EXTRUSION BLOW MOLDING WITH FDM

FORTUS
3D PRODUCTION SYSTEMS

Time Required ■□□ Cost ■□□ Skill Level ■□□

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OVERVIEW

Blow molding is a manufacturing process that makes hollow plastic parts such as beverage containers. It is commonly used for the high volume production of soda bottles and milk jugs. While bottles, tubs and containers are manufactured rapidly and cost effectively, the prototype development process continues to be a slow and costly endeavor.

By replacing machined tooling with FDM (fused deposition modeling) molds manufactured on a Fortus 3D Production System, near-production quality blow molded prototypes are made in less than five days. With minimal labor and expense, the blow molded parts offer proof of design and validation of manufacturing parameters. Due to the properties of Fortus PC, prototypes are blow molded with little change to the tool design or molding process.

Blow molding is a manufacturing process in which air pressure inflates heated plastic in a mold cavity. It is used for the production of hollow plastic parts with thin walls, such as beverage bottles (Figure 1). Since molding pressures are much lower than those for injection molding, blow molding is also ideal for large plastic tubs and containers.

There are three types of blow molding: extrusion, injection and stretch. Extrusion blow molding, both continuous and intermittent, is the most common of the three. In extrusion blow molding, a molten tube of plastic is extruded into a mold cavity and inflated with compressed air (Figure 2). Injection blow molding is a two-step process. The first process injection molds a contoured pre-form. The pre-form is then inserted into a blow mold cavity and inflated. Injection blow molding offers variable wall thickness for part features such as threaded bottle necks. Stretch blow molding uses the same procedures as injection blow molding, but prior to inflation, a ram stretches the pre-form. The stretching aligns the polymer chains, creating stronger parts.

Blow molding uses many common plastics, including polystyrene, PC and polyvinylchloride (PVC). But the most common resins are high density polyethylene (HDPE), low density polyethylene (LDPE) and polyethylene therephthalate (PET).

The design of blow molds and the specification of process parameters combine science, art and skill. A small change in the pinch-off or vent design, or a slight change to die temperature or blow pressure, can dramatically affect the molding results. To validate these parameters and accelerate design approval, prototype tooling is needed. However, machined prototype tooling is both costly and time consuming.

To reduce lead time and expense, blow molders are now adopting FDM. In five days or less, companies can design a mold, build the tool and blow mold near-production quality prototypes.

This process guide provides information on the application of FDM to extrusion blow molding, including both continuous and intermittent parison molding. Since blow molding is an art, combine these general guidelines with existing practices, procedures and preferences.

FDM AND EXTRUSION BLOW MOLDING

When a Fortus system is used to construct blow molds, the lead time for prototype parts is reduced from weeks to less than five days. In addition, the cost for prototype tooling is significantly less than that of machined tools. In most cases, the FDM tooling will cost one-third to one-half that of a prototype aluminum tool.

Figure 1: This near-production quality HDPE bottle was made in less than five days.

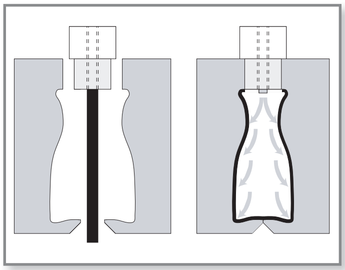

Figure 2: In extrusion blow molding, a molten tube of plastic is extruded into a mold cavity and inflated with compressed air

Figure 3: Polycarbonate blow mold made from the FDM process.

The FDM process is unique in its use of thermoplastics, and it is this feature that provides the benefits of rapid tooling for blow molding. Fortus PC can withstand both the temperature and pressure of blow molding (Figure 3). With no wear or deformation, an FDM tool can produce hundreds, even thousands, of molded parts in common materials like HPDE, LDPE, PET, PVC, PC, polystyrene, and polyethylene (Figure 4).

Unlike other prototype tooling methods, FDM requires only minor modifications to standard tool design and molding parameters. So, any prototype blow molding project can use FDM tools without radical changes to conventional practices. Shop efficiency is maximized with the simple, unattended operation of a Fortus system. Skilled employees are freed up to tackle other projects while the FDM tool is being constructed.

With FDM blow molds, prototype bottles and containers are produced quickly and affordably. The near-production quality of the molded parts expedites product and process analysis and customer design approval.

Figure 4: Prototype bottle molded in PET.

APPLICATION BRIEFS

Prototype Beverage Bottles

A container manufacturer challenged Stratasys to reduce both cost and time for the development of blow molded prototypes. The goal was to decrease the time for prototyping near-production quality parts from several weeks to less than five days.

