OSCILLATORY FLOW OF POLYPROPYLENE AND ITS EFFECT ON CONDUCTOR ECCENTRICITY

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ABSTRACT

Centering of the conductor within the insulation for telecommunication constructions is critical to the electrical and physical properties of the cable. A phenomenon call oscillatory flow, which is observed in linear polymers, has been found to have a major contribution to the conductor being off-centered. In this study, processing variables such as melt temperature and die size are shown to have a direct influence on oscillatory flow of polypropylene and ultimately the eccentricity of the insulated conductor.

BACKGROUND

Poor centering of the conductor (eccentricity) is a common problem in high speed wire insulation processes. For example, in the manufacturing of telecommunication singles, eccentricity can occur at line speeds as low as 150 m/min. In many instances maximum production speeds are limited because, of these eccentricity problems and soon become a major limiting factor to improving the economics of the wire insulating process.

Besides line speed limitations, eccentricity can also deteriorate the electrical and physical integrity of the final cable construction. Wall thickness variations can cause decreased signal performance due to capacitance effects. Also, since electrical breakdown failures are typically caused by pinholes or abrasions in the insulation surface, as wall thickness decreases the frequency of electrical breakdown increase.

Knowing the problems that eccentricity creates, manufacturers have developed many ways of maintaining the concentricity of the conductor. For example, extruder design has a direct impact on conductor concentricity. For high speed

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insulating applications, wire coating heads, dies and guider tips are designed to center the conductor by distributing the pressure exerted by the polymer evenly around the diameter of the conductor to maintain concentricity (Figure 1). Also, rheological stabilizing forces of the polymer have been shown to have a considerable effect on concentricity [(1)]. This paper will concentrate on yet another rheological phenomenon known as oscillatory flow that has a dramatic effect on eccentricity.

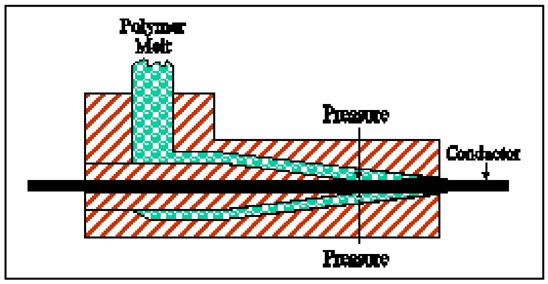

Figure 1

Oscillatory flow can be classified as a type of extrudate distortion or melt fracture that occurs when polymer is being extruded through a die or capillary. Extrudate distortions can be subdivided into general categories that range from surface melt fracture (sharkskin), to helical patterns to gross melt fracture. In the case of linear polymers such as linear low-density polyethylene (LLDPE), high-density polyethylene (HDPE) and polypropylene (PP), the extrudate can have a helical or rope-like appearance, while on a smaller but still visible scale the surface is smooth. Bergem (2) and Piau et al. (3) have shown that this helical pattern is directly related to a swirling motion of the melt at the entrance to the capillary. Other work by Bersted (4) showed that the initiation site for oscillating flow is not in the die entrance region but rather the die itself. To date, the triggering criteria and the physical mechanisms governing the appearance of extrudate instabilities are still the subject of much controversy.

The objective of this paper is to correlate oscillatory flow to the amount of eccentricity that occurs in PP during a wire coating process. Furthermore, process variables such as melt temperature and die size will be evaluated as well to show what effect they have on the occurrence of eccentricity

EXPERIMENTAL TEST METHODS

- *All materials were extruded using a 2-1/2" 20:1 Davis Standard extruder equipped with a Maddock screw and Genca head, die and guider tip.*
- *Wire was extruded onto 24 AWG solid copper wire.*
- *The polypropylenes (PP#1 and PP#2) used in this experiment are classified as impact copolymers with a 2.5 MFR.*
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RESULTS AND DISCUSSION

