Effect of SureFlo® on the Melt Viscosities of Polyethylene

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SureFlo® is a new and cost-effective process additive for a variety of general-purpose plastics such as polyethylene (PE), polypropylene (PP), polystyrene (PS), ABS, Nylon and PET. It is a proprietary blend of hydrocarbon resins in an easily handled pellet form. The benefits of SureFlo® include

- Enhancing the processibility of the material by reducing melt viscosities
- Delaying the crystallization of semi-crystalline polymers to facilitate mold flow
- Helping compatiblize dissimilar plastic components and contaminants
- Serving as a cost-effective black colorant

The current report aims at studying the effect of adding SureFlo® on the melt viscosities of a high-density polyethylene (HDPE) material, and how SureFlo® can be utilized to optimize the process conditions.

Experimental

The sample used for rheological testing was an injection-molding grade HDPE (Marlex® 9006 from Chevron Phillips Chemical Company, LLP) compounded with 7 wt-% SureFlo®. The melt index of neat HDPE is quoted to be 6.6 g/10 min.[1] The viscosity measurement was conducted following ASTM D-3835, Rheological Properties of Thermoplastics with a Capillary Rheometer. A Rosand RH-7 dual bore capillary rheometer (Malvern Instruments Ltd) with two capillaries of different L/D ratios of 16 and 4 was used for the experiments. The obtained results were corrected for Bagley, Rabinowitsch and shear heating.

Results and Discussion

Fig. 1 shows the experimentally measured viscosity profile of Marlex® 9006 blended with 7 wt-% SureFlo® at 3 different temperatures of 190, 210 and 230 °C. The material displays very typical behavior of entangled polymer melts: a terminal (Newtonian) zone at low shear rates followed by a power-law (shear-thinning) zone at high shear rates. The viscosity decreases with increasing temperatures.

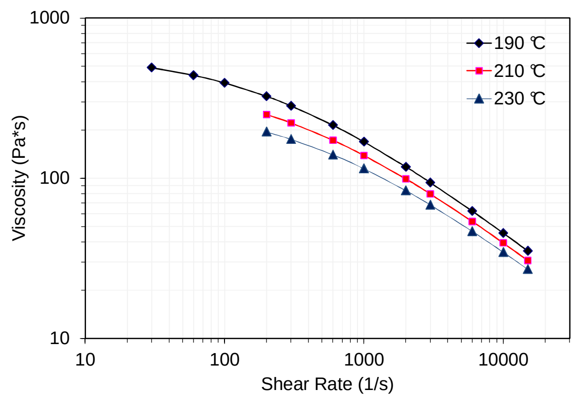

Fig. 1 Experimentally measured viscosity (Pa*s) vs. shear rate (1/s) profile of Marlex® 9006 added with 7 wt-% SureFlo® at 3 different temperatures.

The viscosity data was further analyzed using the Cross-WLF model. Cross-WLF is a well-known rheological model used to predict the viscosities of polymer melts at different temperatures, pressures and shear rates.[2] The model is given as:

$$\eta(T,\dot{\gamma}) = \frac{\eta_0(T)}{1+(\frac{\eta_0(T)\dot{\gamma}}{\tau})^{1-n}} \quad (1)$$

$$\eta_0(T) = D1\exp[\frac{-A1(T-T_r)}{A2+(T-T_r)}] \quad (2)$$

$$T_r = D2 + D3P \qquad (3)$$

where η, $\dot{\gamma}$, τ, P are the visocisty, shear rate, relaxation time and pressure, respectively. T_r is an arbitrary reference temperature and usually chosen as the material T_g. n, $D1$, $D2$, $D3$, $A1$ and $A2$ are model constants. The model (equ. 1-3) was used to fit the experimental data in Figure 1. The obtained model parameters are shown in Table 1. The parameters for neat Marlex® 9006 were obtained from Beaumont Technologies, Inc.

Table 1. Cross-WLF model parameters

	Neat Marlex®	Marlex® + 7% SureFlo®
n	0.3229	0.3129
τ	$1.47*10^5$ Pa	$8.98*10^4$ Pa
$D1$	$1.73*10^{21}$ Pa*s	$3.78*10^{19}$ Pa*s
$D2$	153.15	153.15
$D3$	0	0
$A1$	49.563	43.713
$A2$	51.6 K	51.6 K

Using the model parameters, we can now predict the viscosity profile at a wide range of temperatures and shear rates. For example, **Fig. 2** compares the viscosity profiles of neat Marlex® and Marlex® with 7 wt% SureFlo®. It is clearly shown that SureFlo® significantly decreases the melt viscosity. Such an effect is more pronounced in the low shear regime (10 to 1000 s^{-1}) compared to high shear regime (1000 – 10000 s^{-1}), due to the low shear sensitivity of SureFlo® resin. The range of shear rates in **Fig. 2** covers most polymer processing techniques, for example extrusion (up to 500 s^{-1}) and injection molding (up to 4-5000 s^{-1}). Therefore Surelo® can be used to improve a wide range of processing applications.

