Polycarbonate (PC) blow mold made from the fused-deposition modeling (FDM) process

Stratasys photos

Prototype bottle molded in PET. With no wear or deformation, an FDM tool can produce hundreds, even thousands, of molded parts.

3-D Printing Offers New Route for Mold Makers

Fused-deposition modeling reduces cost, turnaround times

By Kevin Nerem,
senior application engineer
of tooling and manufacturing
Stratasys Ltd.

This article was adapted from a Stratasys process guide that applied fused-deposition modeling (FDM) to the process of extrusion blow molding (EBM), including both continuous and intermittent parison molding.

3-D printing provided a lifeline for a container blow molder hoping to reduce the time for prototyping near-production-quality parts from several weeks to less than five days. To do so, the molder turned to Stratasys for help.

For the project, the molder used a Fortus 400mc printer from Stratasys to create tooling for a 6-inch-tall, 3-inch-diameter (152.4mm-by-76.2mm) bottle.

Using PC resin for the tool cavity and a machined aluminum mold base, the Fortus printer produced prototype blow molds via FDM in only two days — including the design phase. The bottle was blow molded in BP Solvay Fortiflex HP 58, an HDPE resin. In all, the entire process took less than five days, and the molder said that the prototypes met its criteria for near-production quality. In one other project, Stratasys worked with a molder that used Fortus PC tooling to blow mold PET bottles. Due to time constraints and the desired quantity of the prototypes, the molder stopped the testing after making 800 pieces. Inspection revealed that there was no wear, distortion or dimensional change to the FDM-produced tool. The molder concluded that an FDM blow mold could produce thousands of parts, if desired.

Stratasys now has developed a number of insights into the best ways to replace traditional tooling with FDM-produced tooling.

A Fortus 450mc

Tool Design

Stratasys supplies a number of printers that can be used in mold making. In addition to the Fortus 400mc, they include the newer Fortus 450mc, as well as the smaller Fortus 380mc and the bigger Fortus 900, which can print molds as big as 3 feet by 2 feet.

An FDM-produced blow mold requires only minor modifications on standard tool design. It incorporates the pinch-off, flash pocket, cooling system and mounting plate typical of a standard blow mold. However, in a tool created via FDM, vents are not added. Since the mold is somewhat porous, air trapped between the molded resin and tool surface is vented through the body of the tool.

In using FDM printing, a tool's design must be modified to add a sloped, raised rib around the contour of the cavity. This rib acts as a compression seal between the mold halves, which provides clean shutoff and good pinch-off of the parison. In testing, a 0.125-inch-wide (3.2mm) rib that is 0.06 inch high (1.5mm) performed well when blow molding HDPE. The rib has a slope, as shown in Figure 1, on its outer edge. These specifications may vary with part size, resin selection and molding parameters, and therefore, adjustments may be needed.

The mold cavities should be oriented so that the mold face (parting surface) is perpendicular to the Z-axis. Although this vertical orientation will add time to the build, it provides the best surface characteristics for the mold cavity and yields the best shutoff between the mold halves. FDM molds should be constructed using normal build parameters, except in instances when mold makers opt for multiple contours along the cavity walls. Increasing the number of contour paths diminishes porosity in the mold to produce a better part.

In addition to PC, the Ultem family of amorphous thermoplastic polyetherimide (PEI) resins can be used to make molds. While expensive, the materials provide long tool life. However, ABS and polyphenolsulfone (PPSF) are not suitable for blow mold tooling. ABS cannot withstand the temperature and pressure of blow molding. PPSF is strong but retains too much heat, which causes blow molded parts to stick to the tool.

Manufacturing Options

To make its 6-inch-by-3-inch bottle, the molder opted for a hybrid tool. In all, the molder was faced with three options: designing the tooling using only FDM printing, creating a hybrid tool with a block insert or making a hybrid tool with a contoured insert. Selecting the best option required balancing the specifications of the blow molding machines, the needs of the molded part and personal preference.

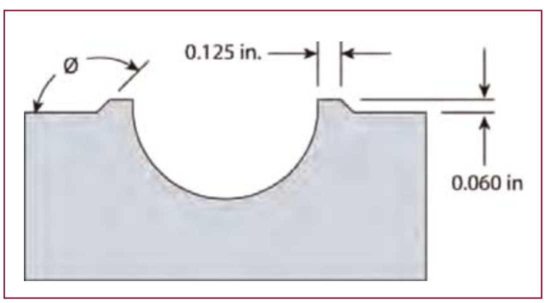

Figure 1: A rib is added to the tool design. The rib follows the contours of the mold cavity.

FDM Tool

A tool built by FDM can be designed like any machined mold, with the exception of venting and the addition of the perimeter rib. Cooling channels may be constructed in the FDM tool, but it is simpler and faster to use a standard mounting plate with cooling lines.

