FIBERGLASS LAY-UPS

FORTUS
3D PRODUCTION SYSTEMS

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

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OVERVIEW

Boat hulls, golf cart bodies, bath tubs and R/C cars are common items made of fiberglass. Other products manufactured with fiberglass reinforcement include theme park rides, swimming pool slides, custom auto parts, and a wealth of covers, tanks and vessels. Although the applications are widely varied, the process of creating these products is essential the same when production quantities are low. Each is constructed from hand-laid layers of fiberglass cloth.

Fiberglass parts are produced in molds through a manual process known as a lay-up. To prepare the mold, it is coated with a release agent and then a gel coat is applied. This layer is then followed by a coating of resin or epoxy. Before setting, fiberglass cloth, which is impregnated with the same resin or epoxy, is laid on the surface of the mold. The lay-up process is repeated until the desired thickness of the part is achieved.

During the manufacturing process, the fiberglass lay-up is compressed to drive out air bubbles; force resin deep into the fiberglass part; consolidate plies; and force the fiberglass into the corners, pockets and recesses of the mold. This compression may be done with hand tools or through vacuum compaction. In the latter method, a vacuum bag surrounds the lay-up, and the air is drawn out. Atmospheric pressure pushes down on the vacuum bag and fiberglass plies to compact the layers.

Traditionally, there have been two options to make the molds for the fiberglass lay-up process, CNC machining and handcrafting. While both methods are used throughout industry, handmade tools are more prevalent in small- to mid-sized shops due to the expense, expertise and overhead needed for CNC machining.

A handmade mold is crafted in the very same manner, and with the same materials, as the fiberglass parts that it will produce. Mold making begins with a plug, which is a master model of the part design. On top of the plug, layers of resin and fiberglass cloth are laid-up until the mold reaches a thickness that will make it stable when making parts. Between each layer, the resin is allowed to partially cure, and when the mold is complete, it is cured for two to three days. For a reasonably sized mold, the entire process may take two to three weeks.

Handcrafting a mold is a labor intensive process that is performed by skilled workers. Much of this labor goes into the mold's lay-up, but a lot of time will go into the iterations needed to adjust the mold to meet design specifications. Fiberglass lay-up has rather loose tolerances, in part due to the high rate of thermal expansion. When doubled—once for the mold and once for the part—the final dimensions of a fiberglass part can be difficult to predict.

In spite of the labor demands, expenses and lead times, handmade molds for fiberglass lay-ups continue to be a preferred tooling approach for many fiberglass part manufacturers.

FDM AND FIBERGLASS LAY-UPS

FDM (fused deposition modeling) is an alternative approach to mold making for fiberglass lay-ups. Replacing the labor-intensive and time-consuming process of hand making molds, FDM addresses the need for shorter lead times, lower expense and higher accuracy.

FDM is a viable tool making option because its thermoplastic materials can withstand the heat generated during fiberglass lay-up, and they can resist the pressure of vacuum compaction. In the mold, resins and epoxies will reach temperatures approaching 200 °F (95 °C). Under vacuum,

APPLIES TO MATERIALS:
- ABS-M30

SUPPLIES:
- CLR1632 resin | CLH6027 hardener

- Weld-On #3 (optional)

- Standard supplies used for fiberglass lay-up

TOOLS & EQUIPMENT:
- Smoothing Station™ (optional)

- Standard tools for fiberglass lay-up

SUPPLIERS:

- Crosslink Technologies: epoxy top coat

Finished Fiberglass part using an FDM mold.

pressure approaches 14.7 psi (101 kPa). Testing has shown that FDM materials, like ABS-M30, can withstand these conditions.

Unlike traditional mold making processes, FDM is automated and labor less. While a mold is being constructed, skilled shop employees are freed to tackle other urgent tasks. Although preparing the mold for the first fiberglass lay-up does require some direct labor, most molds will need less than a few hours of hands-on work. And with the accuracy of the FDM process, there will be no need for the iterative adjustment of the mold to dial in part accuracy. In general, molds are producing fiberglass lay-ups in only two to four days.

