

Feature: Balanced Filling in Thermoplastic Medical Molding

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If molten plastic behaved like a simple fluid, there would be little need to worry about balanced filling during molding. The melt would fill the cavities like water, and the way the mold filled would have little or no influence on the properties of the molded parts. In reality, molten plastics are complex, viscous, and highly compressible fluids. How the mold fills can affect physical characteristics of the part such as size, strength, and appearance. Balanced filling can reduce part variations and improve part quality, both important in medical molding.

Multi-Cavity Balancing

Balanced filling in plastic molding can refer to filling in multi-cavity molds or filling within a single part cavity. Balanced filling in multi-cavity molds typically involves designing the runner system (hot or cold) so each cavity fills at the same time and at about the same temperature. When they fill at the same time and temperature, cavities tend to pack to the same density and are likely to shrink to the same size as the material solidifies.

In unbalanced multi-cavity molds, the ideal processing conditions for the early-filling cavities may be different than for late-filling cavities. The processing settings on the press end up being a compromise. This narrows the processing window and makes quality control more difficult. Cavities that fill first are more prone to flash and core deflection, while late filling cavities can exhibit non-fill and sink.

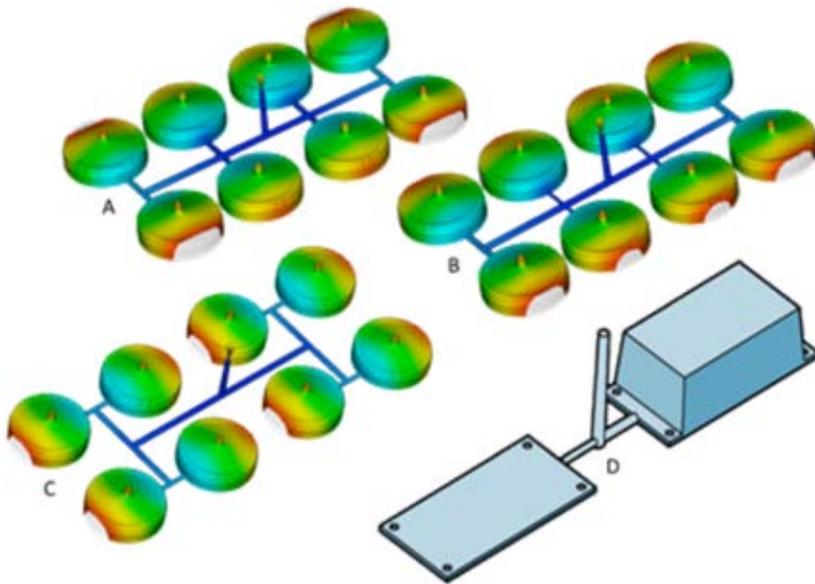
Two- and four-cavity molds tend to be naturally balanced. The distance from where the plastic enters the mold to the gates at each of the parts is the same. When the four-cavity layout is extended to eight cavities as in **Figure A**, an imbalance occurs. The runner distance to the outer four parts is longer than to the inner four parts. The flow simulation in **Figure A** shows the inner parts completely filled, while the outer parts still have the grey area yet to fill.

One solution is to use filling simulation to adjust the runner diameters to balance filling to all cavities. In **Figure B**, the diameters of the short runner segments feeding the inner four parts were reduced to restrict filling. When properly adjusted, all of the parts fill at about the same time.

This method of balancing runners, often called artificial balancing, has been used successfully for decades. It generates compact runner layouts (reducing regrind generation) and corrects many of the problems associated with unbalanced runners. Problems can occur when the restricted runners become too small to deliver adequate packing to the inner parts.

Artificially balanced runners are designed for a specific set of processing conditions. Changes to the filling speed or melt temperature can throw off the balance. Some molders attempt to balance flow by adjusting

Figures A, B, C, D



the gate size. This is not recommended. Differences in gate sizes can lead to variations in packing, material shrinkage and part cosmetics. Gate balancing is also much more sensitive than runner balancing to changes in processing conditions.

An alternative eight-cavity runner option (**Figure C**) branches the runner segments to produce a geometrically balanced runner system. Because the flow distance to each cavity is the same, the parts should fill in a balanced fashion. In reality, runner systems that branch more than once usually fill the inner cavities ahead of the outer cavities.

