REAL APPLICATION

MOLDED FIBER PROTOTYPES AND LOW-VOLUME PRODUCTION

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OVERVIEW

Since the 1930s, molded paper pulp has been used to make containers, trays and caps. Initially, molded pulp, which is also called molded fiber, was only available for large volume, commodity products such as egg cartons, fruit trays and drink cup holders. Today, molded fiber is a popular choice for both high volume containers and low volume, interior packaging (Figure 1).

Following a decline that began in the 1970s, molded fiber experienced a resurgence, fueled by environmental concerns, because it is a sustainable alternative to plastic packaging. Produced from old newsprint, corrugated boxes and a variety of other plant fibers, molded fiber packaging is 100 percent recyclable and biodegradable. It is also a cost-effective packaging solution for 20,000 to over 2,000,000 pieces annually. Other advantages include cost reductions from molded fiber's low cost disposal, ease of packing and minimal warehousing requirements.

Molded fiber provides excellent blocking and bracing functionality and is highly shock absorbent. For interior protective packaging, the relatively soft fibers cushion products and absorb impact. An alternative to expanded polystyrene (EPS) foam, die cut corrugated and foam in place packaging, molded fiber is widely used for electronics, household goods, automotive parts and medical products (Figure 2). It is also an excellent choice for shipping and handling applications when used as an edge protector or pallet tray. Durable, flexible and environmentally friendly, molded fiber is used in a wide range of configurations for a variety of applications, including end caps, trays, cushions, and clamshells.

Forming fiber into a cap, tray or clamshell requires a mold through which a vacuum is pulled. While production of interior packaging is automated, quick and low cost, mold making is a time-consuming and labor-intensive process. Needing cost reductions and rapid delivery of evaluation samples and short run custom orders, molded fiber manufacturers are seeking reductions in time, labor and cost for the fabrication of forming molds. As demonstrated by leaders in the molded fiber industry, fused deposition modeling (FDM) provides the solution.

FDM AND MOLDED FIBER

Replacing the design, machining and screening processes of traditional mold building, FDM automates and accelerates mold production. What would take two to four weeks to complete can be finished in two to four days with only a few hours of labor (Table 1). Using FDM, fiber molders can produce customer samples quickly and affordably. Since FDM fiber forming molds have produced in excess of 30,000 pieces, the prototype tool transitions to a bridgetoproduction solution for highvolume work or the production tool for lowvolume, custom jobs.

The International Molded Pulp Environmental Packaging Association (IMPEPA) classifies four types of molded pulp. FDM has been successfully applied to the two most common, Type 1 and Type 2.

- **Type 1—Thick Walled** (Figure 4)
  - 3/16 to 1/2 inch (4.7 to 12.7 mm) walls.
  - Primarily used for support packaging applications.
  - Surfaces are moderately smooth on mold side and very rough on opposite side.
- **Type 2—Transfer Molded** (Figure 5)
  - 1/16 to 3/16 inch (1.6 to 4.7 mm) walls.
  - Typically used for packaging electronic equipment, cellular phones and household items.
  - Surfaces are moderately smooth on mold side and fairly smooth on transfer mold side.

<table>
<thead>
<tr>
<th>Process</th>
<th>Lead-Time</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional</td>
<td>3 weeks</td>
<td>$10,000</td>
</tr>
<tr>
<td>Machining</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FDM</td>
<td>3 days</td>
<td>$3,000*</td>
</tr>
<tr>
<td>SAVINGS</td>
<td>12 days (80%)</td>
<td>$7,000 (70%)</td>
</tr>
</tbody>
</table>

Table 1: Savings of 70% to 80% when machined tooling was replaced with FDM for a custom pulp fiber protective packaging project. *Outsourced production.

![Figure 1: Molded fiber packaging, such as that used in egg cartons, is often used in high volume applications.](image1.png)

![Figure 2: The soft fibers cushion and absorb impact. Common uses include electronics, household goods, automotive parts and medical products. Image courtesy of UFP Technologies, Inc.](image2.png)

![Figure 3: FDM fiber forming molds serve as both prototype and low-volume production tools.](image3.png)

![Figure 4: Type 1 (thick-walled) molded fiber packaging made from an FDM mold.](image4.png)

![Figure 5: Type 2 (transfer molded) packaging tray molded from an FDM tool.](image5.png)
FDM is uniquely positioned to address the requirements of molded fiber tooling. FDM produces tools in thermoplastics that withstand paper fiber abrasion; are stable in the warm water slurry; are strong and rigid under vacuum; and resist cracking from the stress of vacuum and blow-off cycles. FDM paper fiber molds are tough enough for low-volume production and perfect for prototyping and sampling.