To illustrate the time and cost reductions that FDM delivers, it is compared to the handmade mold approach for a fiberglass lay-up of an R/C boat hull. The estimate for a handmade fiberglass mold is two weeks and $500. In contrast, FDM yields a 70 percent reduction in lead time (3 days) and a 25 percent reduction in cost ($375) (table 1).

Process	Lead Time	Plug	Lay-up	Cure	Refine	Labor Cost	Supplies Cost
Handmade Mold	2 weeks	1 day	1 day	3 days	1 day	$350	$150
Process	**Lead Time**	**Design**	**Build**	**Prep**	**Tool Design**	**FDM Build**	**Mold Prep**
FDM Mold	1 day	0.25 days	1 day	1.5 days	$100	$100	$75
SAVINGS	**TIME REDUCTION WITH FDM: 1.5 weeks (70%)**				**COST REDUCTION WITH FDM: $125 (89%)**		

Table 1: Time and cost comparison of handmade mold and FDM mold model of a rear tire blower nozzle.

PROCESS

Independent of the mold making approach, the fiberglass lay-up process remains unchanged. First, the mold is coated with a release agent. Next, a gel coat is sprayed or brushed onto the mold cavity. After setting, but before hardening, the epoxy (or resin) is applied on top of the gel coat. Then a sheet of fiberglass cloth is pressed into the cavity and epoxy is brushed onto the cloth. This process is repeated until the desired thickness is achieved.

Due the heat buildup during lay-up, the part will be allowed to cure after a number of layers of epoxy and fiberglass have been applied. After the lay-up is complete, the part is allowed to cure for 24 hours at room temperature or 8 hours at 140 °F (60 °C). After curing, the part is then trimmed to size and visible surfaces are sanded and buffed.

If vacuum compaction is used, the lay-up is covered with release film to separate if from the bleeder layer, which absorbs excess resin. After the bleeder layer is the bag film that acts as the vacuum membrane. This film is sealed to the mold or itself. When the vacuum is drawn, air pressure compacts the layers of fiberglass and forces excess epoxy out of the part.

Following are the steps to produce a fiberglass lay-up mold with FDM.

1. Mold Design

Mold design for fiberglass lay-up is simple and straightforward. In CAD, begin by creating a mold block that is slightly larger than the fiberglass part. A 1.0-inch (25.4 mm) allowance is suitable for the four sides and back face of the mold. To create the cavity in which the fiberglass will be molded, subtract the part geometry from the mold block (figure 1).

During the fiberglass lay-up process, the mold will reach temperatures approaching 200 °F (95 °C), and this will cause it to expand. To compensate for the expansion, decrease the size of the mold in accordance with the FDM material's coefficient of thermal expansion (CTE). For ABS-M30, the CTE is 4.9E-05 in./in.-°F (8.82E-05 mm/mm-°C). Therefore, a 12 x 12 x 12 inch mold with this CTE would require that each sided be scaled down by 0.076 inch (1.93 mm), if a change in temperature of 130 °F (54.4 °C) is assumed. This is equivalent to an overall scale factor of 0.9937.

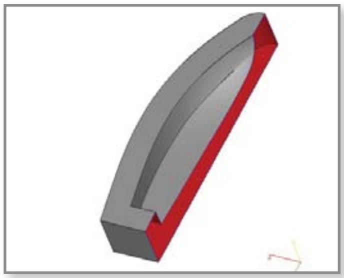

Figure 1: Cross-section view of CAD model of the mold with 1.0-inch (25.4 mm) allowance

If the mold is larger than the Fortus system's build envelope, simply divide the CAD model into smaller pieces and process each as a separate item for the FDM build.

2. Mold Building

Import the mold's file into Insight to prepare it for production in an FDM system. To reduce material consumption and build times, molds are constructed with a Sparse-fill build style. This construction technique replaces the solid core of the mold with a scaffold-like structure that is surfaced with several solid contours. An additional advantage of this build style is that it protects against mold distortion that may result from the elevated temperatures of the lay-up process. If constructed as a solid block, thermal expansion can induce stresses that cause a slight curl in the mold.

