Tribology and chemistry of degraded jet engine lubricants

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The degradation of jet engine lubricants was studied using a ball-on-three-pin (BO3P) tribometer system and liquid chromatography coupled with an ultraviolet-visible (UV-vis) detector. Additional studies were conducted with model mixtures of lubricants aged as a 6 mm thick film at 180°C in a stainless steel dish to investigate the relationship between the tribological properties and the chemical composition of the fluid. A correlation was found between the decrease of the friction coefficient as measured by the ball-on-three-pin system and the formation of degradation products from the ester and initial antioxidants during the oxidation of the lubricants.
Keywords (from 3 to 5 max): tribology, chromatography, lubricant, jet engine

1. Introduction

Lubricants in a jet engine bearing chamber serve to cool and reduce wear of rotating parts. While doing so, lubricants are exposed to high temperatures and undergo hundreds of thermal cycles per hour of flight which *in fine* oxidizes the fluid. To cope with the ever increasing performance demand of the jet engine industry that result in harsher oxidizing conditions for the lubricants, one must study the degradation of oils. Thereby, we propose a study through tribology and chemistry.

2. Experimental

To quantify the lubricants ability to reduce wear, we have studied the evolution of the friction coefficient using a lubricated BO3P rotating system (Figure 1). To investigate the chemical changes in the lubricants, a high performance liquid chromatography (HPLC) was used with a UV-vis detector. Finally, model mixtures of lubricants were aged using a circular stainless steel dish in order to investigate the relationship between the tribology and the chemistry of the fluids.

2.1. Ball-on-three-pin

The tribometer system is a MCR 302 unit manufactured by Anton Paar. Ball and pins, provided by Anton Paar, are made of steel and the measurements were done at ambient temperature using a normal force that was set to 0,47kg.m.s^{-2} +/- 0,01kg.m.s^{-2}.

2.2. High performance liquid chromatography

Reverse phase chromatography was employed to separate the chemicals found in the lubricants. The UV-vis detector was set to 254 nm to analyse the separated chemicals.

2.3. Thin film ageing setup

A circular stainless steel dish was filled with 65 cm^3 of lubricant (which translated to a thickness of 6 mm) and heated to 453,15 K using a hot plate to replicate a thin film oxidation situation.

3. Discussion

Although the rolling materials, temperatures and pressures encountered in a jet engine bearing chamber are well different from those mimicked by the sliding BO3P system, it remains a convenient, easy to use and repeatable system to investigate a lubricants tribological properties at a laboratory scale.

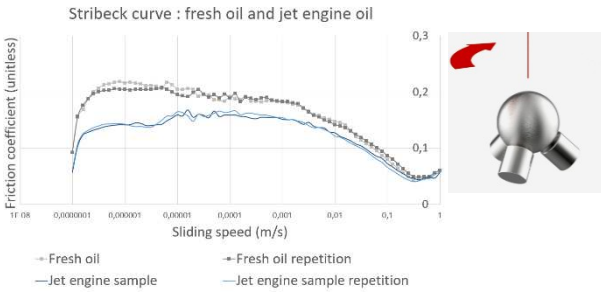

Figure 1: Stribeck curve for fresh and used lubricant samples, obtained with a BO3P system.

This setup allowed us to measure a lower friction coefficient for a jet engine sample when compared to fresh lubricant suggesting that the ageing mechanism of oils confers it better lubricity properties. (Figure 1). Two more lubricants meeting SAE-AS5780 specifications, one of which is classified as high performance capability (HPC) oil, showed the same trend. However, the fresh HPC oil showed a generally lower friction coefficient when compared to the other fresh standard performance capability (SPC) oils. When analyzed with the HPLC system, SPC and HPC oils showed little differences, the main one being the antioxidant package which consists of oligomeric compounds in the HPC oil. Such oligomeric compounds are known to be formed from monomeric antioxidants that can be found in SPC oils [1] partly explaining why aged SPC oils have a similar friction coefficient to fresh and aged HPC oil. Finally, model mixtures aged as thin film allowed us to extract the kinetics tendencies for the formation of the degradation compounds, oils which ultimately gives us a better grasp of what happens to an ageing oil.

4. References

[1] Gatto, V. J. et al., "Study on the degradation and synergistic/antagonistic anioxidzing mechanism of phenolic/aminic anitoxidants and their combinations" Lubr. Oils, 2014, 29, 45-55.