High Pressure Viscosity of Group III Base Oil Lubricants Modified with Polymeric Additives and their Modeling with Free-Volume and Density Scaling

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Group III base oils are mainly composed of cycloalkanes and paraffins and are often used as the main component in lubricants and transmission fluids. They are commonly modified with additives to improve their performance. This study examines the effects of functionalized additives of different molecular weights and concentrations on the viscosity and the volumetric properties of selected Group III base oils as a function of pressure (from 10-40 MPa) and temperature (at 25, 50, 75 and 100 ^{o}C).

The viscosity is measured at high pressure and temperature conditions with varying shear rates using a uniquely designed rotational viscometer. This viscometer consists of a rotating cylindrical shaft with jewel bearings to reduce the friction. A magnet is embedded in the shaft on the top to allow magnetic coupling of the shaft to an outside torque transducer which allows the rotational speed to be controlled without compromising the sealing arrangement of the system.

The density is determined under high pressure and temperature conditions using a variable volume view cell. The density is fit to the Sanchez-Lacombe (SL) equation of state along isotherms ranging from 25˚C to 125˚C across pressure scans from 10-40 MPa. The SL descriptions of density are then used to evaluate the derived thermodynamic properties such as the isothermal compressibility, isobaric expansivity, and internal pressure.

Viscosity is then modeled with density using both the free-volume or density scaling formalisms. Both models correlate the viscosity well. The density scaling approach reduces all the data generated at different pressures and temperatures into a master curve if the data is plotted as a function of (ρ^{γ}/T) where the exponent γ is the scaling parameter.