ASHLAND

Cycletime Tips - General

Volume 35: Crystallinity

By Mike Van Duine

It has been experienced over the years that crystalline materials can be difficult to process, maintain dimensional control of and optimize properties. Some of this phenomenon can be attributed to crystallinity and its development. Polyolefins, Nylon, and Acetal are understood to be semi-crystalline by nature. Their properties are affected by the amount of crystalline Vs amorphous regions within the polymer and by the orientation that occurs during the molding process. Molding conditions and post mold handling also play a key role in crystal formation. It is not the intent here to develop an in-depth discussion of crystallinity but to provide you with an overview of its effects on properties.

In the melt state, crystalline materials are amorphous and as cooling starts crystal growth begins at the nucleus, (there may be more than one nucleus). Nuclei are initiated in three different ways or in combination, i.e., random motion of the polymer chain, referred to as spontaneous or homogenous nucleation, non-homogenous melts, (unmelt), can form nuclei, and foreign substances, (nucleating agents, color, etc). The predominant player is spontaneous nucleation. Crystal formation will continue until the temperature of the material drops to a point where chain mobility inhibits further growth. The rate at which crystallinity develops is highly temperature dependent and referred to as the cooling rate.

Effects of Crystallinity on Properties:

Tensile Strength: As crystallinity increases tensile strength increases. This is generally recognized because of the compact structure of the crystalline matrix. Studies have shown slow cooling rate of a polypropylene will have yield strength of 3750 psi and elongation at break of 50%. Where as, a fast cooling rate will reduce its crystallinity, resulting in yield strength of 3000 psi and increase its elongation to 800%.

Impact Strength: Impact strength will decrease as crystallinity increases. Impacting of all crystalline materials will have a tendency to transmit energy along the face of the crystals where they break. Seventy- percent crystalline PP has a notched izod of 2.8 ft-lb/in. Increasing the crystallinity to 95% reduces impact to .9 ft-lb/in.

Stiffness: Increases as crystallinity increases. Plastic are viscoelastic in nature their flexibility depends on segment rotation. Crystal structure impedes said rotation, so these materials are stiffer.

Density: Increases as crystallinity increases. Again, a crystalline structure is more compact than amorphous and the higher the crystallinity the denser the material becomes.

Heat Properties: Thermal Properties increase as crystallinity increases. This can be readily observed in reviewing DSC curves. For example, a 70% crystalline PP has a deformation temperature of 257 degrees F where a 95% has a deformation temperature of 304 degrees F.

Permeability: Decreases as crystallinity increases. This is due to the closeness of the crystalline structure. It becomes more difficult for liquid or gas molecules to pass through.

Shrinkage: Increases as crystallinity increases. Again, as more crystals develop there is more volume change. The more volume changes the more the shrinkage.

Crystallinity Regulation: A processor can regulate crystallinity to a point with cooling rate, post mold cooling method, cycle time, and pressures.

Cooling Rate: Slow cooling rate will result in higher crystallinity. In other words, high mold temperatures provide the mechanisms to promote more and or larger crystal growth.

Post Mold Cooling: The quicker the material is cooled out side of the mold the less crystalline the material will be.

Cycle Time: Cycle time can be used to increase and decrease crystallinity. There is however interplay of sorts between other variable within the molding process that can effect this as well.

Pressures: An increase in pressure will generally increase the rate of crystallinity, as it will bring the segments closer together.

As with many things in the injection molding business, there is a balance between the variables that produce what is an acceptable product. Crystallinity is one such variable. However if it controlled can be used to your advantage in end use performance.

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