APPLICATION BRIEF:

HEAVY GAUGE THERMOFORMING WITH FDM TOOLING

STRATASYS®
3D Printers and Production Systems

OVERVIEW

Thermoforming is performed by heating plastic sheeting to a temperature where it becomes soft but does not melt, and then stretching it over a mold. The most popular method of forming the sheet is using vacuum suction to pull the sheet over a mold. Other methods include applying pressure to the side of the sheet opposite to the mold and using a matched die to force the sheet against the mold.

Heavy gauge thermoforming is normally used to produce large parts ranging up to 15 feet by 15 feet with depths up to three feet such as automobile doors, instrument panels, refrigerator liners, utility vehicle beds and plastic pallets. A key advantage of heavy gauge thermoforming is that the tooling is considerably less expensive than other molding processes such as injection molding where the plastic is melted prior to forming.

APPLICATION OUTLINE

A number of different types of tools are used for thermoforming including CNC machined aluminum molds, cast aluminum molds and composite molds. Each of these types of molds involves fairly high costs and lead times. This is because of the cost and lead time involved in programming and machining the many holes that are usually required to pull a sheet over the mold using vacuum suction. These costs can be justified for high production volumes but they create a problem when production volumes are lower.

Another concern is that the initial die often needs to be redone which adds to the expense and lead time. A common concern is webbing which occurs when geometry that is close together collapses to fill what is supposed to be a corner or other opening. In this case, the normal approach is to modify the placement of the vacuum holes in order to draw the sheet more closely to the mold in the critical area. Secondary tools known as web killers are also sometimes used to pre-stretch the hot plastic down to the tool base prior to pulling the vacuum.

Thermoforming manufacturers have attempted to address these challenges by making tooling using a number of different rapid prototyping technologies. Additive manufacturing, sometimes called rapid prototyping or 3D printing, can produce the tool at a substantially lower cost and reduced lead time. This advantage is typically multiplied several times for each part because several tooling iterations are often required to produce a part that meets customer specifications.

However, thermoforming is a very challenging application for most additive manufacturing technologies. Tools must be able to withstand high temperatures and mechanical forces involved in the thermoforming process. Additive manufacturing materials have generally not been able to stand up to these requirements primarily because of their lack of high temperature performance.

APPLICATION CHECKLIST

FDM TOOLING IS A BEST FIT FOR THERMOFORMING WHEN:

- √ The lead time for the project is relatively short
- √ You are interested in reducing the cost of tooling
- √ Producing a prototype early in the development process is advantageous
- √ The tooling is complex or difficult to produce using conventional methods
- √ You need to produce short-production runs
- √ Design changes are likely, and/or if there is a benefit to customizing parts

BENEFITS OF THERMOFORMING TOOLS INCLUDE:

- √ FDM tooling can be produced in a fraction of the time and cost of conventional tooling
- √ FDM eliminates the need for costly machining of the contour of the tool and the holes required to draw the vacuum
- √ FDM molds can be run alongside traditional molds with no alteration to process variables
- √ There is no limit to the geometries that can be produced, enabling design improvements
- √ FDM tools are lighter and more ergonomic

FDM heavy gauge thermoform tooling

FDM tool mounted in thermoforming machine

Thermoformed parts after trimming

Stratasys offers several materials for Fused Deposition Modeling (FDM®) that provide excellent thermal and mechanical properties for use in thermoforming tooling applications. FDM Technology™ is an additive manufacturing process that builds plastic parts layer by layer, using data from CAD files. ULTEM 9085* provides ideal properties for most thermoforming applications including a deflection temperature of 307oF (153oC) at 264 psi and excellent mechanical shock resistance. PPSF (polyphenylsulfone) offers similar high-temperature performance but somewhat lower mechanical shock resistance. Other materials such as PC (polycarbonate) and PC-ABS (polycarbonate - acrylonitrile butadiene styrene) can be used for lower temperature materials and single quantity forming.

FDM heavy gauge thermoforming tools can be produced in a fraction of the time and cost of conventional tooling because the FDM tool can be produced to be both porous and rigid. FDM can generate positive air gaps in the raster fills throughout the build that creates channels through the entire tool through which the vacuum can be drawn. Build parameters can be specified to produce porosity over large areas of the part or the entire tool rather than being limited to machined holes. This more flexible approach to porosity makes it possible to deliver a much more even vacuum pull and provide the precise amount of vacuum needed in every area of the part. This gives thermoforming manufacturers a powerful new tool to improve quality by eliminating or reducing the incidence of webbing.

CUSTOMER TESTING

Designing and testing of FDM thermoforming tools were performed in partnership with Kintz Plastics of Howes Cave, New York. Test pulls were processed with Kydex T 0.250 inch/6.35 mm sheet stock. Kydex T is a fire-retardant thermoplastic sheet commonly used in aerospace applications. Test pulls were processed on a Monark SPF Series thermoformer with liquid propane heating. Test tools were mounted on the top frame of the machine to allow the natural draping of the heated plastic to complement the deep draw of the geometry.

The FDM tool was bolted to a plywood base consisting of 5 layers of 0.750 inch thick plywood. The Kydex sheets were heated in the oven for 230 seconds. The temperature of the sheets when they were removed from the oven was 180oC +/-5o.Vacuum was applied gradually to lessen the chance for webbing in the corners. After 20 to 30 seconds of pulling vacuum, cooling fans were turned on. After a total of 300 seconds for cooling, the vacuum was released on the tool. Then air pressure was applied to the tool at 20 to 30 psi to assist with automated extraction.

Seven successive pulls were performed using this program on an ULTEM 9085 FDM tool. The tool was not cooled with any additional time or any other methods between pulls in order to duplicate a short-run production scenario on a single-station thermoforming machine. ULTEM 9085 performed the best of the four FDM materials that were tested. A total of 12 pulls were performed with this material. Mechanical tool extraction by the forming machine was successful with no observed damage to the tool. The three other materials tested were PC, PC-ABS and PPSF.

The testing showed that FDM tools provide as good or better processing times than traditional tooling methods and materials. It is believed that the internal porosity of the FDM tools causes them to more slowly absorb the heat generated during thermoforming. The result is that the tool cools faster.

The three other FDM materials, PC, PC-ABS and PPSF were able to successfully pull and extract the tool. PPSF is a compatible material for thermoforming due to its high-temperature capabilities, but manual tool extraction rather than mechanical extraction should be used. PC and PC-ABS materials are recommended for lower temperature materials.

FDM can also be used to produce secondary tooling such as web killers and trim fixtures. In these applications, FDM reduces tooling costs and leadtimes by 50% to 75%.

KINTZ PLASTICS, INC.

Thermoforming tool design and testing was performed in partnership with Kintz Plastics.

For more information about Stratasys systems, materials and applications, contact Stratasys Application Engineering at 1-855-693-0073 (toll free), +1 952-294-3888 (local/international) or ApplicationSupport@Stratasys.com.

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