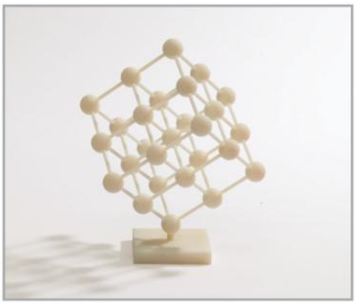
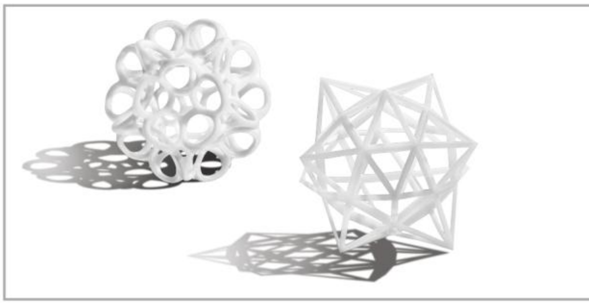
Using Objet technology for molding fiber reinforced plastics

Objet Ltd.





Introduction

Fiber reinforced plastics are a group of composite materials consisting of a polymer matrix reinforced with fibers. Commonly used fibers are glass (fiberglass), carbon and aramid (Kevlar). The common resins used as a matrix to hold the part's shape are epoxy and polyester. The composition of the matrix and fibers results in a high performance, strong yet lightweight material. The technology goes back to the mid 1930's with the introduction of fiberglass reinforced plastic. Since then many developments were introduced and the applications were broadened significantly.

Figure 1: Colored scanning electron micrograph (SEM) of carbon fiber-reinforced plastic. The plastic (epoxy resin, yellow) and High-strength carbon fibers (grey) embedded in it. (Magnification: x1920)

Figure 2: Woven Glass (white), Carbon (black), and Kevlar (yellow) fibers clothes.

Major industry segments utilizing fibers reinforced plastics:

- Aerospace
  - Being very strong while lightweight materials, fiber reinforced plastics go hand in hand with the aerospace industry needs. The high mechanical properties of these materials address many of this industry's specific requirements.

Figure 3: A Micro-Unmanned Air Vehicle **(**MUAV**)** made of carbon fibers

- Automotive
    - In the automotive industry, fibers reinforced plastics are used to reduce weight hence energy consumption of a vehicle moving on the road. Other than this, the vast possibilities of the geometries these materials allow, is widely used in the automotive industry.

Figure 4: Carbon fibers air duct and a break handle on a motorcycle (left) and a side mirror cover made of carbon reinforced epoxy (right)

- Sporting goods
    - Fibers reinforced plastics found their way also to the sporting goods industry. The material's high strength and low weight make them well-suited for bicycle components, hockey sticks, pedals, helmets, ski equipment, tennis rackets and more.

Figure 5: Molded fiberglass fins on a surfboard (left) and a full bicycle chassis made of carbon fibers reinforced epoxy (right)

- Consumer goods
    - In recent years, fibers reinforced plastics are being used also in consumer goods. Carbon fibers are the most commonly used mainly thanks to their luxurious appearance.

Figure 6: Luxurious carbon fibers iPhone cover (left) and a lightweight carbon fibers suitcase (right)

- Bio-medical
  - The high requirements of the constantly improving design of prosthesis led to the incorporation of fibers reinforced plastics into the bio-medical industry. The prosthesis needs to be strong, light and customized which makes the fiber reinforced plastics an ideal solution.

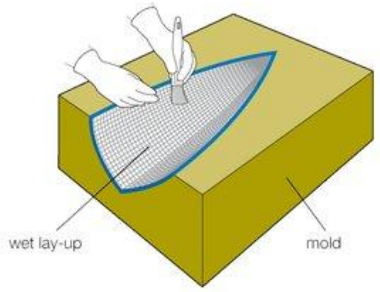
Figure 7: carbon-fiber prosthetic running blades (left) Carbon Fiber Ankle Foot Orthosis (AFO) for treating conditions such as Drop Foot (right).