Hybrid Tool — Block Insert

A hybrid tool with a block insert pairs a rectangular FDM insert with a pre-fabricated aluminum mold base. In making one, mold makers should allow at least 0.5 inch (12.7mm) around the periphery of the mold cavity.

For example, a 6-inch-tall, 3-inch-diameter (152.4mm by 76.2mm) bottle would have two rectangular mold halves that measure 7 inches by 4 inches by 2 inches (177.8mm by 101.6mm by 50.8mm).

To make the tool, mount the FDM inserts in a machined aluminum mold base that has a rectangular cavity with the same dimensions. To minimize the cost and time needed to make the mold bases, establish an inventory of standard sizes and design the FDM insert to fit within one of these standards.

Note that this design option may result in stress fractures. The aluminum mold base restrains the PC insert as it expands during blow molding; to avoid fractures, molders should increase the duration of the cooling cycle.

Hybrid Tool — Contoured Insert

This type of tooling offers the advantages of reduced material consumption and mold build time. It also reduces molding cycle times because the insert retains less heat. To date, hybrid tools with contoured FDM inserts have performed best.

In this option, an FDM insert that follows the contours of the molded part is paired with a pre-fabricated aluminum mold base (Figure 2). For the face of the insert, mold makers should allow at least 0.25 inch (6.4mm) around the periphery of the mold cavity.

Unlike the rectangular insert, each FDM insert will have a contoured back side (Figure 3). Following the contours of the molding surface, the molder should create a surface that is offset by at least 0.25 inch (6.4mm).

As with the rectangular inserts, mold makers should have aluminum mold bases that are appropriate for the standard sizes of molded parts. These mold bases should have a rectangular cavity that holds the FDM insert. Because the insert is contoured, the area between the back side of the FDM insert and the aluminum cavity will have an air gap.

Cooling System

Hybrid tools use standard cooling-channel design and incorporate the cooling system in the aluminum mold base. Tools made entirely from FDM may have the cooling system in the PC tool or the mounting plate. To reduce cycle times, cooling lines can be supplemented with compressed air blown onto the face of the tool after ejection of the molded part.

Figure 2: FDM hybrid tool with contoured insert mounted in a machined mold base

Figure 3: CAD illustration of a contoured insert

Stratasys photos

To minimize cycle times, FDM-produced tools or inserts are made hollow with coolant flooding the internal chamber. Although no design specifications are available, research on flood cooling is ongoing.

Preparing the Tool

After building the FDM tool, mold makers must remove all support structures, mask off the parting surface and any sharp corners and blast the cavity with plastic blast media using a pressure of 60 pounds per square inch (psi) to 90 psi. Bead blasting eliminates all labor for sanding and filling while protecting dimensional accuracy. This procedure saves hours of manual labor and will produce a tooling surface that molds near-production-quality parts. The faces of the tools will not need any machining or handwork. The untouched surface provides good shutoff and minimal flash. The final step is to mount the PC cavity in a prefabricated aluminum mold base.

Blow Molding with the Printed Tool

Prototype blow molding with PC molds requires only one change to the process. Since the PC cavities retain heat, the cooling cycle must be extended. Because the duration will vary depending on the tool, as well as on the part and resin being molded, trial and error will determine cycle time.

Molders should start with a cooling cycle that is five times longer than that for a metal blow mold. If molding is successful, they should decrease the duration and repeat, continuing to reduce the cycle time until the molded part begins to stick. They should then return to the last successful molding cycle and begin blow molding the prototype parts.

If the tool is not pinching off the parison or if there is too much flash, the molder can add a shim between the PC cavity and the aluminum mold base.

Even though the cooling cycle is lengthened, the PC cavity temperature will continue to increase, and molding parts will begin to stick to the tool. When this happens, the molder should open the tool and allow it to return to operating temperature. Optionally, compressed air can be blown on the tool to accelerate cooling.

After the prototype parts are blow molded, the molder needs to remove pinch-off material and flash. The prototype blow molded parts are now complete and ready for review.

Conclusion

Using these guidelines, FDM can overcome the obstacles to prototyping, namely time and cost. Delivery time of molded prototypes can be slashed by 50 percent to 75 percent and the cost of the prototype tooling is reduced by 50 percent to 60 percent.

Since tooling made via FDM replaces conventional tooling with only minor design and process changes, this prototyping technique is easily incorporated within any blow molding operation. Near-production-quality prototypes and compatibility with a broad selection of blow molding resins make FDM an ideal choice for any blow molding project. Both quick and affordable, FDM expedites product and process analysis and customer design approval.

For more information
Stratasys Ltd.
Eden Prairie, Minn.
800-801-6491 (Option #4), www.stratasys.com