Residence Time

Residence time is the time it takes a plastic pellet to journey from the throat until it exits the nozzle. The calculation of residence time is important to understand, because if the plastic spends too much time in the heated barrel it may degrade, resulting in a change of appearance, a reduction in properties, or both. Residence time is often overlooked by processors. The major definition of machine size is clamp tonnage, and too many times a mold is set up in a molding machine simply because it physically fits within the clamping capacity. Many processing guides suggest that 70 to 90% of the capacity be used for the shot size of a particular mold. Less than 70% will allow the plastic to reside too long in the injection unit, which may result in thermal degradation of the plastic. Using over 90% of the capacity may leave insufficient material for process adjustments and for cushion.

To determine the residence time of plastic within the barrel, the processor needs to know the weight and volume of the plastic held within the barrel when it is full. Engel rates the capacity of our injection units in terms of ounces of general-purpose polystyrene (GPPS).

Example: A plastics processor is using a 10 oz (GPPS) capacity molding machine to process glass-filled nylon. The mold requires a shot size of 8 oz. The molding cycle is 30 sec. What is the residence time of the plastic in the barrel?

Consult the machine manual to obtain the barrel capacity (plastic material contained in a full injection unit). Let’s say it is 40 oz of GPPS. We must then correct the barrel capacity for the glass-filled nylon. The specific gravity of GPPS is about 1.04, and the specific gravity of 33% glass-filled nylon is 1.34. The difference in specific gravity means that the barrel will be able to hold (1.34 ÷ 1.04) times as much glass-filled nylon as GPPS, or 1.29 times as much weight. Therefore the corrected barrel capacity for the nylon is 1.29 x 40 oz, or 51.6 oz. Every 30 sec, 8 oz of nylon is injected into the mold. At this rate, it will take 51.6 oz ÷ 8 oz/cycle, or 6.45 cycles, to use all the plastic in the barrel. Thus the residence time is 6.45 cycles x 30 sec/cycle, or 193.5 sec (3.23 min.). If a mold half the size was placed in the molding machine, the plastic material would reside twice as long, or nearly 6½ min., within the barrel.

Temperature Profile

A typical injection screw is usually comprised of three zones or profiles: the feed zone, the transition zone and the metering zone. Each of these zones is used to progressively melt the plastic pellets. The barrel heater bands must therefore be set to a level that provides a similar thermal progression. At the Feed Zone, the temperature controller for that heater band is set 20° to 30° F below the melting temperature of the plastic being processed. This lower temperature ensures that the screw will be able to convey the plastic pellets in the initial stages of processing. If the heater temps are too high in the feed zone, the screw will slip, resulting in no conveyance of plastic.

Assuming there are four zones, the Middle Zone may have a temp setting 10° to 15°F higher than that of the feed zone, and the temp setting of the Front Zone will be set to approximately equal to the desired melt temp of the plastic being processed. Finally, the Nozzle temp is set equal to or 10°F higher than that of the front zone. This is because the plastic within the nozzle receives all its thermal energy from the electrical heater, and the processor wants to keep the plastic melted.

Screw Control

Injection Pressure is the pressure generated by the screw tip on the plastic melt. There is a hydraulic pressure continuum from the screw through the plastic in the mold. Until this pressure is generated, the only pressure on the plastic melt is associated with its resistance as it fills the mold. The most important consideration in decoupled molding is the selection of the point where speed control is transferred to pressure control.

Holding pressure is used to maintain the cavity pressure after the cavity has been packed with plastic (to compensate for plastic shrinkage as the plastic cools but before the gates freeze off)

Back pressure is the amount of resistance applied to the rear of the screw as it rotates when conveying plastic. If a constant screw speed is maintained, increasing the backpressure increases the shear force that causes friction and, in turn, melts the plastic. If there is too much back pressure, the turning screw may return erratically or will be unable to return. Too much frictional heat will be generated, and the plastic in the transition and feed zones may melt. If there is too little or no back pressure, the screw will speed back to its set shot size position (C1). There will be a low level of shear and possibly too low a density of the plastic melt in front of the screw. This could cause defects in the plastic parts, such as underfill or sink marks.

Injection rate is the speed of the screw in its ram (plunger) mode. The rate of forward action of the screw affects the cycle time, shear rate, and cooling of the plastic melt as it is forced into the mold. With Engel’s microprocessor control, processors can profile the 10 positions to quickly inject when the sprue and runner of the mold are being filled, then slowed down as the plastic passes through the narrow gates into the cavity. To use this tool effectively, a thorough understanding of the mold filling process is needed.

Cushion is the plastic melt that remains in front of the screw after the plastic melt has been injected. Without a “cushion” the injection piston bottoms out and there will be no hold pressure. It is important to remember that there must be a cushion at the end of hold. However, this cushion should be as close to zero as possible to prevent a large quantity of plastic from remaining in the nozzle area as the next shot but sufficient enough to allow for process correction (microflow correction).