Investigation of Environmentally Acceptable Lubricants for a Hydrodynamic Stern Tube Bearing Using Various Testing and Modelling Methods

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To minimize the negative environmental risk and impact of mineral oils entering the marine environment, recent legislation requires the use of environmentally friendly lubricants (EALs) for marine stern tube bearings. During misalignment conditions, these hydrodynamic contacts experience high loads, high film pressures, high temperatures, and high shear rates. This study investigates the effects these conditions have on the EAL products compared to a traditional mineral oil product. Comparisons are achieved over a range of standard lubricant tests, along with two bespoke hydrodynamic test programs.

Keywords: Rheology; Environmentally Friendly Lubricants; Fluid lubrication; Hydrodynamic Lubrication; Experiments in tribology

1. Introduction

Stern tube bearings are large hydrodynamic plain bearings that support the propeller shaft at the rear of a marine vessel, Figure 1. In 2013 the VGP regulation was introduced that commercial vessels larger than 79 feet must use Environmentally Acceptable Lubricants (EALs) at all oil-to-sea interfaces to reduce negative impact on the marine ecosystem. These EALs perform as well as their mineral oil counterparts using standard lubricant testing methods, however industrial users have reported discrepancies in their performance in the field.

When a vessel makes a hard turn, the bearings experience misalignment and result is an extremely aggressive highly loaded lubricated tribosystem with high temperatures, high pressures and high shear rates.

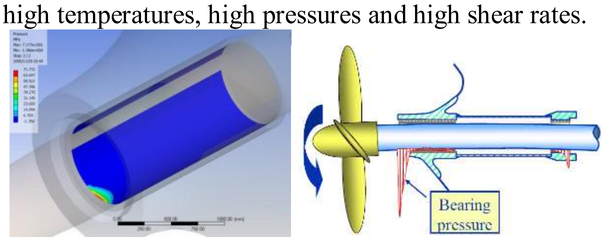

Figure 1: (Left) FEA analysis of bearing load & (Right) schematic diagram of stern tube under high load.

The aim of this investigation was to understand the effects of these different EAL products attempting to differentiate between shear-viscosity, pressure-viscosity, and temperature viscosity effects.

2. Method

In order to understand the different performance characteristics of a range of EAL and mineral oil products, the following testing was undertaken:

- Temperature-viscosity testing
- Rheological testing over a range of shear rates
- Pressure-viscosity testing
- MTM testing
- Journal bearing testing & modelling
- Thin shim rig hydrodynamic testing

3. Results

The EAL products all reported lower pressure-viscosity coefficients than the mineral oil sample as shown in Figure 2. Conversely they all displayed a higher viscosity index and thus maintained a higher viscosity as temperature increased.

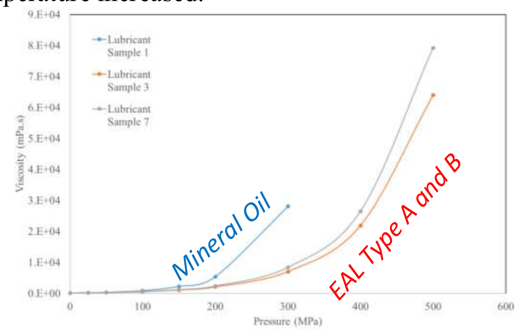

Figure 2: Pressure-viscosity measurements.

Figure 3 shows the measured journal bearing hydrodynamic film thicknesses over a range of loads for the different lubricant samples at 65°C.

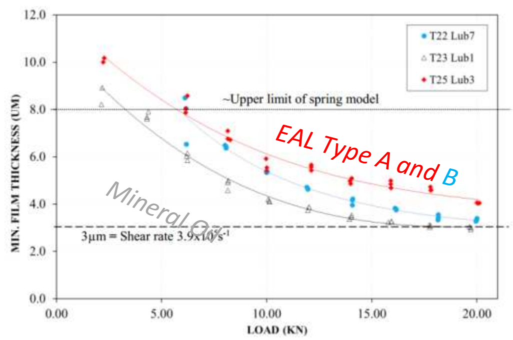

Figure 3: Film thickness measurements.

4. Discussion

The EAL products show lower pressure-viscosity effects, but in a hydrodynamic contact, the temperature-viscosity relationship has a dominant effect on the lubricant film thickness.