Understanding How a Sheet Stretches[1]

We began our discussion of part design by reviewing why we might not want to quote on a job. But let's suppose that we did quote on the job. And we got it. Now what?

Forming into a Mold v. Forming onto a Mold

In the not-so-politically-correct jargon of the day, if we form ***into*** a mold cavity, the mold is called a "female cavity." A better PC[2] phrase is "negative mold." If we form ***onto*** a mold, the mold is called a "male mold." The proper PC phrase is "positive mold." Is there a difference in forming "into" v. forming "onto"? Of course. Let's consider for the moment, forming a very simple truncated cone. If we use a mold cavity, the sheet first drapes into the open cavity, then stretches into the cavity with the sheet progressively laying on the mold surface. Keep in mind that the sheet that contacts the mold surface usually doesn't stretch any further. As a result, the sheet that is free of the mold becomes thinner and thinner as it is stretched to the bottom of the mold. The wall of the resulting part is thickest at the rim and thinnest at the bottom. The thinnest region of the part is in the corner where the wall meets the bottom. We can show arithmetically that if the wall makes a 60-degree angle with the horizontal rim, the wall thickness decreases linearly from the rim to the corner. If the wall makes a 90-degree angle [think soup can], the wall thickness decreases exponentially.

Now consider using a truncated cone male mold. The sheet first touches the mold at the bottom of the part being formed. As the mold pushes into the sheet, the sheet stretches between the clamp and the bottom of the mold. If the sheet doesn't touch the sides of the mold until the mold is completely immersed in the sheet, the sheet thickness is usually quite uniform. If the sheet progressively touches the sides of the mold as the mold is being pushed into the sheet, the wall of the resulting part will be thickest at the bottom and thinnest at the rim.

Does it make a difference whether we form into a cavity or over a mold? If part performance is important, probably not, if the part draw ratio[3] is very low [think picnic plate or aircraft engine cover]. As the draw ratio increases, however, the thinnest sections of the part begin to control the performance of the part. Several other factors can influence our decision, such as:

- Is it easier to prestretch the sheet when forming into a cavity or over a mold?
- Is it easier to machine a cavity or a male mold?
- Is the rim thickness important, as in the case of thin-gauge containers?
- And does the customer need the inside or the outside of the part to be the positive surface[4]?

Usually – but not always – mechanical plugs are more effective in stretching sheet into a cavity, female molds are easier to fabricate than male molds, and rim thickness is better controlled with female molds. We'll revisit some of these factors later.

Forming "Up" v. Forming "Down"

What does this mean? If the mold is placed above the sheet, the mold is immersed in the sheet and the part is formed up onto or into the tool. If the mold is placed below the sheet, the sheet sags into or onto the mold and the part is formed down onto or into the tool. Why is this an issue? In thin-gauge thermoforming, forming up has advantages with female molds. Gravity helps when releasing parts from multi-cavity tooling. And the parts are properly oriented for in-line trimming. Having said that, keep in mind that it is easier to mechanically prestretch the sheet into female cavities if the molds are below the sheet.

Although the mold weight may prevent mounting the mold over the sheet in heavy-gauge forming, there are some advantages here too. For example, when a male mold is mounted over the sheet plane, sheet sag acts to prestretch the sheet prior to the mold immersion. The sheet is formed down for most heavy-gauge forming into female molds. Again, sheet sag acts to prestretch the sheet prior to forming. And certainly, it is easier to activate and maintain mechanical plugs if they reside above the sheet rather than below.

Mating Parts

It should be apparent that the part side against the mold maintains a more accurate dimension than the other side. The mold side is chosen whenever the part is to mate with another dimensioned part. For example, for an integral-lid container to be liquid tight, the outside of one half must mate with the inside of the other. This may require that one half is formed into a female mold while the other is formed on a male tool.

An Observation

When quoting on a job, it is always advisable to keep in mind the capability of your equipment to form the part in the most efficacious[5] and least costly manner. If you can't form up, don't quote on a job that is best produced in this fashion. The more tortuous the path to perfect parts, the greater the degree of difficulty. And surely the greater the chance for quality issues. ■

Keywords: positive mold, male mold, negative mold, female mold, draw ratio, forming up, forming down, sag

[1] This is the third in a series that focuses on part design.

[2] PC. Politically correct.

[3] We discuss draw ratio in the next lesson.

[4] By "positive surface," we mean that surface that the customer considers to be the more important one. Usually the surface against the mold is considered the positive surface, but not always.

[5] Efficacious: Producing or capable of producing a desired effect.