CARBON FIBER LAY-UPS

FORTUS 3D PRODUCTION SYSTEMS

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

By Jesse Hanssen, Stratasys, Inc.

OVERVIEW

Today, it seems that every so-called "high-performance" product uses carbon fiber as some vital component of its construction for either structural integrity or appearance. Although it was originally used in the aerospace industry, carbon fiber continues to move into the mainstream in products ranging from notebook computer cases to mountain bike frames.

Carbon fiber, like any composite material, is created from two dissimilar materials that, when combined, act as one. As the name suggests, carbon reinforcement fibers are held together in a resin matrix. When the two component materials are brought together through a process known as a lay-up, the carbon fiber and resin form a new material with physical properties that far exceed those of either constituent material by itself.

Composites, as a rule of thumb, offer their greatest strength along the direction or axis that the fibers run. This characteristic lets users optimize or "tune" a composite's strength based on the orientation of the fibers. For example, if strength is required over the length of a part, align the fibers lengthwise.

There are literally hundreds of types of resins available, such as epoxy and polyester, and each has its own distinct chemical and physical characteristics. Carbon fiber is available in several different forms as well, and is chosen based on physical property requirements. These forms include woven (also known as cloth), filament (also known as roving or tow) and unidirectional. This discussion will focus on the use of woven (cloth) carbon fiber composite material and FDM part built on a Fortus 3D Production System.

Carbon fiber material is available with or without the resin matrix. With a "wet" lay-up, carbon fibers are applied to a form and resin is poured and brushed onto the cloth. The alternative is a "dry" lay-up, which uses pre-impregnated (pre-preg) fiber that is delivered with the resin matrix applied. Although pre-preg is easier to use, it is more expensive and is available with fewer varieties of resins.

Carbon fiber Bicycle seat made an FDM mold.

FDM car door with carbon fiber overlay.

FDM AND CARBON FIBER LAY-UPS

When using FDM (fused deposition modeling) as an overlaid pattern or a mold, the lay-up procedure is largely the same as that for machined parts, molded cores or machined tools. However, FDM offers the advantages of reduced weight, lower cost, faster delivery and flexibility for design changes.

In contrast, the traditional methods of machining patterns and tooling are time-consuming and labor-intensive processes. Requiring skilled labor to program, set up and supervise the machining operations decreases efficiencies and drives up costs. For the bulk of carbon fiber projects that need tooling for lay-ups and overlays, the expense and delays increase with every design revision or part customization.

Replacing machining with FDM accelerates the process and minimizes start-up expenses. Since it is an unattended operation, patterns build through the night without the need for staffing. And when design changes arise, they are incorporated without any delay or additional expense. FDM also does what no molding or machining operation can; it makes hollow parts with an internal framework that reduces weight without sacrificing strength. FDM for carbon fiber lay-up has a great degree of potential, but bear in mind that development is still in the early stages. Therefore, this application guide will address the process in generalized terms. For more specific information on the materials and processes involved, please contact a Stratasys Applications Engineer.

PROCESS OVERVIEW

The overall process that combines FDM and carbon fiber composites is commonly called lay-up or overlay. The carbon fiber cloth is laid over a mold to produce an "open" part or around a core to create an “enclosed” structure. The enclosed parts are described as having a carbon fiber wrap, skin or shell.

Carbon fiber can be overlaid with two different processes, and FDM has proven suitable for both. The first process is known as “wet carbon fiber lay-up.” A dry carbon fiber sheet is laid over the part or mold and resin is applied by hand. The resin provides the stiffness for the dry sheet, and it is the bonding agent for a carbon fiber wrap.

The second process is known as “pre-impregnated carbon-fiber lay-up.” This method uses fiber that is impregnated with resin. Pre-preg provides much better penetration of the resin and more uniform resin thickness than the wet lay-up process. The pre-impregnated roll is frozen by the vendor prior to delivery to prevent the resin from curing. The fiber is thawed at the lay-up site and hand laid over the part or mold. Typically, it is then vacuum compacted and baked in an oven or autoclave at 250 to 350 °F (121 to 177 °C) for a prescribed amount of time.

Prior to the actual lay-up, core parts are produced for enclosed applications and molds are made for open parts. Molds are typically hand-carved or CNC machined from a clay or foam (such as polyisocyanurate). Currently, the most common FDM application is for the production of cores for carbon fiber overlay to make enclosed parts. However, it has also been used to produce molds.

Carbon fiber overlay creates a very strong, lightweight and durable skin. The fiber wrapped parts are used in a variety of racing vehicle, airfoil and aerospace applications. Overlays are also used to construct parts, such as those in a customized vehicle, that have complex surfaces that must be durable and cosmetically pleasing.

Carbon fiber can be applied to any size part, and the part can have complex, freeform surfaces. However, a part’s intricacy can have a negative impact. Since the carbon fiber cloth is wrapped around the core or placed into a mold, some features may be lost and others may lose definition.

