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The ordinary viscosity is a measure of resistance to flow. Actually, technically speaking, we should say resistance to shearing. Shearing is the motion of a fluid, layer-by-layer, like a deck of cards. When polymers flow through straight tubes or channels they are sheared and the resistance is expressed by the viscosity. The melt flow index (MFI) which is the number of grams that are extruded in 10 minutes under the action of a standard load is an inverse measure of viscosity. High melt index implies low viscosity and low melt index means high viscosity. Polymers are shear thinning, which means that their resistance to flow decreases as the shear rate increases. This is due to molecular alignments in the direction of flow and disentanglements.

Extensional or elongational viscosity is the resistance to stretching. In fiber spinning, in film blowing and whenever molten polymers are stretched, the elongational viscosity plays a very important role. An Irish born physicist named Trouton (1906) tested very stiff liquids, including pitch, like solids in tension and found that the resistance to stretching was three times larger than in shearing. In the ‘60’s, however, researchers discovered that for some polymeric liquids the elongational viscosity could increase (Tension stiffening) with the rate, although the shear viscosity decreased.

Melt strength is an engineering measure of the extensional viscosity and is defined as the maximum tension that can be applied to the melt without breaking. Linear polymers such as LLDPE, HDPE, and PP generally have poor melt strength. The reason is that in extension the linear chains slide by without getting entangled. However, branched polymers like LDPE exhibit higher melt strength and elongational viscosity because the long branches get in the way. Shear and elongational viscosity measurements reveal that LDPE is "stiffer" than LLDPE in shear but "softer" in extension. This is entirely due to the molecular architecture. LDPE has very long branches and is more compact than the LLDPE which has very short branches and is for all practical purposes, and in name, linear.

The lower elongational viscosity allows LLDPE to be easily down gaged since there is no strong tension stiffening...however, the low elongational viscosity and melt strength is bad for bubble stability. To increase the melt strength, we blend LDPE into LLDPE. Actually, there is evidence of a synergistic effect. A blend in the right proportions, say 70/30 LDPE/LLDPE, might have higher melt strength than both LLDPE and LDPE.

HDPE is also tension thinning, but due to crystallization during the cooling of a bubble, it is overall tension stiffening and it can be processed in the blown film process. By MD stretching first for a long neck and subsequent blowing superior film properties are obtained. On the other hand, PP is tension thinning even with cooling and it is difficult to be processed in the usual manner. So, for film blowing, PP is extruded downwards, water quenched to form a strong crystalline structure and subsequently reheated and then inflated.

The extensional viscosity level and whether it is increasing with tension (tension stiffening) or decreasing (tension thinning) play very important roles in bubble stability and downgageability.

- John Viachopoulos, McMaster University

See also:

- Blown film versus the cast film process
- HDPE LDPE properties
- Linear low density polyethylene
- MD flow lines
- Effects of molecular structure, rheology, morphology & orientation on blown film properties
- "Wave"pattern instability in multilayer coextrusion

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