Within Insight there are two styles of Sparse builds, Sparse and Sparse Double Dense. For fiberglass lay-up molds, Sparse Double Dense is recommended. Apply this style to the mold geometry without any changes to its default parameters. If the fiberglass lay-up will not be vacuum compacted, the Sparse build style may be used, but it is not recommended.

The next step in preparing the build file is to align the FDM deposition seams. To preserve the quality of the molding surface, position these seams, which are on each layer, on the back face of the mold. Finally, select ABS-M30 as the model material for the FDM build. While other FDM materials may be suited to the fiberglass lay-up process, they have yet to be evaluated for this application.

Once the files are readied for building, download them to the Fortus system and begin the construction process.

3. Mold Preparation

After the molds have been built, remove them from the Fortus system. Next, remove the support structures from the mold and rinse thoroughly to remove any residue from its surface (figure 2).

There is no need to sand the FDM mold's surface prior to making the first fiberglass part because a protective, barrier coat of epoxy will be applied. This top coat of epoxy will fill in build lines on the molding surface. Additionally, sanding and buffing of the fiberglass parts will remove any remaining surface imperfections.

Although sanding is unnecessary, the Stratasys smoothing process is highly recommended. This optional process not only smooths the mold's surface, it seals it. Sealing will prevent the epoxy top coat from leaching into the mold, which can cause pitting. If the mold's surface has these imperfections, de-molding a fiberglass part may be difficult.

To seal the mold, place it in the cooling chamber of the Smoothing Station for five to 15 minutes. Then, transfer the mold to the smoothing chamber. Return the mold to the cooling chamber after 30 seconds. Repeat this process three times and then allow the mold to cure overnight. When cured, transfer the mold to the Burnishing Station for a light soda blasting. Alternatively, the mold surface may be lightly sanded. This operation removes the glossiness of the smoothing process to promote better adhesion of the epoxy top coat.

Next, wash the mold thoroughly to remove any dry soda or sanding residue. If left on the mold's surface, adhesion of the epoxy top coat may be inhibited.

If the mold was sectioned prior to the FDM build, bond the pieces using IPS Corp.'s Weld-On #3. Do not attempt to bond the mold sections before the smoothing process since it will weaken or break the adhesive's bond.

The final step in mold preparation is the application of a CLR1632 epoxy top coat to protect the ABS-M30 mold's surface (figure 3). When molding fiberglass parts, the resins and epoxies will chemically attack the ABS material. So, an epoxy barrier coat is applied to the mold's cavity, either by brushing or spraying it on. After an 8-hour cure at 140 °F (60 °C), the mold is ready to make fiberglass parts.

4. Fiberglass Lay-up

Once the mold has been constructed and prepared (figure 4), the fiberglass lay-up process proceeds as usual. There are no changes to the materials used or methods applied, including vacuum compaction (figures 5 and 6).

CONCLUSION

With FDM, fabricators have a digital, rapid tooling solution for their fiberglass lay-up projects. It replaces the inherently labor intensive, skill-based, messy and time consuming process of handcrafting fiberglass lay-up molds. In doing so, FDM automates, expedites and improves the mold-making process.

Figure 2: After support removal, the FDM mold can optionally be smoothed using the Smoothing Station offered by Stratasys.

Figure 3: The epoxy is uniformly applied to all surfaces that will have contact with the fiberglass resin.

Figure 4: After the epoxy has cured, the mold surface is sanded and buffed to the desired finish.

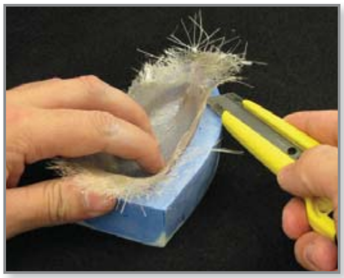

Figure 5: After the lay-up process, the part is trimmed and removed from the mold

Figure 6: The finished fiberglass part is now ready for use.

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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