# Tribofilms on Turbine Engine Bearing Steels and Lubricants Part 1 – WTC 2021, Lyon

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Aerospace bearings operating at high speeds while lightly loaded have an increased likelihood of experiencing scuffing and subsequent catastrophic bearing failure. Bearing steels exhibit varying resistance to scuffing, and it is thought this is influenced by a steel's ability to form a tribofilm to protect the underlying material in low specific film thickness conditions. Thus far, only a limited amount of work has been done to characterize the tribofilms formed on these steels. This work uses a chromatic confocal optical profilometer to study the morphology of the tribofilms formed on various bearing steels tested in the same MIL-PRF-23699 lubricant.

**Keywords:** scuffing, tribofilms, Pyrowear 675, M50, Enhanced Ester

## 1. Introduction

Various tribological tests to investigate and compare the scuffing resistance of aerospace bearing steels have revealed the tendency of different steels to experience a catastrophic scuff. The composition of the oxides present on the surface of these steels differ, e.g. iron oxide for some or chromium oxides for others, and this along with other factors affect how a steel reacts with turbine engine lubricants. The nature of this reaction is believed to be the distinguishing mechanism whereby some steels exhibit excellent scuffing resistance where as others show poor behavior under the same conditions [1]. In order to investigate this hypothesis, various aerospace bearing steels are tested and the resulting tribofilms studied with particular attention to growth rate, morphology, and wear resistance.

## 2. Methods

2.1. Experimental Setup

To develop tribofilms under conditions similar to bearing applications in a manner suitable for extensive study, a ball-on-disk tribometer is used. The load, speeds, and temperatures are controllable, and sample materials and surface roughness are selectable. Table 1 shows a subset of conditions under which tribofilms can be generated.

Table 1: Typical Test Parameters

| | |
|---|---|
| **Load / Stress [N/GPa]** | 630 / 2.0 |
| **Entraining Velocity [m/s]** | 0.65 |
| **Sliding Velocity [m/s]** | 0.35 |
| **Temperature [°C]** | 150 |

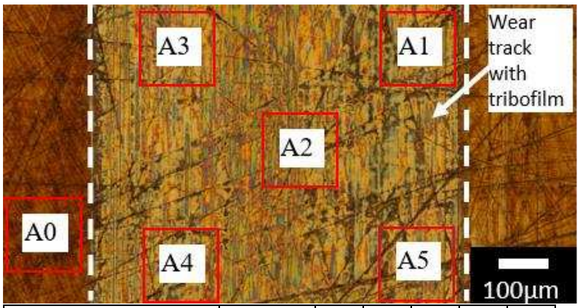
For streamlined documenting of the tribometer samples, an optical microscope as well as a separate chromatic confocal optical profilometer are attached to the rig. The profilometer provides topography data for the wear track and surrounding regions in three dimensions with nanometer resolution.s

2.2. Materials

A selection of common bearing steels of various types are investigated including through-hardened tool steel (M50), carburizing stainless (Pyrowear 675), high nitrogen stainless (Cronidur 30), as well as nitrided, and carbonitrided variants of some of those above listed steels. The disparity seen in the adhesive wear resistance of these steels would suggest that their film formation behavior will also vary and correlate with their scuffing resistance [2]. A fully formulated MIL-PRF-23699 Enhanced Ester (EE) Class lubricant is used for all testing, and select tests are also ran using the same lubricant with the anti-wear additive removed.

2.3. Results

The in-plane and thickness characteristics of the tribofilm can be studied using profilometry data such as that depicted in Figure 1. Here a step height tool is used to ascertain the film thickness above the unrubbed surface which is used as the reference.




| Measurement Area | A0(Ref) | A1 | A2 | A3 | A4 | A5 |
|---|---|---|---|---|---|---|
| Step Height (nm) | N/A | 59 | 44 | 164 | 92 | 55 |

Figure 1: Image of tribofilm shown within white lines, and film thickness determination

## 3. Discussion

The films are seen to be pad-like with regions of little to no film growth. The thickness is seen to vary greatly with preferential growth in the A3 and A4 regions.

## 4. References

[1] Trivedi, H. K. et al., "Effect of Silicon Nitride Ball on Adhesive Wear of Martensitic Stainless Steel Pyrowear 675 and AISI M-50 Races with Type II Ester Oil," Tribology Transactions, 59, 2, 2016, 363–374.

[2] Wedeven, L. et al., "Advances in Aeropropulsion Tribology and Design Using Five Key Parameters," WIT Transactions on Engineering Sciences, 66, 2010 83–94.