Current challenges and the Objet solution:

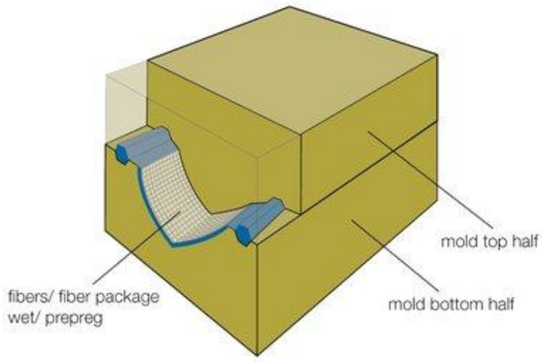
Fabricating fibers reinforced parts requires molding. There are two distinct categories of molding processes using fibers; these include composite molding and wet molding. Wet molding combines the fibers reinforcement and the matrix during the molding process. Composite molding uses prepreg (pre-impregnated) fibers, meaning the resins are already absorbed in the fibers before the molding process. This process involves high temperatures and pressures to harden the prepreg fibers inside the mold to achieve the desired geometry. In this document we will concentrate on the wet molding processes as they are more relevant to the Objet solution.

There are several different molding methods and the most relevant are explained below. Other methods exist, but most of them are very similar to the ones described here.

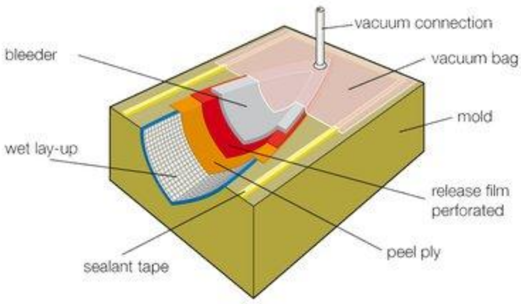
Wet Layup – The fibers and the matrix, a few (2-3) components resin are put into the mold. The resin components (usually named base & hardener) react and solidify to create a solid, fibers reinforced part.



Wet Compression – This process is very similar to the wet layup process. It differs by the fact that in this method, after the fibers and resin are put in the mold, a second half of the mold is placed onto them to make sure the material follows the mold's pattern.



Vacuum layering – This molding method involves a vacuum bag instead of a compression mold to make sure the mold is fully filled and no air bubbles are trapped.



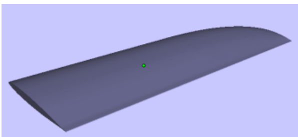
Vacuum layering is also the method used in the case described below.

As one could realize, no matter which molding method is to be used, a mold is needed. Traditionally, molds for fibers reinforced resins are made of machined aluminum, or of fibers reinforced resins put onto a fabricated master. In fact, when the latter option is used, masters can be easily and quickly fabricated with an Objet 3D printer. The accuracy and surface quality of the printed models are of extreme importance at this point. This document describes an even faster and easier method – 3D printed molds.

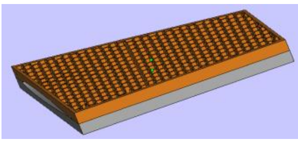
Advantages of Objet technology for fibers reinforced plastics molding:

The user can easily print a mold from a CAD file within a few hours. The printed mold can be used to generate a few copies. If many copies are needed, one of the copies can be used as a master for fabricating another mold in the traditional way. In this scenario the printed mold acts as a bridge to provide parts quickly while the traditional mold is made as well as a tool to create the master for the traditional mold.

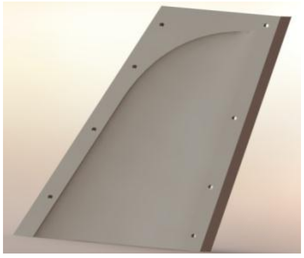
- The process:
  1. Part's CAD file –
     The part is designed using CAD software.

  2. Mold's CAD file –
     The mold design is derived from the part design in the CAD software

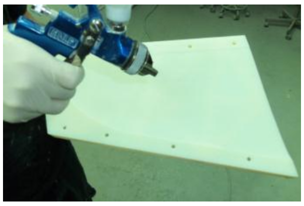
3. Printing the mold –
   Print the CAD designed mold on an Objet 3D printer



4. Polishing the printed mold –
   The mold can be polished if a very high surface smoothness is required

5. Applying release agent –
   To make sure that the part will be easily released from the mold, release agent is required.