With only a few minor adjustments to the construction parameters, FDM molds are made to be porous. Eliminating the need to manually add a metal screen to a machined mold accelerates the process, eliminates skilled labor and produces an exact duplicate of the design detail (Figure 6). There is no screen forming, bending, cutting or welding because the FDM tool is both porous and rigid. Another advantage is that the molding process, which is unique to each company, requires no modification. FDM molds can be run alongside traditional molds with no alteration to the slurry formula, cycle time, vacuum pressure or other process variables. This means that FDM is easily integrated into any molded fiber operation.

FDM produces a fiber forming mold that delivers vacuum flow to all molding surfaces while resisting paper fiber clogging. Testing has demonstrated that FDM paper fiber molds are perfect when time is critical, skilled tradesmen are in short supply and cost must be kept low. The testing also shows that ideal applications are those where the molded pieces are complex.

**PROCESS OVERVIEW**

Molded fiber manufacturing begins with fiber slurry made from ground newsprint, kraft paper or other fibers and a high concentration of water. Mounted on a platen, a mold (Figure 7) is dipped or submerged in the slurry, and a vacuum is applied to the backside. The vacuum pulls the slurry into the mold to form the shape of the piece. While still under vacuum, the mold is removed from the slurry tank, which allows water to be drawn from the pulp. The molded fiber piece is then ejected when air is blown through the tool. The part is deposited on a conveyer that moves through a drying oven.

In Type 2 molding, a transfer mold is added to the process. It mates with the fiber mold and a vacuum is pulsed through it to hold and lift the molded article. The transfer head then moves the molded article to the drying conveyer.

High-volume production molds are machined from metal billet, and a metal screen is fabricated to mount on the molding surface. For low-volume work and prototyping, a similar process is used, but easily machined materials are substituted for the metal base. For extremely low-volume prototyping, typically less than 30 units, porous foams are machined, which eliminates the screening operation. Although faster and cheaper, the foam material wears and clogs quickly. Additionally, details in the tool begin to degrade with the first molded piece. The FDM process yields equal, or greater, time and labor benefits to that of machined foam, yet it offers precise molded parts in quantities that range from 1 to 30,000 pieces (Figure 8).

**FDM MOLD PRODUCTION PROCESS**

Note that the following information is offered as a general guideline for production of fiber forming molds. Since each manufacturer has customized molding lines and proprietary molding parameters, such as the slurry’s fiber to water ratio, these guidelines may need slight alteration to adapt to a manufacturer’s process.

**Mold Design**

Fiber forming molds and transfer molds are designed as they would be if conventional techniques were used. This is true for both shell molds—surface profile backed with a castable fill material—or solid molds—rectangular block with a molding cavity. However, to maximize performance and efficiency while further reducing time and cost, molders may elect to incorporate design modifications. For example, the wall thickness of a shell mold may be reduced to decrease build time and material consumption. To ensure rigidity for the thinner walls, supporting ribs may be added. Additionally, modification can be made to the vacuum channels to increase the air flow in specific areas of the tool. Depending on the size of the tool and the geometry of the molded piece, a shell thickness of 1/8 to 5/16 inch (3.2 to 8.0 mm) is recommended. (Figure 9)

**Build Preparation**

The CAD model of the mold is exported as an STL file. This file is then processed in Insight, FDM preprocessing software, to specify build parameters. Within Insight, userdefined variables are modified to produce porosity, which allows vacuum flow while maintaining surface finish and mold strength. This is the most important step in mold building because the processing variables
must maximize air flow and minimizing clogging from the pulp fiber. This is achieved by altering the raster gaps in the FDM deposition tool path to create pathways for air flow (Figure 10).

Insight’s custom groups allow fiber molders to predefine ideal build parameters and selectively apply them to the mold (Figure 11). Building on early successes, the recommended custom group settings have been refined to improve surface quality without degrading the vacuum flow. Also, an optional custom group has been created to allow surfaces to be sealed where vacuum in not needed.

There are three customs groups applied to a fiber forming mold.

Group 1: Apply to even-numbered layers (slices). (Figure 12)

- Settings
  - Contour style: None
  - Adjacent rasters: 0.010 in. (0.25 mm)

Group 2: Apply to odd-numbered layers. (Figure 13)

- Settings
  - Contour style: perimeter/raster
  - Adjacent rasters: 0.080 in. (2.00 mm)

Group 3: Apply to up-facing surfaces that use Group 2 settings.