The company selected a six-inch tall, 3-inch diameter (152 x 76 mm) bottle for the pilot project. Using Fortus PC material for the tool cavity and a machined aluminum mold base, the blow mold was designed and built in only two days. With only minor changes to the tool design and molding process, the bottle was blow molded in BP Solvay Fortiflex® HP 58, an HDPE. The entire process was completed in less than five days, and the company stated that the molded prototypes met their criteria for near-production quality.

Tool Life Analysis

Using Fortus PC tooling, one manufacturer successfully blow molded 800 bottles in PET. Due to time constraints, and the desired quantity of prototypes, the testing was stopped after molding 800 pieces. Inspection revealed that there was no wear, distortion or dimensional change to the FDM tool. The company concluded that an FDM blow mold could produce thousands of parts, if desired.

PROCESS OVERVIEW

Extrusion blow molding begins with heating of a plastic resin, typically between 350 and 500°F (175 - 260°C). The molten resin is then extruded through a die to create a round hollow tube of plastic called a parison. In continuous extrusion (Figure 5), the parison is clamped between the mold halves. As the mold closes on the parison, it pinches off and seals the tube of plastic. In intermittent extrusion (Figure 6), molten plastic fills an accumulator, and a ram extrudes the parison within the mold cavity.

After the parison is extruded, it is pierced with a blow pin. Compressed air, typically 85 to 120 psi (586 to 827 kPa), then inflates the parison, which forces the plastic against the mold surface. The molded part is then cooled and ejected.

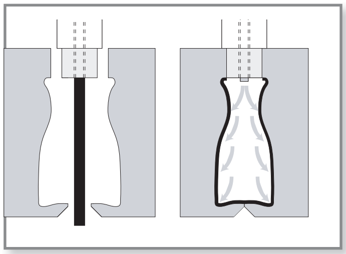

Figure 5: Continuous extrusion blow molding. The parison is extruded through a die (left), and the mold closes on the tube of plastic. The parison is then inflated (right) to force the plastic to the contours of the tool.

PROCESS

A Fortus PC tool, or tooling insert, replaces a machined blow mold, which is commonly made from aluminum, tool steel, stainless steel or beryllium copper. For prototype blow molding, the FDM tool eliminates the labor and expense needed to machine metal tools.

TOOL DESIGN

An FDM blow mold requires only minor modification to standard tool design. The FDM mold incorporates the pinch-off, flash pocket, cooling system and mounting plate typical of a blow mold. However, in an FDM tool, vents are not added. Since the FDM cavity has a small amount of porosity, air trapped between the molded plastic and tool surface is vented through the body of the tool.

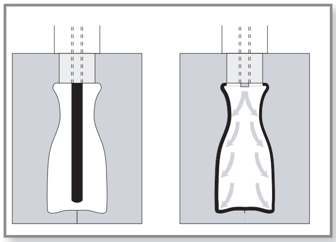

Figure 6: Intermittent extrusion blow molding. The parison is extruded within the mold cavity (left) and inflated with air pressure (right).

The tool's design is 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 gives clean shut-off and good pinch-off of the parison. In testing, a 0.125 in. wide (3.2 mm) rib that is 0.060 in. high (1.5 mm), has performed well when blow molding HDPE. The rib will have a slope, as shown in Figure 7, on its outer edge. These specifications may vary with part size, plastic selection and molding parameters, and therefore, adjustment may be needed.

There are three tool design options. Selection of the best option balances the blow molding machines specifications, the needs of the molded part and personal preferences.

1. FDM Tool: The entire tool is constructed with FDM (figure 8).

2. Hybrid Tool - Block Insert: A rectangular FDM insert is paired with a pre-fabricated aluminum mold base.

3. Hybrid Tool - Contoured Insert: An FDM insert that follows the contours of the molded part is paired with a pre-fabricated aluminum mold base (figure 9).

To date, the best performance has been with hybrid-contoured FDM inserts.

FDM TOOL DESIGN

With the exception of venting and the addition of the perimeter rib, the tool is designed like any machined mold. 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 Design:
Allow 0.5 in. (12.7 mm), at a minimum, around the periphery of the mold cavity. For example, a six-inch tall, three-inch diameter (152.4 x 76.2 mm) bottle would have two rectangular mold halves that measure 7 x 4 x 2 in. (177.8 x 101.6 x 50.8 mm).

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, increase the duration of the cooling cycle.

Hybrid Tool - Contoured Insert Design:
For the face of the insert, allow 0.25 in. (6.4 mm), at a minimum, around the periphery of the mold cavity. Unlike the rectangular insert, each FDM insert will have a contoured back side (Figure 10). Following the contours of the molding surface, create a surface that is offset by at least 0.25 in. (6.4 mm).

This tooling option offers the advantages of reduced material consumption and build time. It also reduces molding cycle time because the insert retains less heat.