6. Painting –
   Painting the mold after applying release agent allow the final part to be released painted.

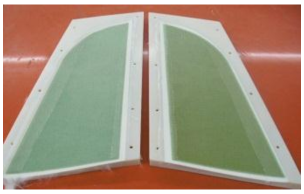


7. Materials preparation –
   Fabrics are cut to fit mold's size and shape, epoxy is mixed. Any additional components to be prepared at this point if needed.

8. Impregnating the fibers –
   In this stage the fibers first meet the matrix resin. It is important to make sure the resin is well absorbed in the fabric.

9. Vacuum bagging the mold –
   The mold and material are put in a vacuum bag. The vacuum removes excess resin, makes sure the reinforcing fibers are close-fitted to the mold and no air bubbles are trapped.

10. Debagging and excess trimming –
    After the epoxy resin hardens the mold is removed from the vacuum bag and excess fabrics are trimmed.



11. Closing the 2 halves –
    At the final stage, the two halves are glued together inside the mold. The part is then removed from the mold, result in a strong, lightweight painted part.

In traditional methods, mold making takes longer times either by using CNC and more significantly when creating a mold made of fibers reinforced resin from a master mold. The Objet solution enables to reduce the time required to have a real part in hand considerably. The solution can also be used as a bridge to manufacture parts on a very short notice while a longer term mold is being made.

The table below concentrates the comparison between the molding methods for the case described here:

	Fabrication time	No. of copies (estimation)
CNC machined mold	10 days	200
Fiberglass mold	12 days	150
Objet printed mold	2 days	20

Molding and estimations by: Aerosol aeronautical solutions IL.

Design considerations

- Some resins heat up while solidifying. It is recommended to print the mold with one of Objet's higher temperature materials. The material used in the case described above is Objet High-Temperature material RGD525.
- In the vacuum bag, the mold has to withstand high pressures for as minimum as several hours. To assure the mold's surface endures such pressures, make sure the mold's surface is thick enough. In the case described above, the mold's thickness was 10mm.

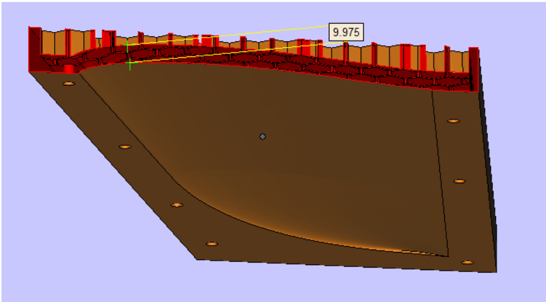


Figure 8: A section view of a of the printed mold CAD file. The surface thickness is 10mm.

- For enhanced mechanical properties of the mold, design it with enough supporting ribs. In our case, a honeycomb structure was used to allow even support to the full mold area.

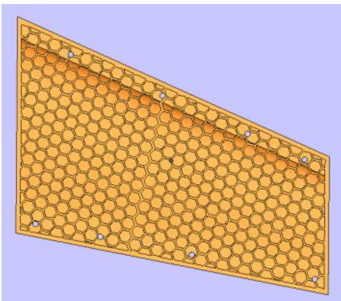


Figure 9: A bottom view of a of the printed mold CAD file. The whole mold area is supported with honeycomb support ribs.

- For best fit between the two mold halves, matching holes can be designed in both halves to assure easy alignment when gluing the two halves.
- Molded parts will copy exactly the mold's surface. To achieve mold with high surface quality, print the parts in high quality mode, gloss finish facing up. If a smoother surface is needed, the Objet materials can be easily polished to further improve surface quality.

Conclusion

Using Objet technology for molding fiber reinforced plastics is very much possible, and preferable when time constrains exist. The short mold fabrication process makes this technology a very beneficial solution for prototyping parts made of the end part material. Objet's printed model's high accuracy and excellent surface quality make this solution very suitable to the fibers reinforced plastics molding demands. Objet's technology fits well also into the traditional mold making process by providing accurate smooth parts with complex geometry to be used as masters for molds.

This project was held in full collaboration with Aerosol aeronautical solutions IL. :