The reason involves the way the hot shear layer in the runner segments splits at branching intersections. Dr. Beaumont of Beaumont Technologies, Inc. discovered that as flow in the runner splits at the first runner branch, the hotter shear layer near the runner wall hugs the inside-corner side of the runner. The cooler core material goes to the opposite side. After the split, the melt flowing within the runner then has a hot side and a cool side. When the flow splits again at the second runner branch, the melt on the hot side fills the runner going one way and the melt on the cooler side fills the opposite runner. The hotter material follows the inside corners to fill the inner cavities. Because melt viscosity is temperature dependent, this temperature difference within the runners creates a filling imbalance.

To remedy this, Dr. Beaumont devised inserts that modify the runner branch intersections and rotate the hot and cool sides 90 degrees, so equal amounts of hot and cool material enter each part cavity. This MeltFlipper® technology can be purchased and licensed from Beaumont Technologies, Inc.



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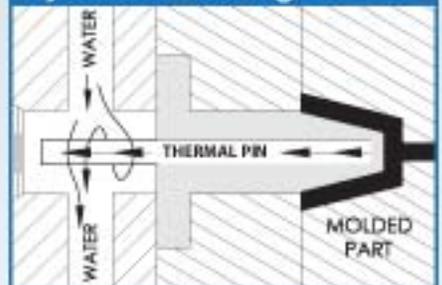
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Family molds (molds producing different parts geometries at the same time) often exhibit flow balancing problems, particularly if the parts are significantly different in size or shape. In the example in **Figure D**, the molder wanted to produce the box and lid at the same time to save molding costs and to ensure a perfect color match between the mating parts. If nothing was done to balance the flow, the smaller lid would fill ahead of the larger box. Increased packing in the lid could cause a variety of problems including flash and a gloss difference. More importantly, reduced shrinkage in the highly packed lid could affect the alignment of the screw holes in the lid with the holes in the box. By reducing the diameter of the runner to the lid, the flow can be restricted, so both parts fill at the same time.

