HIGH PRESSURE RHEOLOGY

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Summary

High-pressure rheology plays an important role in many areas of science and technology. For instance, the accurate determination of the pressure-temperature-viscosity relationship is very important in lubrication science and in the polymer industry. In spite of its importance, the influence that pressure exerts on materials mechanical properties has been less studied than the influence of temperature, mainly due to the well-known difficulty to develop reliable rheological equipment for conducting rheological tests under pressure. High-pressure rheology combines conventional experimental techniques on rheometry with those specific for high-pressure analysis. The pressure-temperature behavior of Newtonian simple materials, such as organic low molecular weight liquids, is well described by simple expressions of viscosity as a function of pressure and temperature. For time-dependent non-Newtonian materials, such as complex mixtures, suspensions, emulsions, high molecular weight polymer solutions and melts, etc., the effect of pressure on the rheological behavior is much more complex. Consequently, more sophisticated analysis, such as, for instance, reduced variables and time-pressure-temperature superposition methods, are necessary.

1. Introduction

High-pressure rheology plays an important role in many areas of science and technology. For instance, the accurate determination of the pressure-temperature-viscosity relationship is very important in lubrication science, because the liquid lubricant is submitted to high pressures, and large shear rates, over a wide range of temperature. In the polymer industry, processing parameters such as pressure and temperature are essential in order to obtain the desired quality in products made by extrusion, injection molding, compression molding, etc.

The effect of pressure on viscosity is quite small for most organic liquids. Generally, the viscosity approximately doubles its value when the pressure is increased from atmospheric pressure to 100 MPa. On the contrary, for lubricating liquids, pressures of the order of 1 GPa in the point of contact may increase the viscosity of the lubricant in several decades. For polymer injection molding, pressures of about 0.1 GPa may increase between 10-100 times the viscosity of the melts, depending on polymer molecular weight. It is worth pointing out that water, at ambient temperature, is an exception to the general evolution of viscosity with pressure. Thus, water viscosity decreases as pressure increases up to about 0.1 GPa (Barnes, 2000).

In spite of the importance of pressure in many processes and phenomena, the influence that pressure exerts on materials mechanical properties has been less studied than the influence of temperature, mainly due to the well-known difficulty to develop reliable rheological equipments for conducting rheological tests under pressure. Simple materials, such as organic low molecular weight liquids, are well characterized by its Newtonian viscosity. Their pressure-temperature behavior is well described by simple expressions of viscosity as a function of pressure and temperature. For time-dependent non-Newtonian materials, such as complex mixtures, suspensions, emulsions, high molecular weight polymer solutions and melts, etc., the effect of pressure on the rheological behavior is much more complex. Consequently, more sophisticated analysis, such as, for instance, reduced variables and time-pressure-temperature superposition methods, are necessary.

2. Experimental Techniques for High-pressure Rheology

High-pressure rheology combines conventional experimental techniques on rheometry with those specific for high-pressure analysis. Working under a pressurized medium implies a deep knowledge of high-pressure methods. Thus, for instance, for the piston-cylinder system, the classical theory of elastic and plastic deformation of the cylinder is of paramount importance in order to give an insight into the deformation and stresses in high-pressure cells. The effect of temperature on high-pressure equipments must be also taken into account, since high-pressure rheology studies may be accomplished in the low and/or high temperature regions. Finally, reliable techniques for detecting pressure values, transmitted torque, and measured deformation in systems that operate at high pressure are necessary in order to obtain useful rheological parameters.

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