- Settings
  - Contour style: perimeter/raster
  - Adjacent rasters: 0.015 in. (0.38 mm)

By applying Group 1 and Group 2 to alternative layers, vacuum is maximized and pore blockage is minimized (Figure 14). Applying Group 3 to the molding surfaces of the tool that have the larger adjacent raster setting improves the surface quality of the tool and molded fiber part. As previously noted, these following specifications work for many molds, but they may need refinement based on tool geometry or molding process standards.

To seal surfaces and block vacuum flow, follow these guidelines:

- Create a layer range for the surfaces to be sealed.
- Offset curves, towards the inside of the mold, by 200% of the contour width and retain the original.
- Offset the newly-formed curve to the inside by 0.0001 in. (0.003 mm) and retain the original.
  - Now there are two separate closed curves
- Curve 1—outside curve
  - Apply default Part Group
- Curve 2—inside curve
  - Apply Groups 1 and 2 (above) and Group 3 if sealing is necessary.

For Type 2 molded fiber, a transfer mold is also constructed with the FDM process. Since the transfer mold is not subject to fiber clogging, and the vacuum only needs to hold the molded piece, it is constructed using a sparse fill build style with default parameters. This style creates an internal lattice that is covered by a solid surface. In Insight, the contours (outer surfaces) have a default thickness of 0.020 to 0.040 inch (0.5 to 1.0 mm). In cases where pulp thickness is not predictable and modification is likely, the contour thickness may be increased to 0.100 inch (2.5 mm) to allow refinement of the transfer mold with conventional machining.

The final consideration is build orientation. Ideally, the mold is oriented to minimize the amount of support structure, material and build time. If this orientation has the molding surface facing downward, support structures will connect to the mold where the air gaps are the smallest. To minimize pore blockage, the support structure configuration may need modification.

Material Selection

For fiber forming molds, ABS-M30 and polycarbonate (PC) are the preferred materials. PC is used when strength and stiffness are desired. ABS-M30 is used when strength is needed but a
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small degree of flex ("give") is advantageous. However, most FDM materials can be used in fiber forming applications. Transfer molds are typically made of ABS-M30.

FDM Building
Following preparation in Insight, the build files are transferred to a Fortus 360mc, 400mc or 900mc. After the build process is started, the fully automated operation is completed without operator attendance.

Post processing
Following the build, the mold is removed from the FDM machine, and the support structure is removed from the mold. No other processing is required— the mold is ready to be mounted to the platen of the molding line, if it is a solid, block mold. If using shell molds, the FDM tool is backfilled with the same material used for production molds. Since transfer molds have a solid outer surface, drill 1/8 to 3/16 inch (3 to 5 mm) holes through the faces to allow air to pass through the tool.

Molding
FDM molded fiber molds are installed and operated like traditional tools. No process modification is required. The mold can be run with production tools that are conventionally manufactured (Figure 17).

Mold Maintenance
All forming molds require frequent cleaning to remove fibers that clog the tool and decrease the vacuum flow. FDM molds are no exception. As with machined molds, the FDM tools are cleaned with a high pressure water jet that blows the paper fibers out of the vacuum holes. Typically, the cleaning process is repeated after thirty minutes of molding operation.

CONCLUSION
Whether a project requires 100 samples for testing or thousands of custom parts, the FDM technology enables manufacturers to economically produce molded fiber packaging in only a few days. Fast and automated, FDM allows manufacturers to respond quickly to their customers’ demands for prototype and production molded fiber. Reducing the demand for skilled labor, FDM also increases plant efficiency and throughput. With no change to standard molding practices, molded fiber manufacturers can easily integrate the technology within their operations (Figure 18).

FDM is an innovation in molded fiber production. Relatively unchanged from the 1930s, mold making now benefits from the additive fabrication process used by many industries. And yet, research and development continues. Techniques and designs that promote fiber pass through are being tested. When successful, FDM will also become a solution for high-volume molded fiber production. As one test site commented, "FDM will replace conventional tooling in our industry."

FDM PROCESS DESCRIPTION
FDM® (fused deposition modeling) is a direct digital manufacturing process patented by Stratasys, Inc.

The FDM process creates functional prototypes, tooling and manufactured goods from engineering thermoplastics, such as ABS, sulfones, and polycarbonate, as well as medical versions of these plastics.

FDM machines dispense two materials—one for the model and one for a disposable support structure. The material is supplied from a roll of plastic filament on a spool or in a cartridge. To construct the model, the filament is fed into an extrusion head and heated to a semiliquid state. The head then extrudes the material and deposits it in layers as fine as 0.005 inches thick.

Unlike some additive fabrication processes, FDM requires no special facilities or ventilation and involves no harmful chemicals and byproducts.

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