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Rheology

Viscosity measurement of LDPE samples with the same MFR value

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Abstract

In the plastics industry, measuring the melt flow rate (MFR) is one of the simplest and most commonly used test methods for determining the flow behavior of polymers. However, the following practical case shows that this method is not always sufficient to determine the melt properties of a substance. The two LDPE (low-density polyethylene) samples in this investigation both had the same MFR value, but in practice showed different behavior during processing.

Introduction

The two LDPE samples described were produced by different suppliers. Both samples had an MFR of 4.0 g/10min. However, one of the LDPEs caused major problems in production.

Materials and methods

Polymer: LDPE

Test arrangements

- Torque-Rheometer System: Thermo Scientific[™] HAAKE[™] PolyLab[™] OS Torque Rheometer
- Torque-Rheometer drive unit: Thermo Scientific[™] HAAKE[™] RheoDrive 7 OS Drive Unit
- Analysis software: Thermo Scientific[™] HAAKE[™] PolySoft OS Capillary Software
- Laboratory single screw extruder: Rheomex 19/25 OS
- Extruder screw: L = 25 x D, compression ratio 2:1
- Melt pump with bypass valve
- Slit capillary die: 0.8 x 2.0 mm
- Melt-pressure sensors.

Test conditions

- Extruder feeding zone: liquid cooled
- Temperature profile extruder: 180° / 240° / 280°C
- Temperature of melt pump: 280°C
- Temperature at die: 280°C
- Speed of extruder: 100 rpm
- Speed of melt pump: 5 to 60 rpm (programmed)



Figure 1: Measurement with melt-pump.

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Test procedure

The polymer pellets are melted and homogenized in the extruder. Via a bypass valve the melt is transferred into the melt pump (Figure 1).

The melt pump transports a defined volume (Q), depending on the pump speed, through the slit-capillary die. The apparent shear rate ($\dot{\gamma}$) can be calculated from the capillary geometry (W, H) and the volume flow (Q).



With pressure transducers the pressure drop (p') in the capillary is measured. From the capillary geometry and the pressure drop the shear stress (τ) is calculated.

$$au = \frac{H}{2} \bullet p'$$

The apparent viscosity (η) is then calculated from the apparent shear rate and the shear stress.

$$\eta = \frac{\tau}{\dot{\gamma}}$$

By gradually increasing the speed of the melt pump, increasing shear rates are set. By measuring the pressure drop at each speed step, the viscosity function of the polymer melt is obtained.



Figure 2: slit-capillary measurement with LOPE (MI 4).

Results and discussion

Figure 2 shows the results of the viscosity measurements of the two LDPE samples in one graph. It can be clearly seen that the samples have the same viscosity behavior at low shear rates. However, during processing, the shear rates varied considerably, and the graph shows that there are clear differences between the samples at higher shear rates.

The MFR method, by measuring only one point in the viscosity behavior at low shear rates, could not show these differences.

Summary

This test shows that it is possible to differentiate between the two samples with the extruder capillary rheometer. The MFR method was not able to give any different readings, because it only measures one point of the viscosity behavior and this at such low shear rates.



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