Square One – Polymer Selection[1]

Bill McConnell is fond of saying that polymer problems account for more than three-quarters of processing troubles. In short, there would be no thermoforming without thermoformable polymers and without thermoformable polymers in sheet form. Earlier, we discussed the general characteristics of polymers. In the next set of lessons, we consider additional characteristics that are needed to produce quality thermoformed products.

Extrusion Basics

Thermoforming is considered a secondary process, since it begins with sheet. Extrusion is the primary process. The most common form for an extruder is a single auger-like screw turning in a horizontal heated, steel barrel. Polymer, in the form of powder or pellets, is fed into the extruder through a hopper. The solid polymer is conveyed down the barrel length where it is heated and melted or plasticated. The plasticated melt is pressure-metered through the end of the barrel into a shaping or slot die. The molten extruded sheet is then laid onto a rotating, cooled cylindrical steel roll. In some instances, the molten extruded sheet is "nipped" or squeezed between this roll and another "kiss" or "gauge control" roll. It is then conveyed from this cooled roll to another cooled roll, where it is further cooled. These three rolls are usually called the "chill roll stack." The roll stack acts to size and cool the extruded sheet.

Somewhere along the cooling path, the sheet is trimmed to the purchase order-specified width. Depending on the material specifications, the trim may be ground and returned immediately to the extruder hopper.

Further cooling can be achieved, either in ambient air or in a cooling tunnel. If heavy-gauge sheet is being extruded, the sheet is either saw-cut or guillotined into appropriate lengths, and stacked and palletized. If thin-gauge sheet is being extruded, the sheet is fed to a takeup roll.

THERMOFORMING 101

Polymer Characteristics in Extrusion

Extrusion is a high-shear, high-temperature process. In general, extrusion plants wish to maximize throughput. That is, they try to minimize the cost needed to produce a pound or kilogram of sheet. For a given polymer, throughput is increased by increasing temperature and shear rate.

Thermally sensitive polymers such as rigid PVC and polyethylene terephthalate or PET may suffer thermal damage during extrusion. Certain polymers such as olefinics may form gel particles during extrusion. Gels or "fish-eyes" are usually partially crosslinked particles. Some polymers that contain rubber such as impact polystyrene and ABS may generate black specks. Many extrusion-grade polymers are provided with antioxidant packages to minimize damage from high-temperature oxygen in the air in the early portions of the extrusion process.

Selecting a polymer with low melt viscosity and elasticity will also increase throughput without necessarily increasing temperature and shear rate. However, we know in thermoforming that lower melt viscosity usually means greater sag in the sheet as it is being heated. And low melt elasticity can mean difficulty in plug-assist stretching into deep cavities.

Another factor of great importance to thermoformers is orientation in the sheet. Polymer molecules are stretched during extrusion through the die. If the polymer is cooled before the molecules are allowed to fully recover, the sheet will have orientation in the extrusion direction or the MD or "machine direction." If the extruded sheet is squeezed between the first two chill rolls such that the polymer is forced outward toward the roll edges, the sheet will have orientation in the cross-machine or TD direction. It is usually the case in very wide sheet that both MD and TD orientations will vary in degree from the center of the sheet to its edges.

MD and TD orientations are really "frozen-in strain." When the sheet is reheated in the thermoforming oven, this strain is relieved. If the frozen-in strain is great, the sheet will distort and may pull from the clamp frame or pin chain.

To achieve the lowest levels of MD and TD orientations, the sheet should be extruded slowly and at moderately low temperatures. Of course, these conditions are not conducive to produce the highest throughput possible. And so compromises are needed. ■

Key words: extrusion, plasticated, MD orientation, TD orientation

[1] ***Thermoforming 101*** is designed to be a tutorial on the basic building blocks of the thermoforming industry. The first series of lessons concluded in TFQ **21**:3, 2002. This is the second in the second series of lessons that have as their objective to fill in the gaps from the first series of lessons.

[This is one in a series of articles introducing general concepts in thermoforming.]