track to examine the subsurface for deformation and deformation induced transformations as well as measure the thickness of tribofilms formed on the surface.

2.3. X-ray Photoelectron Spectroscopy

XPS excels at revealing the composition and chemical bonding within the first few nanometers of the surface. With the addition of ion-beam milling, depth profiling can be accomplished for high resolution characterization of tens of nanometers at the surface. With the use of XPS depth profiling, the chemical nature of any tribofilms formed on the surface can be probed along with the interface between the tribofilms and the steel substrate.

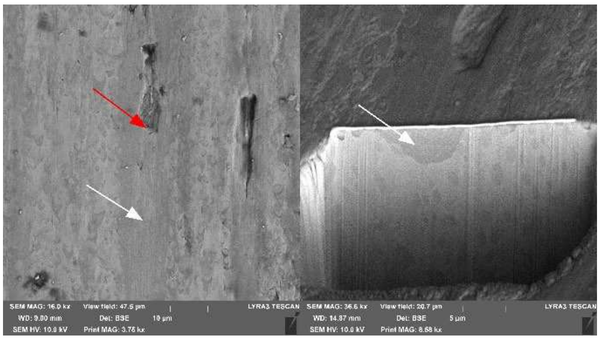

Figure 1: Adhesive wear damage on P675 after a 30% slip test in a self-mated configuration. Adhesive damage present at red arrow. Dissolution of carbides at white arrows.

3. Discussion

Figure 1 shows back-scattered electron images of both the surface (left pane) and cross section after FIB milling (right pane) of a Pyrowear 675(P675) adhesive wear test track. The red arrow indicates an area of adhesive damage while the white arrows point to a transformed region depleted of hard-carbides. This analysis indicates that the tribofilms formed on P675 was insufficient to prevent metal on metal contact at the test condition presented. Further investigation is being performed to better understand this phenomenon.

4. References

[1] Pereira, G. et al., "A multi-technique characterization of ZDDP antiwear films formed on Al (Si) alloy (A383) under various conditions," *Tribology Letters*, 26, 2, 2007, 103-117.

[2] Philippon, D. et al., "A multi-technique approach to the characterization of iron phosphide tribofilms," Thin Solid Films, 524, 2012, 191-196.