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Film Forming Properties of Polyalkylene Glycol Aqueous Solutions and its Sol-Gel Transition in Elastohydrodynamic Lubrication Regime

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The film forming properties of polyalkylene glycol (PAG) aqueous solutions with several concentrations were investigated in elastohydrodynamic lubrication regime. We identified the gelation temperature of PAG aqueous solutions and analyzed the film forming mechanisms for concentrations and temperatures below and above the sol-gel transition. The film thickness evolution of the neat PAG and the PAG aqueous solutions as a function of entrainment product showed that the continuous phase of the PAG solution governs the iso- or piezo-viscous response in the film forming mechanisms.

Keywords: polyalkylene glycol, film forming mechanism, sol-gel transition, iso- vs piezo-viscosity

1. Introduction

Polyalkylene glycol (PAG) is one of the most widely used material for water containing lubricants such as hydraulic fluids and metal working fluids. The film forming properties of PAG aqueous were investigated using different molecular weight and concentration [1] and was correlated to their sol-gel transition.

2. Experimental

2.1. Lubricants

Aqueous solutions were prepared with deionized water and ADEKA Pluronic L-64 polymer concentration varying from 10 to 100%.

2.2. Viscosity measurement

The lubricant rheology was measured on a cone-plane rheometer AR2000 (TA Instruments) with a cone diameter and angle of 60 mm and 2°, in the range 15-60°C and fixed shear rate of 0.1, 1.0 or 10.0 s^{-1} depending on aqueous viscosity.

2.3. Film thickness measurements

A lubricated contact was established between a AISI52100 ball with diameter of 19.05 mm and a silica disc coated with a semi-reflective chromium layer and a silica spacer layer. Film thickness measurements were conducted using optical interferometry on the IRIS tribometer [2] in pure rolling with the entrainment velocity ranging from 0.05 to 0.8 m/s and applied load of 15N at room temperature.

3. Results and Discussion

The gelation temperature was defined as the temperature where the viscosity reaches a minimum before a steep increase. Figure 1 shows the gelation temperature, the transition between aqueous solution and gel as a function of PAG content. The film thickness of the neat PAG and PAG aqueous solutions for which the gelation temperature is lower than the test temperature increased with the entrainment product (Figure 2), following a piezo viscous behavior. For those with a gelation temperature higher than the test temperature, the slower increase in thickness with entrainment product suggests an iso-viscous behavior. This showed that the continuous phase of solutions governs the film forming capability. The effect of the inlet zone properties were also discussed.

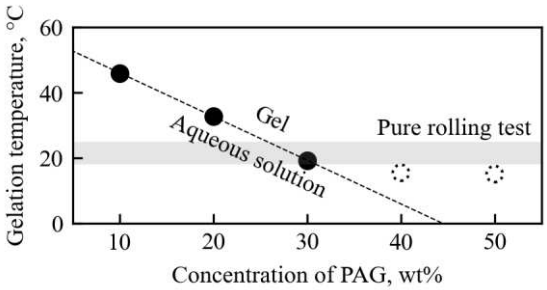

Figure 1: Gelation temperature vs PAG concentration. The transition boundary was drawn as dashed line. The test temperature was indicated with the gray zone.

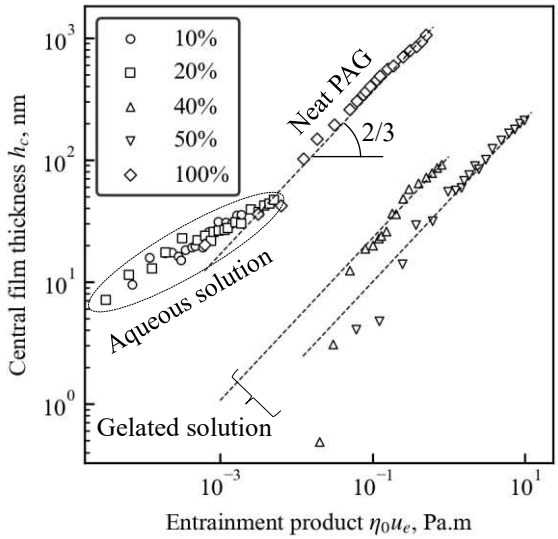

Figure 2: Central film thickness of the PAG aqueous solutions. The dashed line follows $h_c \propto \eta_0 u_e^{2/3}$ although the exp. data at lower concentrations, diverging from this trend were highlighted.

4. References

[1] C. H. Zhang, et al., "EHL Properties of Polyalkylene Glycols and Their Aqueous Solutions," Tribol Lett, 45, 2012, 379-385.

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