To further illustrate how SureFLO® can improve polymer processing, **Fig. 3** shows the viscosity profile of Marlex® with 7% SureFlo® at 180 °C compared to neat Marlex® at 200 °C. Reduced viscosities at low shear regime can still be obtained with SureFlo® even at 20 °C lower, while the high shear regime is comparable to neat Marlex®. This indicates that by using SureFlo®, the processing temperature can be effectively reduced by at least 20 °C (or 36 °F) without significantly altering other process conditions. The reduced processing temperature can lead to faster cycle time (less mold cooling required) and reduced energy consumption.

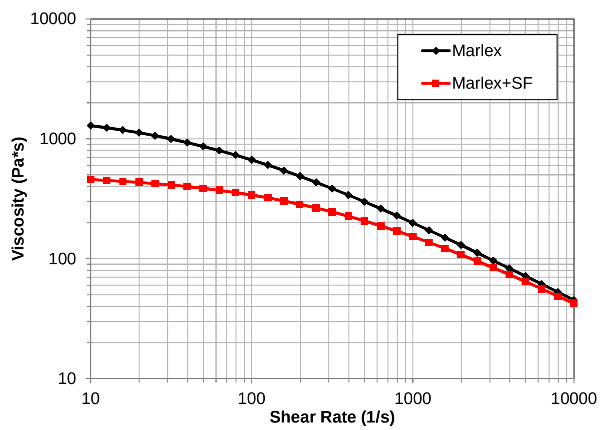

Fig. 2 Comparison of viscosity profiles of neat Marlex® and Marlex® with 7% SureFlo® at 200 °C.

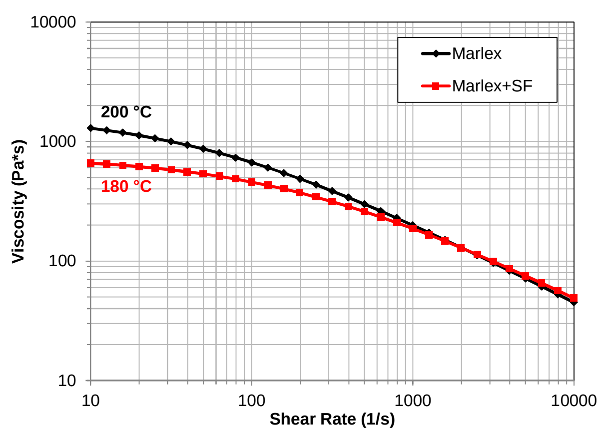

Fig. 3 Comparison of viscosity profiles of neat Marlex® at 200 °C and Marlex® with 7% SureFlo® at 180 °C.

Fig. 4 displays the temperature dependence of viscosities at selected shear rates, for neat Marlex® and Marlex® with

SureFlo®. Such a plot allows one to more accurately estimate temperature reductions based on initial processing temperature and shear rate. Suppose one has a HDPE that is normally processed at 210 °C and 1000 s^{-1} (injection molding of small parts, for example). Drawing a horizontal line connecting the two curves (neat Marlex® and Marlex® with SureFlo®, as shown in **Fig. 4**) shows that the same viscosity can be achieved at 25 °C lower (i.e. at ~185 °C). Therefore the processing temperature can be potentially lowered by the same amount, too.

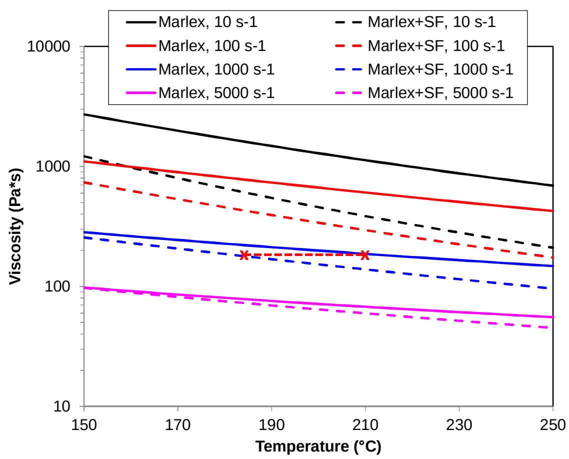

Fig. 4 Viscosity vs. temperature plots of neat Marlex® and Marlex® with 7% SureFlo at selected shear rates.

Conclusions

This study has clearly demonstrated the effectiveness of SureFlo® in reducing the melt viscosities of polyethylene. The results indicate the applicability of SureFlo® for a wide range of processing applications. In practice, SureFlo® can be used to significantly reduce the processing temperature to achieve faster cycle time and reduced energy consumption. Most plant trials we have conducted or witnessed so far have well proved this benefit.

References

[1] Marlex® product specifications sheet, http://www.cpchem.com/bl/polyethylene/en-us/tdslibrary/Marlex%209006.pdf, accessed March 14, 2011

[2] Jena et al., *Polymer Testing*, **29**, 933-938 (2010)