During high speed insulating processes, a cross-section of insulated wire is used to determine the amount of eccentricity. A common misconception when using this test method is to assume the center of the conductor is a continual distance from the center of the construction (Figure 2a). Upon closer examination during processing conditions that favor oscillatory flow, the conductor is forming a helical pattern within the insulating medium (Figure 2b), producing n% eccentricity at every cross-sectional point of the cable where:

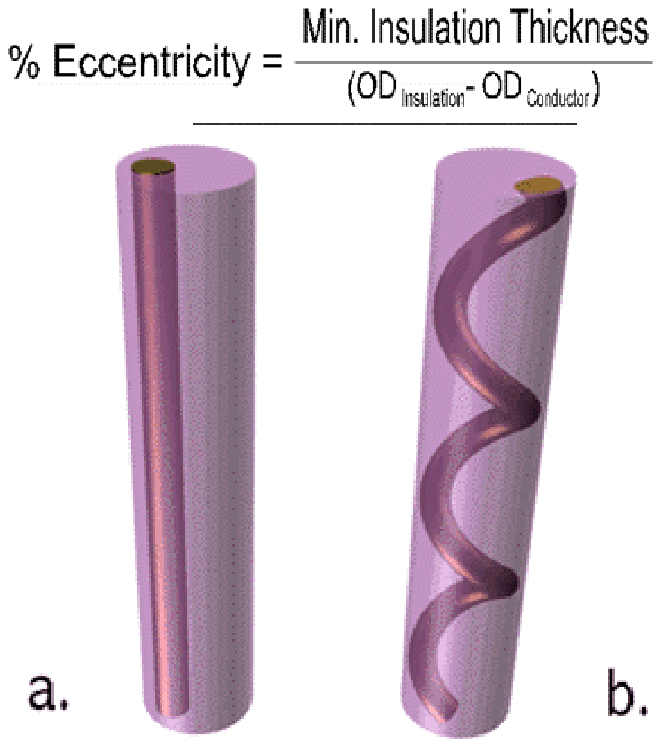

Figure 2

Upon removal of the conductor from the process and extruding polymer directly onto the floor, a helical extrudate (Figure 3) is also observed under similar processing conditions. This helical flow is consistent with oscillatory extrudate distortion that occurs in linear polymers such as PP. With the conductor back in place and under extrusion conditions that produce oscillating flow, the conductor will again begin to oscillate.

Figure 3

Using the 'conductorless' method, the system is comparable to a large-scale capillary rheometer in which the screw is providing the load to the melted polymer and the wire die is acting as the capillary. Capillary rheometers are used primarily to determine viscosity for a given shear rate range. To calculate viscosity, the wall shear stress and wall shear rate are needed. Equations 2, 3 and 4 describe viscosity (h), wall shear stress (s) and wall shear rate (g) for Newtonian fluids in a capillary where R is the capillary radius, Q is the flow rate, L is the capillary length and P is the driving pressure.

$$\eta = \sigma / \gamma \quad (2)$$

$$\sigma = \frac{\Delta P \cdot R}{2L} \quad (3)$$

$$\gamma = \frac{4Q}{\pi R^3} \quad (4)$$

In a wire process, increasing the screw speed will increase the pressure and flow rate causing a growth in the wall shear rate and wall shear stress. Figure 4 shows the typical ... *ıer flowing through a capillary* [5]*. As* ... *te goes through the typical melt fra* ... *ırface melt fracture (sharkskin), oscilla* ...

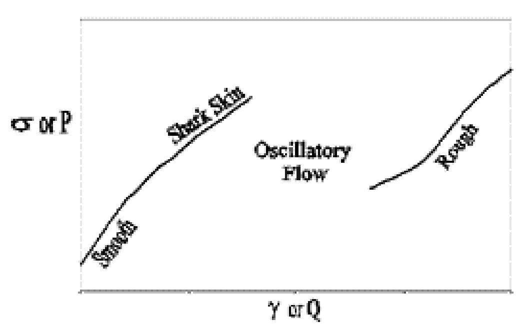

Figure 4

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