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HOW TO CONTROL THE SWELLING AT THE DIE OUTLET?

A. CALCULATIONS

The swell ratio *B* is the ratio between the diameter of the extruded strand D_e and the diameter of the capillary D_c. If the measurement is performed at 23 ° C, it is called conventional swell ratio. The equation is given below.

$$B = \frac{De}{Dc}$$

More generally, the swelling is expressed using the percentage of elastic memory. This is the difference between the diameter of the extruded strand and the diameter of the capillary expressed in percentage. At the test temperature, it is called apparent percentage whereas at 23 ° C it is called conventional percentage.

$$\%\ \mathbf{extrudate\ swell} = \frac{De - Dc}{Dc} \times 100$$

B. METHOD

The tests carried out for the needs of this study were performed on a MFI M3350 with the same test conditions as above (see article 1 and 2).

Diameter measurement was made by an optical system (accuracy ± 10 µm) measuring the strand diameter continuously.

The distance between the die exit and the optical system was set at 25 mm. The value of the diameter used for calculating the swell ratio is those of a 50 mm long strand.

C. RESULTS

The results obtained during the swell ratio measurement are shown below (*Figure 1*), it is noted that the swelling decreases as the temperature increases for a given viscosity. Indeed, the process of stress relaxation requires sufficient energy so that the molecules stresses exceed the energy barrier for the molecular rotation. Therefore, an increase in temperature may increase the rate of stress relaxation, causing a decrease in the rate of swelling. In addition to the increase in the stress relaxation rate, a decrease in the viscosity caused by a temperature increase rate contributes to reduce the swelling by reducing the stress applied to macromolecules.

It may further be observed that, for the highest values of viscosity of each test temperature, the swell ratio is negative. For these values of viscosity, the macromolecules are in a very low stress. The polymer therefore has a Newtonian behavior. The macromolecular chains are very slightly deformed. The die exit, polyethylene being semi-crystalline, its macromolecular organize when the temperature approaches the temperature of crystallization. The crystalline phase being denser than the amorphous phase (state of the melt), a reduction volume, and therefore of the section, is measured.

Furthermore, net slope breaks are observed for the curves obtained at 150 ° C, 170 ° C and 190 ° C. They seem to correspond to areas of switching between the Newtonian behavior and the shear thinning behavior (see article 2).

The *Figure 2* affords a view of the swell ratio increase with the shear rate independently of the temperature. The swell ratio increases rapidly at first, then the increase slowed down and seems to strive towards a plateau at 1.35 (35% percentage of elastic memory). This result is logical, the stress relaxation rate in the first place being related to the flow speed of macromolecules into the die.

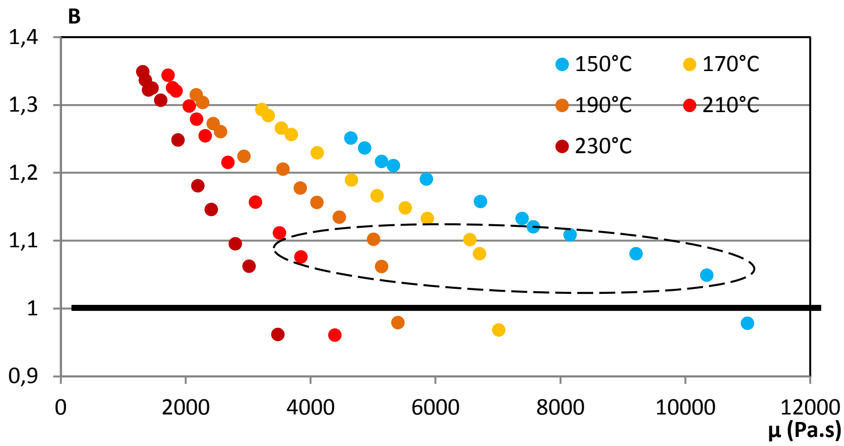

Figure 1: Swell ratio vs dynamic viscosity for different temperatures.

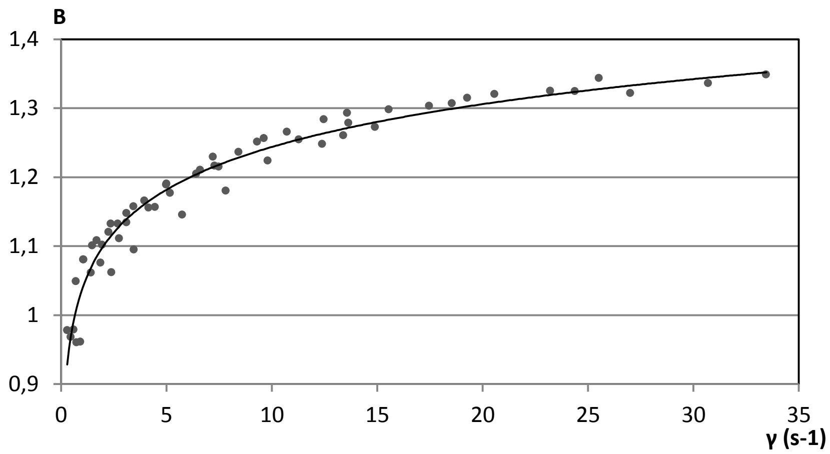

Figure 2: Swell ratio vs shear rate.

D. CONCLUSION

We have seen through this article series it is possible to extract a lot of valuable information about the rheological behavior of thermoplastic polymers without resorting to complex rheometer. For the current study, we simply used a MFI-type instrument.

By applying the basic rheological models, we were able to:

- Draw a rheogram of the polymer at different temperatures;
- Determine the rheological constants;
- Measure the behavior at the die exit.

For the polymers user familiar to using only the MFI, access to such additional data will allow him to optimize his process and/or assist the selection of a material based on an application or a processing method.

Suggested bibliographic reference

[1] C. Sirisinha, *A review of extrudate swell in polymers*, Journal Science Society of Thailand 23 (1997) 259-280.

[2] ASTM D3835: Standard Test Method for Determination of Properties of Polymeric Materials by Means of Capillary Rheometer

[3] ISO 11443:2014 : Plastics -- Determination of the fluidity of plastics using capillary and slit-die rheometers