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# Characterizing Fuel Dilution Effects on Rheological and Tribological Behavior of Engine Lubricant

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Excessive fuel dilution into a crankcase may undesirably accelerate bearing wear due to reduced lubricant viscosity and film thickness. However, a comprehensive understanding of fuel dilution effects on lubricant performance is not yet revealed. In this paper, diesel-diluted, gasoline-diluted, and neat fully-formulated engine lubricant are separately assessed through experimental investigation, with measurements 1) of viscosity at swept shear rates (up to $10^7$ $s^{-1}$), 2) of lubricant film thickness under elastohydrodynamic (EHD) condition, 3) of Stribeck frictions showing lubricant performance throughout full-film/mixed lubrication regimes, and 4) of boundary friction and wear. Results show fuel dilution reduces lubricant viscosity differently as dependent on shear rates and contact pressure, on the other hand, inhibits friction additives more than surface additives.

**Keywords:** fuel dilution, lubricant, viscosity, additive, friction

## 1. Introduction

Fuel dilution effect is a thriving research area that is especially meaningful for automotive manufacturers in terms of lubricant development and engine efficiency improvement [1]. To comprehensively understand fuel dilution effects on engine lubrication performance, this study aims to characterize 1) how fuel dilution changes lubricant viscometrics in terms of shear thinning and contact pressure dependency, and 2) how fuel dilution affects lubricant performance additives throughout full film/boundary lubrication regimes.

## 2. Methods

In terms of the assessment on diesel dilution effects, a group of lubricant are properly selected, including 1) a representative fully-formulated lubricant, neat Shell Helix 0W-30 Ultra Professional AJ-L (denoted “0W-30” in the present work), 2) the above “0W-30” blended with diesel at a concentration of 15% by weight (denoted “0W-30D” in the present work). 3) “0W-16”, which is blended with the same composition of base oil and performance additives as 0W-30, but contains a lower concentration of viscosity modifier additive so as to give low pressure/low shear viscosity equal to that of 0W-30D, 4) the base oil as commonly in 0W-30, 0W30D and 0W-16, and 5) the diesel. It worth noting that 0W-16 is added here to reveal whether discrepancies between “0W-30” and “0W-30D” are solely caused by rheological nature.

Similar selection procedures are also applied to the investigation of gasoline dilution effects.

2.1. Viscometrics and shear rate, pressure dependency
A Stabinger viscometer is employed to measure the viscosity of selected lubricant, before Walther mixing rule [2] applied to theoretically calculate viscosity against fuel concentration. Tests with an Ultra Shear Viscometer (USV) are preformed to show the shear thinning behavior with the shear rate swept up to $10^7$ $s^{-1}$.

2.2. Stribeck friction force and film thickness
The film thickness and friction forces under EHD towards mixed lubrication regimes are measured by an Ultra-Thin Film Interferometry (UTFI) and a Mini Traction Machine (MTM) respectively, before friction and wear at the boundary lubrication regime quantified by a High Frequency Reciprocating Rig (HFRR).

2.3. Case study of engine journal bearing lubrication
A real connection rod is modified and fit in a Journal Bearing Machine (JBM, as shown in Figure 1) to perform Stribeck friction measurements with swept steady-state engine loads.

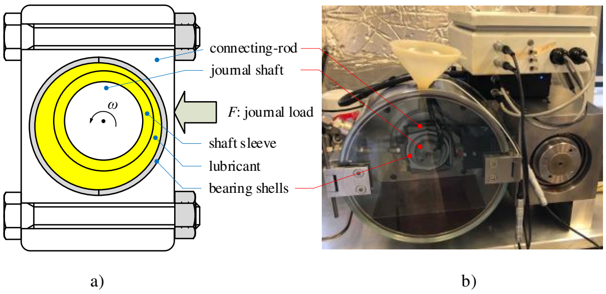


Figure 1: a) illustration of journal bearing lubrication and b) Stribeck friction tests in a journal bearing machine.

## 3. Discussion

Fuel dilution effect in the hydrodynamic lubrication regime is solely a reduction in lubricant viscosity. The existence of diesel hinders polymer additives bonding and acting on the contacted surfaces, thus introducing more frictions in mixed lubrication regime, whereas the diesel dilution rarely inhibits surface additives under boundary lubrication condition. All of these also correspond to Stribeck friction measurements in a journal bearing machine. Moreover, care must be taken in using viscometrics to predict dilution behavior due to its dependence on shear-rate and pressure.

## 4. References

[1] Holmberg, K., *et al.* (2012). Global energy consumption due to friction in passenger cars. *Tribology International*, 47, 221-234.

[2] Centeno, G., *et al.* (2011). Testing various mixing rules for calculation of viscosity of petroleum blends. *Fuel*, *90*(12), 3561-3570.