Process – Cycle Time

(Editor's Note: This is the first Thermoforming 101 article written by your new technical editor. Dr. Throne wrote 34 articles that date back to 1998, Volume 17, Number 3. He had originally intended to write a series of 18 general interest articles but the 101 series has become a mainstay of the Quarterly. The year-end booklet that contains every 101 article to date is a great reference source for thermoforming practitioners. This technical editor has every intention of maintaining the series and the booklet which is becoming the perfect reading material for people entering the industry or seasoned personnel who need help on a specific problem. Jim wrote 4 articles last year that dealt with part design. I hope he will forgive me for not continuing with the "Trimmed Edge" topic he suggested for this lesson. I will deal with this topic when we take a closer look at the subject of "Die-Cutting." This Thermoforming 101 article deals with a subject about which we should all be more diligent. Foreign competition has forced us to maximize efficiency and become more competitive. So let us review the basic factors that determine cycle time.)

General Assumptions

We all should be aware that if we let the operator determine when a machine cycles, our production rate will suffer. Running thermoforming machines on manual mode is necessary for set up and of course if all you have is a simple shuttle machine with rudimentary controls you have no other choice. So let's just deal with thermoforming in automatic mode. We will only deal with the forming part of the process. Trimming of heavy gauge parts is another topic. Also for this purpose we will assume that when thinking roll-fed, we are using a machine with in-line die-cutting.

The Basic Concept

If we take all the segments of the rotary or in-line thermoforming process: heating. indexing the sheet, closing the press, forming the part, cooling the part, opening the press, trimming and stacking (if in-line), the cycle time is dictated solely by the slowest segment of the process. Most people looking at our process for the first time will say it has to be the heating segment that is the slowest part of the process. This is not necessarily so.

Roll-Fed

It is especially not so with roll-fed machines that usually are designed to have 4 indexes in the ovens. For example if the maximum mold size in the index direction is 36". The oven length will be roughly 4 times 36" or 12 feet long. So if you are running .020 PVC which would normally be in the oven for 20 seconds to get up to forming temperature, your cycle time, based on a 4 index oven, is 5 seconds (20 divided by 4) or 12 cycles per minute. This is not bad for running smaller and medium size quantities but it can be a lot better. I will explain later.

Sheet-Fed

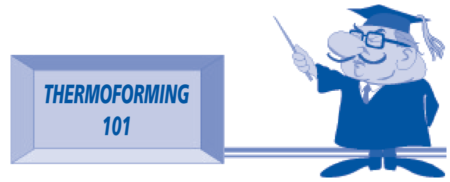
OK, so what about heavy-gauge, sheet-fed forming? The same principle applies. In North America the machinery manufacturers recognized early on that they must do something about the length of time it takes to heat the sheet evenly and thoroughly. So the 4 station rotary machine was designed which cut heating time dramatically by using 2 heater banks through which the sheet travels on its way to the mold. So why not build a 5 station rotary with 3 heater banks and really cut heating time? The answer is, there would be no point unless the part could be formed and cooled in a time less than one third the heating time. In fact the cooling of some materials is so difficult that one heater bank on a 4 station would have to be shut off or set at a lower temperature to allow time for proper cooling. So if we can do things to speed up the heating of the sheet, what can we do to cool the part quicker? This is where it gets tricky.

The Forming Segment of the Cycle

On roll-fed machines, unless you are dealing with super fast lines, you can forget about the trimming and stacking segments of the cycle when looking for what is slowing you down. Concentrate on the forming segment from the time the sheet leaves the heaters to the time the formed part leaves the form station. Let's break down the actions that take place.

Index speed is the speed that the sheet travels from the heaters to the form station. Roll-fed pin chains can travel up to 95 inches per second. A rotary turntable moves a lot slower. On both roll-fed and sheet-fed lines the stopping and starting actions can become too violent if the index speed is too fast which may cause the hot sheet to move as the mold closes on it. Move the sheet as fast as possible but make sure that the drape is stationary when the mold closes.

Shut height or platen travel is the distance the form platens must travel from the open position to the closed position. All too often set-up people will not take the time to reduce the shut height to optimum levels. I have seen a roll-fed job running very shallow pill blisters with a female tool on the bottom and the plugs on the top showing 3 inches of daylight between the plugs and the sheet line because the operator did not lower the shut height of the top press. This added at least 1 second to the cycle time and over a 30 hour run at 15 cycles per minute added over 2 hours of unnecessary labor and machine time. If you don't have shut height adjustment on your form press the only way to do this is to add build ups behind the



tooling. Fortunately the new machines have electric presses which make setting the shut height so much easier.

Press speed affects the length of the cycle time but sometimes it is necessary to slow the press closing speed to accommodate plug or assist action. If you are having difficulty with de-molding you may need to slow the opening speed. Other than these conditions, you can move the platens as fast as you want. Third motion tooling or independent plug control with individual cavity clamping can greatly improve cycle time but this is getting beyond the scope of a 101 article.

Cooling time is by far the most important factor in achieving a fast cycle time. In my very early days of thermoforming we tried running an epoxy mold on a modern in line machine. Even with a water cooled base under the mold the best we could do is 2 cycles per minute simply because the mold never got a chance to cool down. Using an aluminum mold on a water cooled base allows you to run most jobs at reasonable speeds as long as the height (or depth if it's a female) of the mold is no more than say 2 inches. To achieve maximum efficiency and reduce cooling time the mold must be kept at the target temperature as specified by the material supplier. Hot material at 350 degrees F hitting the metal mold requires a very efficient cooling system to maintain that mold temperature that may have to run at 200 degrees F constantly to run fast cycles. The only way to do this is to run cooling lines in the mold itself usually no more than 2" to 3" apart depending on the size and configuration of the mold. Cast-in lines are the norm for aluminum cast molds and machined in lines are the norm for machined aluminum molds.

Cooling time on sheet-fed rotary machines running thick HDPE can be improved by using external fans, water mist or cold air directed onto the part but care must be taken not to form in stresses. A well built water cooled mold is still necessary for the most significant improvement in cycle time.

So how do some roll-fed thermoformers get 50,000 parts per hour? This will be the subject of technical articles in the future. It's not a subject for the 101 series but here is a hint: third motion tools, cavity clamping, pre-heaters and great cooling in the molds.

Cycle time is just one way to make our operations lean and more competitive. Other ways will be discussed in future Thermoforming 101 articles. ■