583e Rotational Rheometry of Polymers under High Pressure Carbon Dioxide

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Polymer based foams can be used in many applications, such as packaging, insulation, and even scaffolds for tissue engineering. Carbon dioxide (CO_2) is a new physical blowing agent for foams. To expedite the introduction of CO_2 to industrial foaming applications, it is important to understand its effects on viscosity, since viscosity is so important to foam extrusion. Several studies have measured the viscosity of polymer melts under high pressure, using a variety of techniques. However, few studies assist in foaming design because most do not contain predictive scaling. Here scaling factors are used. The pressure and concentration shift factors are defined, respectively, as follows:

(1)

(2) There are some minor differences in the definition of the shift factors, but the definitions are all similar. The product $a_c a_p$ should be conceptually the same for all studies. These shift factors are completely analogous to WLF time-temperature superposition [1]. Of the studies that report predictive scaling, none contain measurements in the low shear rate region. The reason is that these studies use extrusion slit dies and capillary rheometers to measure CO_2-impregnated viscosity. Accurate characterization of the entire viscosity curve is needed for die design in foam extruders. If the viscosity at low shear rates is off by a factor of two (very likely based on the noise of previous experiments), simulations predict significant deviations in properties, such as pressure drop and viscous heating. In this study, a high pressure couette rheometer is used to measure the viscosity of polymer melts under a carbon dioxide atmosphere. Rotational rheometry overcomes the capillary/slit problem of averaging pressures since the polymer reaches equilibrium with its headspace (static pressure). Furthermore, it has the ability to measure low shear rates that often correspond to the Newtonian regime (zero-shear viscosity). Preliminary results were obtained using polystyrene (PS). The zero-shear viscosity of PS-CO_2 was directly measured for a variety of CO_2 concentrations and temperatures. The viscosity depression due to carbon dioxide is much more significant than those in the literature using high shear rate rheometers [2-4]. **References.** 1. M. L. Williams, R. F. Landel and J. D. Ferry, *Journal of the American Chemical Society*, 77 3701 (1955).

2. C. Kwag, C. W. Manke and E. Gulari, *J. Polym. Sci. B: Polym. Phys.*, 37 2771 (1999).

3. J. R. Royer, Y. J. Gay, J. M. Desimone and S. A. Khan, *J. Polym. Sci. B: Polym. Phys.*, 38 3168 (2000).

4. R. Gendron and M. F. Champagne, *SPE ANTEC Proceedings*, 1747 (2003).