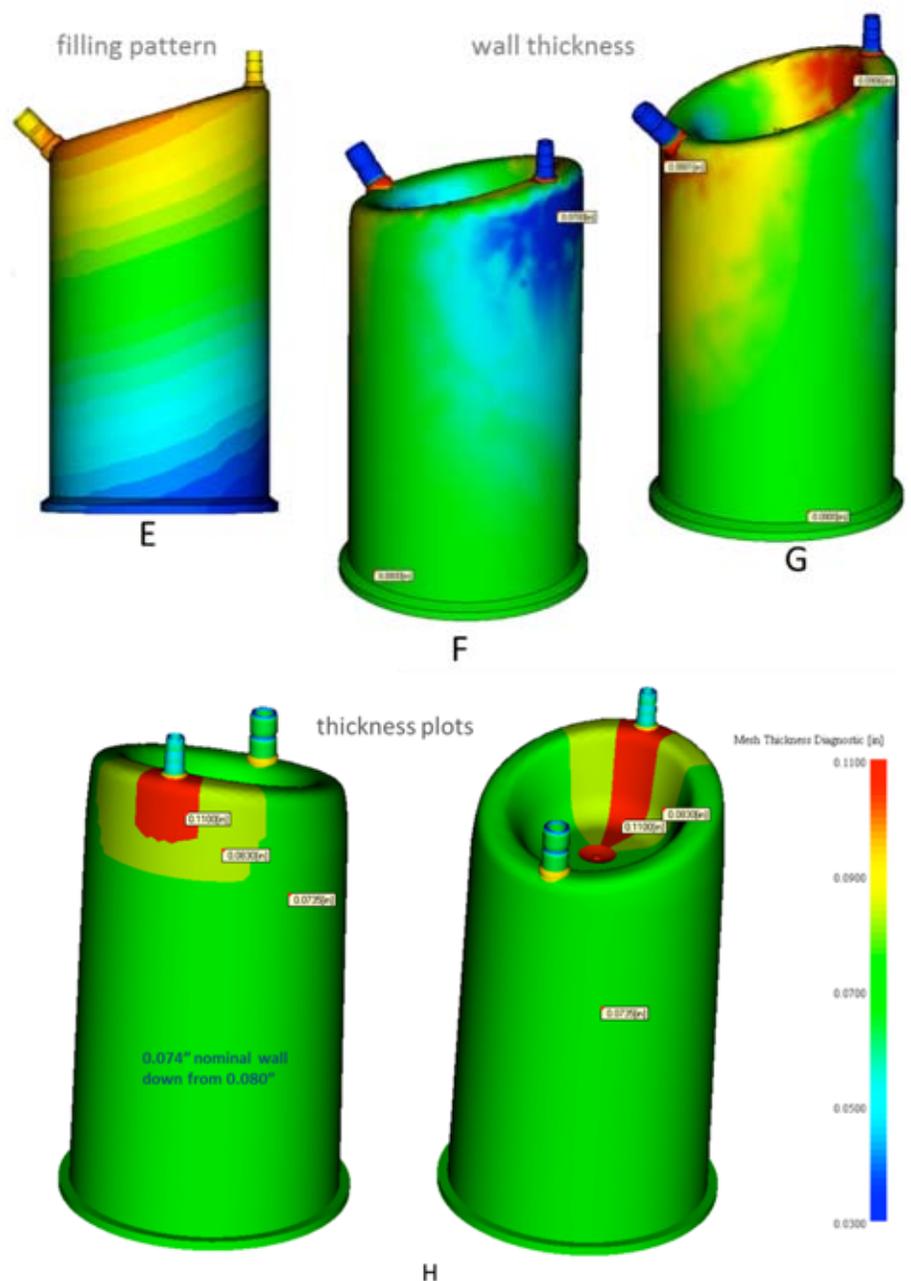
Part Balancing

Flow imbalances within a single part cavity can also create problems. The logical place to gate the medical part shown below is in the middle of the recessed pocket at the closed end. Because the flow length over the taller side is longer, the flow front lags behind on that side (**Figure E**). The resulting filling imbalance is probably not enough to cause flash or packing problems, but it is enough to flex the main core that forms the inside of the part.

The thickness plots in **Figures F** and **G** show the predicted wall thickness variations caused by the core deflection. The core bends toward the taller side causing the red areas to get thicker and the blue areas of the main body to get thinner. Deflection occurs at the upper, unsupported end of the core. Core deflection alters the part wall thickness but can also cause filling and demolding problems as well as fatigue failures in the core.

Design permitting, wall thickness adjustments can balance filling around the main core and greatly reduce core deflection. **Figure H** shows the part with flow leaders added to balance filling. Flow leaders are areas of

Figures E, F, G, H



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increased wall thickness which are intended to improve part filling. In this example, flow leaders were extended from the gate up toward the highest tubing port and partially down the other side. The thickness of the red flow leader was increased from the original nominal wall thickness of 0.080 inches up to 0.110 inches. The yellow-green regions represent the blending area where the thickness tapers down to the new nominal wall thickness. In thickening the longest flow path, the flow leaders also reduced the pressure needed to fill the part. This allowed the nominal wall thickness to be reduced from 0.080 inches to 0.074 inches resulting in weight and cost reduction.

The flow leaders change the original angled flow front (**Figure E**) to a straighter flow front shape that better balances the melt pressure around the core. This reduces the predicted core deflection by over 70 percent.

As a general rule, parts should fill such that the flow front reaches the part extremities at about the same time. This reduces the required filling pressure and provides more uniform packing and shrinking throughout the part. Gate placement can play a key role in balancing filling. For example, a rounded part would have a shorter flow length and require less filling pressure when gated from the center instead of at the edge.

Not every part needs to be or should be balanced. The penalty for providing balanced flow may outweigh the gains. If filling is straightforward and free of potential problems, then the cost and complexity to add a center gate may not be justified. In the case of long, narrow parts, it is often preferable to gate at one end to align the polymer chains and reduce warpage. Cosmetic constraints may also restrict the gating options. That said, the matter of part balancing should at least be considered.

Summary

Balanced filling can improve the quality and consistency of molded medical parts. Runner balancing in multi-cavity molds improves the chance that all cavities will fill and pack the same way. This broadens the processing window and improves cavity-to-cavity consistency. Flow balancing is particularly important in family molds, which produce parts that differ significantly in size or shape. Runner balancing is highly recommended for multi-cavity molds.

Flow balancing within parts can be achieved with flow leaders or gate placement, and can reduce problems such as core deflection, excessive filling pressure or localized over or under packing. In some instances, the benefits of balancing flow within parts may not be worth the costs or performance penalties. This needs to be evaluated based on the specific part performance and molding requirements. While not always required, the merits of flow balancing within parts should always be considered.

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