Study of Rheological Behavior of Polymers

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Introduction:

Rheology is the science dealing with deformation and flow of liquid-like materials such as polymer melts[1]. It provides necessary knowledge for processing plastics or other polymers into products. Liquid-like materials in many industrial processes possess a wide range of flow behavior. Satisfactory operation of these processes requires a knowledge of the material's flow properties under operational conditions[2]. Thus, understanding rheological behavior of materials can help improve the processing technology. Moreover, rheological behavior of polymer melts will also affect the ultimate material properties of products.

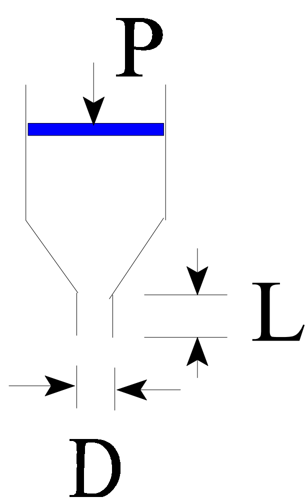

Figure 1 Principle of capillary rheological testing system

Rheometry is the art of measuring deformation and flow properties of materials. Figure 1 shows the principle of a typical capillary tube viscometer[3]. Capillary rheometer is one of the simplest and most widely used instruments for rheological characterization. The barrel temperature is maintained at a preset level by a temperature controller. Thus, the polymer pellets in the barrel will be heated to and maintained at a constant temperature. A plunger drives the sample material through a slit capillary at either constant or programmed flow rate. When using slit capillaries, one can measure the pressure difference directly in the capillary. Viscosity is measured in terms of the pressure difference at certain shear rate.

Capillary rheometry has found its main area of application in the measurement of polymer melt viscosities at shear rates below 1000 s^{-1} and at temperatures up to 500 ºC [4]. There are many advantages in using capillary rheometers. These include the relative ease of filling, the ability to change temperatures and shear rates readily, the similarity in shear rates and flow geometry to those actually found in extrusion, the ability to detect some indication of polymer elasticity, and the ability to study the surface texture of the extrudate. The main disadvantage of the technique is that shear rate varies across the capillary, and that corrections are needed in order to obtain accurate viscosity values.

Rheological behavior of polymers not only provides insights for polymer processing such as injection molding or extrusion, but also offers understanding on change in the polymeric structure due to processing. This paper describes a typical capillary rheological testing system and its application to study the viscosity of polymer melts at various strain rates and temperatures. Experimental data will be presented for rheological behavior of composites made of recycled high density polyethylene (HDPE) and recycled rubber particles.

Equipment:

1. Polymer pellets or blends to be tested.
2. Rheological testing system including load frame, temperature controller, and data acquisition system.
3. Mittens or gloves for high temperature applications.
4. Cleaning tools such as brass brushes, cotton balls etc.
5. Time watch
6. Digital balance.

Experimental Procedure:

A capillary rheometer, INSTRON Rheopack, was used for this study[5]. The loading frame of testing system has the capability of controlling shear rate for polymeric composites under compression. The testing frame is controlled by a microcomputer using a software, Rheosoft, which can manipulate the cross head movement according to the established velocity schedule. The system measures the resistance or load to press the polymeric melt through a capillary die, corresponding to the shear rate. Apparent shear rate, shear stress and viscosity are recorded while corrected shear rate, shear stress and corrected viscosity are calculated using Rabinowitsch correction. All the data are recorded in a report data file.

To investigate the effect of shear rate on the viscosity of the composites, shear rate was varied from 1.167 to 116.7 s^{-1}. This was achieved by setting up a velocity schedule for the plunger movement controlled by the microcomputer.

In the experiment, a composite of recycled high density polyethylene with 5% recycled tire particles was used as one example. The particles of the recycled tire chips was 40 mesh. The blend of the two constituents were extruded, water cooled and then pelletized into pellets of approximately 4 mm in diameter. The extruder screw has a L/D ratio of 30:1, which promotes mixing while extruding.

Results and Conclusions:

Figure 2 shows variation of corrected viscosity with shear rate for composite of recycled high density polyethylene (HDPE) with 5% recycled tire rubber particles at various temperatures. The figure shows the following main findings.

1. As the shear rate increased, the viscosity of the polymeric blend decreased.

2. At lower shear rate, the decrease in viscosity with increasing shear rate is more drastic than at higher shear rate. The viscosity became leveled off at higher shear rate.

3. The viscosity of the composite decreased with increasing temperature.

Bibliography:

1. Cogswell, F. N. (1981). Polymer Melt Rheology: A Guide for Industrial Practice. NY: John Wiley & Sons.
2. Charrier, J-M (1991). Polymeric Materials and Processing: Plastics, Elastomers and Composites. NY: Henser.
3. Schramm, G. (1994). A Practical Approach to Rheology and Rheometry. Gebrueder HAAKE Gmbh, Karlsruhe, Germany.
4. Yanovsky, Y. G. (1993). Polymer Rheology: Theory and Practice. London: Champman & Hall.
5. Instron Model 3213 Rheometer: Operator's Guide 1991.

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PING LIU obtained his B.S. degree in mechanical engineering, an M.S. degree in materials science and engineering, and a Ph.D. degree in mechanical engineering. His major research interests rest on polymer and applications, biomedical devices, polymer rheology, materials tribology, electrical sliding, corrosion, and failure analysis. He is currently a full professor at Eastern Illinois University, Charleston, IL.

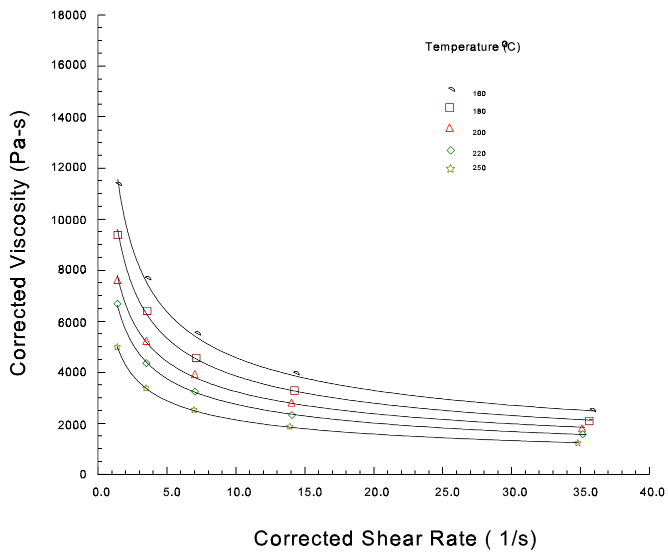

Figure 2 Variation of corrected viscosity with corrected shear rate for composites of recycled high density polyethylene (HDPE) and recycled tire particles.