OPTIMIZING FDM AND CARBON FIBER

Companies that inquire about FDM for carbon fiber applications are seeking an alternative that reduces lead time for part production, decreases core weight, enables customization and reduces tooling cost. When traditional machining processes for patterns or molds are replaced with FDM, customers are discovering all of these advantages.

It is relatively expensive to create a CNC block mold for carbon fiber parts and very expensive to create tooling to mold cores. Beyond the expense, the drawbacks to traditional methods are the time needed to produce tooling and the inability to make changes. Customization of parts is becoming very popular in the carbon-fiber industry, which leads to very expensive products due to the need to create custom tooling that constantly changes.

As part of the carbon fiber lay-up process, FDM can be used in prototyping, bridge-to-production and manufacturing applications. For example, one customer produces FDM cores for airfoils, which are later assembled and overlaid with a carbon fiber skin. In this instance, a Fortus system manufactures the cores. However, in other applications, it is used to manufacture the carbon fiber molds.

Using FDM, rather than traditional CNC machining for production, changes the pattern-making or mold-making steps. In most cases, it is not difficult to change from machining and molding to the FDM methodology. Making the patterns or molds is simple, and the process is easy to learn. With CAD files and access to FDM technology, patterns and molds are created with little effort. For many, the only hurdle to making the conversion is determining the best combinations of carbon fiber cloth, resin and Fortus material for good adhesion.

FDM is an ideal additive fabrication technology for production of carbon fiber components. There are several unique characteristics of FDM that create compelling reasons for using it instead of other additive fabrication technologies. First, FDM has the ability to produce large and accurate parts that are strong enough to serve as the core for an enclosed application. Second, the inherent porosity of FDM parts aids in adhesion. Third, Fortus materials are capable of withstanding the pressure of vacuum compaction and the temperature of an oven or autoclave.

SIMPLIFIED FDM AND CARBON FIBER LAY-UP PROCESS

Because there are many variables involved with FDM and carbon fiber, and research is in the early stages, the steps in the process are described in generic terms. Additionally, the steps listed are for a pattern overlay where the FDM part becomes the enclosed core. However, much of what follows can be applied to a broad range of application possibilities.

PREPARE AND BUILD THE FDM PATTERN

The carbon fiber shell will provide the majority of the stiffness and impact strength for the part. The FDM pattern is primarily subjected to shear, which means the internal part geometry does not require a great deal of strength. For this reason, it is best to process the part with sparse or sparse double-dense fill in order to reduce part weight, build time and material consumption. For adhesion and shear strength purposes, a shell thickness of at least 0.050 inch (1.3 mm) is recommended.

Build layer lines are easily hidden under the composite wrap, so the part does not need to be oriented with any consideration for surface quality. Instead, orient the part to minimize the part's height, which will produce the fastest build. The pattern can be made from any Fortus material. However, polycarbonate (PC) has the best combination of adhesion and durability.

PREPARE THE FDM PATTERN FOR LAY-UP

This is an easy step because there is not much that needs to be done to prepare the FDM pattern. Lightly sand the part to remove any loose material and to knock down the sharp layer edges. This will help improve the part strength by increasing the bonded surface area. After sanding, clean the part thoroughly to remove any excess dust.

COMPOSITE LAY-UP

Lay the composite fabric over the FDM pattern. Mix a small amount of epoxy resin (if too much is mixed, it will cure before it is applied) and begin application. Apply pressure while dabbing the resin on the fiber, working out air bubbles and promoting adhesion to the pattern. Continue this process until the entire part is covered.

Allow the lay-up to cure and add further resin coats until the part achieves the desired thickness, strength and gloss. When the overlay is complete, it may be necessary to wet sand and polish if a high-gloss finish is desired.

CONCLUSION

Applying FDM to the manufacture of carbon fiber parts promotes a more cost-effective process, especially for parts that would require expensive, machined tooling. It can also result in parts with superior strength to weight ratios.

Although combining FDM with carbon fiber is a relatively new technique, it has great potential that is only limited by the imagination. It is already saving money and time, producing superior products and adding to the bottom lines of progressive companies that seek out alternatives to traditional methods. These companies are pushing the limits of possibility, taking giant strides into the future and enjoying the many advantages.

ACKNOWLEDGEMENT

Stratasys would like to acknowledge Dynastrosi Laboratories (www.dynastrosi.com) for its assistance in producing this document.

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**

Fortus 3D Production Systems
Stratasys Incorporated
7665 Commerce Way
Eden Prairie, MN 55344
+1 888 480 3548 (US Toll Free)
+1 952 937 3000
+1 952 937 0070 (Fax)
www.stratasys.com
info@stratasys.com

Fortus 3D Production Systems
Stratasys GmbH
Weismüllerstrasse 27
60314 Frankfurt am Main
Germany
+49 69 420 9943 0 (Tel)
+49 69 420 9943 33 (Fax)
www.stratasys.com
europe@stratasys.com

FORTUS™
3D PRODUCTION SYSTEMS