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

COOLING SYSTEM

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

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

TOOL CONSTRUCTION

Orient the mold cavities such that the mold face (parting surface) is perpendicular to the Z-axis. Although the vertical orientation will add time to the build, it provides the best surface characteristics for the mold cavity and will yield the best shut off between the mold halves. With only one exception, construct the FDM molds using normal build parameters. The exception is

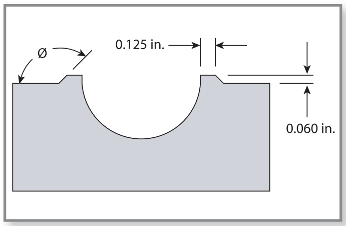

Figure 7: A rib is added to the tool design. The rib follows the contours of the mold cavity.

Figure 8: FDM blow molding tool made from polycarbonate.

Figure 9: FDM hybrid tool with contoured inserts.

Figure 10: CAD data for a contoured insert that is mounted in a machined mold base.

to use multiple contours along the cavity walls (Figure 11). Increasing the number of contours paths diminishes porosity in the mold to produce a better part.

Note that ABS and PPSU/PPSF (polyphenolsulfone) are not suitable for blow mold tooling. ABS does not have the properties to withstand the temperature and pressure of blow molding. Although PPSU/PPSF is strong and heat resistance, it retains too much heat, which causes blow molded parts to stick to the tool. For these reasons, use only PC for blow molding.

After building the FDM tool, remove all support structures and bead blast the cavity with plastic blast media. This simple and quick two-step process will produce a tooling surface that molds near-production quality parts.

Prior to bead blasting the tool, mask off the parting surface and any sharp corners. Then place the tool in a bead blaster-loaded with plastic blast media-and spray the cavity of the tool using a pressure of 60 to 90 psi (414 to 621 kPa). For additional information, refer to the Bead Blasting Finishing Guide. Bead blasting eliminates all labor for sanding and filling while protecting dimensional accuracy. This simple procedure saves hours in manual labor for benching the tool cavities. The faces of the tools will not need any machining or hand work. The untouched surface provides good shut-off and minimal flash. The final step is to mount the PC cavity in a pre-fabricated aluminum mold base. The tool is now ready for blow molding.

BLOW MOLDING

Prototype blow molding (figures 12 & 13) requires only one change to the process. Since the PC cavities will retain heat, the cooling cycle is extended. The duration will vary by tool, part and molded plastic, so the cycle time is determined through experience and trial-and-error.

Start with a cooling cycle that is five times longer than that for a metal blow mold. If molding is successful, decrease the duration and repeat. Continue to decrease the cycle time until the molded part begins to stick. Return to the last successful molding cycle and begin blow molding the prototype parts.

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

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

After the prototype parts are blow molded, pinch-off material and flash are trimmed. The prototype blow molded parts are now complete and ready for review (Figure 14).

CONCLUSION

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

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

Figure 11: To mold the PET bottle, this hybrid insert uses a cylindrical design.

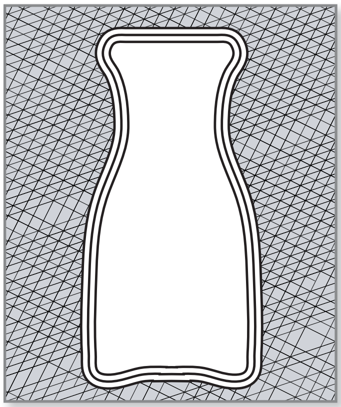

Figure 12: Increasing the number of contour passes reduces porosity and improves part quality.

Figure 13: Prototype hybrid FDM tool mounted in blow molding machine.

Figure 14: Prototype hybrid FDM tool opens and HDPE bottle is ejected.

FDM PROCESS DESCRIPTION

Fortus 3D Production Systems are based on patented Stratasys FDM (Fused Deposition Modeling) technology. FDM is the industry's leading Additive Fabrication technology, and the only one that uses production grade thermoplastic materials to build the most durable parts direct from 3D data. Fortus systems use the widest range of advanced materials and mechanical properties so your parts can endure high heat, caustic chemicals, sterilization, high impact applications.

The FDM process dispenses two materials—one material to build the part and another material for a disposable support structure. The material is supplied from a roll of plastic filament on a spool. To produce a part, the filament is fed into an extrusion head and heated to a semi-liquid state. The head then extrudes the material and deposits it in layers as fine as 0.005 inch (0.127 mm) thick.

Unlike some Additive Fabrication processes, Fortus systems with FDM technology require no special facilities or ventilation and involve no harmful chemicals and by-products.

For more information about Fortus systems, materials and applications, call **888.480.3548** or visit **www.fortus.com**

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