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WHITE PAPER

BENEFITS OF 3D PRINTING VACUUM FORM MOLDS

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FATHOM is driven by advanced technologies.

We leverage our expertise in 3D printing and additive manufacturing to help our customers innovate faster and more efficiently.

Our product portfolio includes professional 3D printers and manufacturing systems, prototyping and advanced manufacturing services, with design and engineering resources in support of these.

We strive to be our customers' preferred partner by providing best-in-class equipment, services, and support.

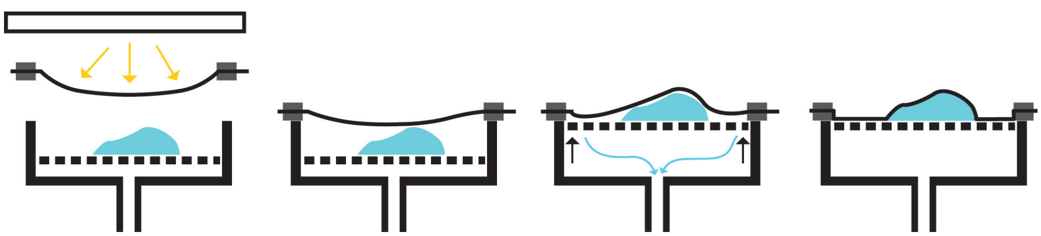
BENEFITS OF 3D PRINTING VACUUM FORM MOLDS

INTRO

Vacuum forming is a versatile and easy to learn process. With affordable 3D printed tooling and a wide variety of applications, it could be the perfect fit for your next prototyping project. Vacuum forming with 3D printed molds is a great way to quickly create 3D parts from plastic sheet material. This document outlines how to take advantage of the unique benefits of Stratasys 3D printers for vacuum forming applications.

OVERVIEW

During the vacuum forming process a plastic sheet is uniformly heated until an appropriate processing temperature is reached. The sheet is then stretched and forced against the mold's surface by a vacuum, producing a plastic sheet formed to the shape of your mold.



PLASTIC MATERIALS

A wide range of plastic sheet materials are compatible with the vacuum forming process.

A few notable materials are:

- ACRYLONITRILE BUTADIENE STYRENE **(ABS)**
- ACRYLIC
- CO-POLYESTER **(PETG)**
- POLYSTYRENE **(PS)**
- POLYCARBONATE **(PC)**
- POLYPROPYLENE **(PP)**
- POLYVINYLCHLORIDE **(PVC)**

Each material has its own unique processing requirements, and some grades may be more suitable than others for your project. Refer to the manufacturer's documentation for specific information on your material. Check your machinery capabilities and material data before investing resources in tool design and printing.

3D PRINTED VACUUM FORM MOLDS

FDM (Fused Deposition Modeling) is the most common technology used for creating 3D printed molds for vacuum forming and offers many unique benefits.

FDM allows you to print in various sparse fill densities, giving the molds an inherent porosity that results in a uniform vacuum to be drawn throughout the tool. This can greatly simplify the fabrication of the tool. In addition, FDM machines are capable of printing molds in a variety of durable, heat resistant plastics that prolong the life of the mold.

PolyJet (UV-Cured Photopolymer Jetting) is another common technology used for 3D printing molds. PolyJet-based machines build parts with fine layer resolution, and as a result, produce parts with very smooth surfaces. PolyJet vacuum form molds require little to no post processing and are great for making molds with organic and curvy surfaces. PolyJet molds don't share the porosity of sparse fill FDM molds, but air vents can easily be designed into critical areas of the mold prior to printing, eliminating the labor and potential inconsistency of manual drilling.

Both technologies simplify the tool fabrication, allowing engineers and designers to test multiple tooling strategies concurrently, and shortening the time to produce the first articles of a design. Other additive manufacturing technologies can be considered.

TOOL DESIGN CONSIDERATIONS

Draft // Adding draft to the vertical surfaces of a part will help when removing the mold from the newly formed plastic part. Best practice is to use a minimum draft angle of 1°-3° and a draft angle of 5° or more — this greatly helps when releasing the tool from formed parts. Undercuts can be successfully vacuum formed in special cases depending on your part geometry and material thickness.

Webbing // Geometries with deep draws and vertical walls are usually at risk for webbing during processing. More draft will help with webbing in these types of geometries.

Shrink // Most plastic sheets shrink during the vacuum forming process. Shrinkage rates depend on the type of plastic used and its thickness, but usually range between 0.4% and 0.8%. You can accommodate for shrinkage in the mold design.

Sharp Corners // Use a minimum radius of curvature on tool features that is greater than the material thickness of the plastic you will be vacuum forming.

Venting // If molds are to be built in PolyJet, design vents to pull vacuum in female molds and in critical areas and recesses of male molds. Smaller diameter holes will be less noticeable on the surface of the formed parts, but size holes large enough that they are not too difficult to remove support from.

TOOL PRINTING CONSIDERATIONS

FDM // Insight software available on Stratasys' Fortus 3D production systems provides users with a lot of control over raster densities on the interior volume of your mold. The tool paths can even be specified to be built with air gaps throughout the entirety of the part, or you can create custom groups if you wish to vary the porosity throughout the tool. Stratasys printers with Catalyst software can print molds in two different sparse fill densities or solid.

Tool Finishing // The plastic sheet used for vacuum forming tends to pick up the texture of the mold. This is especially apparent when using thin or clear plastic sheets. FDM molds will likely need to be sanded to smooth the layer lines on the mold. Start with 120 grit sand paper and use successively finer grits as necessary to meet the surface finish requirements for your application.

APPLICATIONS

Vacuum forming, and thermoforming (pictured below), is well known for use in packaging applications, but this versatile process has numerous application uses:

- Interior trim panels in automotive and aerospace applications
- Agricultural applications (seed trays and flower tubs)
- Architectural model making and furniture
- Lighting covers, panels, and diffusers
- Consumer electronics enclosures and screen bezels
- Movie and drama props
- Medical equipment enclosures, protective equipment
- Machine guards and safety equipment in manufacturing environments
- Models making in cars, boats, and aircraft
- Packaging, point of purchase, signage applications
- Food, gelatin, and chocolate molds
- Protective cases

CASE STUDY

CREOS is an internal project designed, created, and produced by the FATHOM team in an effort to demonstrate the many uses of 3D printing and advanced prototyping technologies for the product development process.

CREOS is a 3D printed action figure with detachable arms and legs built on the Objet500 Connex in VeroWhite, TangoBlackPlus, and VeroClear (PolyJet Technology Materials). The hat is created in Nylon12 on an SLS machine and dyed yellow in post-processing. The calipers were made on a uPrint SE Plus (FDM) in real ABS thermoplastics. All CAD development was completed in-house by FATHOM's design and engineering team.

To demonstrate the many ways 3D printing can be used in an application, CREOS is encased in a PETG plastic shell that was vacuum formed using a 3D printed FDM tool.

1. The design of the molds began by extruding profiles around the CREOS' body, sneakers, and calipers at a draft angle of 3°
2. The front and back extrusions of the body were trimmed with a curved surface to accommodate sectional differences in the parts
3. All knife edges were filleted and sides of the base of the mold were drafted at 3°
4. Once the CAD modeling for the mold was complete, each part was printed in ABS on a uPrint SE Plus (this material was chosen to take advantage of FDM's sparse fill)
5. Since the molds were simple in geometry, light sanding was required to attain the desired smoothness
6. Once sanded and approved, the molds were ready for vacuum forming