Draft Angles

Some time ago, we discussed shrinkage and warpage. At that time, we pointed out that plastic, like most other materials, increases in volume when heated and decreases in volume when cooled. And we said that to form the desired shape, the hot plastic is pushed against a cool mold surface. It follows that as the plastic cools, it shrinks. But the mold doesn't change in dimension. If the mold is male or positive, or if even a portion of the mold is male or positive, the plastic will shrink onto the mold surface. And if the mold is not properly designed, we will have a devil of a time getting the part off it. Thus we face the subject of draft angles.

Draft Angles – Defined

The best definition of a draft angle is the angle the mold wall makes with the vertical. If the mold wall is vertical, the draft angle is zero. Recall that most thermoforming molds are single-surfaced. That is, the sheet is pulled into or over a single mold surface. For draw-down into a female or negative mold, the sheet is constrained on its outer surface by the mold. As a result, when the sheet cools, it tends to shrink away from the mold surface. As a result, it is entirely feasible to thermoform into a female mold having zero draft angles. Most part designers prefer a slight draft angle, say 0° to 2°, "just in case." The average is generally 1/2° to 1°.

On the other hand, when the sheet is drawn over a male or positive mold, it is constrained on its inner surface by the mold. As a result, when the sheet cools, it tends to shrink onto the mold surface. To release the part from the mold, it is necessary to provide a draft angle on the vertical mold surfaces. The amount of draft depends strongly on the volumetric change in the polymer. If the polymer is amorphous – PS, PVC, PC – the draft angle may be no more than 2° to 3°. If the polymer is crystalline – PE, PE – the draft angle may be in excess of 5°. The average is generally 4° but the designer must be alert to effects of temperature variation and recrystallization rates.

A textured surface requires an increase in draft angle. It is recommended that the draft angle be increased at least 1° for every 0.2 mils [0.0002 in or 5 microns] in texture depth. Keep in mind that increasing applied pressure, sheet temperature, and mold temperature will result in greater penetration of the sheet into the texture.

What About Parts With Male and Female Components?

Multiple-compartment trays and pallets[1] can pose series drafting issues. Consider a female cavity bordered by two male segments. The sheet will attempt to shrink away from the female mold surface but onto the male segments. Excessive draft on the male segments may allow the sheet to release from the female mold surface before the sheet has replicated the mold surface. On the other hand, inadequate draft on the male segments may allow the sheet to satisfactorily form the female mold surface, but the sheet may "lock" onto the male segments. The problem is exacerbated[2] when molding compartment trays where the male portions are interrupted. Essentially interrupted walls in the molded part. In addition to the shrinkage issues, interrupted male

segments may also be sources of internal webbing[3].

How Serious is the Draft Problem?

The draft angle can lead to serious dimensional changes in the formed part. Consider a simple example, a 10-inch male mold. The vertical wall is 1 inch wide at the top. Consider a draft angle of 5°. The width at the bottom of the vertical wall is determined as follows:

The increased width on one side is 10 x tan 5° = 0.875 in. The total width at the bottom is then 1 + 2 x 0.875 = 2.75 in.

This is a substantial dimensional change in the thickness of the vertical wall.

When is the Draft Angle Not a Draft Angle at All?

When it is used for something else. The classic example is the drink cup. The sidewalls are tapered as much as 20° for stacking purposes, not shrinkage. In multi-compartment parts, care must be taken in the design to accommodate both the draft angle required for shrinkage and the necessary stacking taper. Stacking lugs, stand-offs, or rings are often designed into complex parts, simply because it is not always possible to predict the exact local shrinkage. ■

Keywords: draft angle, taper, shrinkage

[1] These parts are sometimes called androgynous, meaning that they have both female and male characteristics.

[2] Exacerbate: To aggravate.

[3] Webbing will be discussed in a later lesson.