Molding Fiberglass

Composites offer tremendous possibilities for part fabrication once a few basic concepts are understood. The key lies in understanding the different materials available, their applications, and the best ways to handle them.

This brochure is intended to be a general overview of composite fabrication, with an emphasis placed on the fabrication of parts in molds. The broad scope of this brochure limits the amount of detail included about basic fundamentals and mold construction. Fibre Glast Developments offer brochures, which delve into specific aspects of these areas in more detail.

Terminology

The best place to start when learning about composites is an understanding of the vocabulary used in this field. The following terms are often used in describing the composite fabrication process:

Piece: The finished product, which you are making.

Plug: The actual item to be duplicated in fiberglass or other composite materials, which is used to construct the mold. The plug can be the actual part or a custom-fabricated shape, made from virtually any type of material.

Mold: The item from which the piece will be made. There are two main types of molds, male and female. A male mold is identical to the item being duplicated, and the piece is made over the mold. A female, or cavity, mold is the reverse of the item to be duplicated, and the piece is made inside the mold. The word can also be used to describe the composite fabrication process: Molding a part.

Laminate: A solid part constructed from a combination of resin and reinforcing fabric. This term can also be used to describe the process of laying up a part: Laminating a part.

Gel Coat (or Surface Coat): The term gel coat is often used generically to describe any resin-based surface coating, but the term technically applies to polyester-based materials. The term surface coat can be used to describe either epoxy or polyester materials. Surface coats are specially formulated, thickened versions of resins which can be applied to the surface of a mold or piece to serve as a cosmetic and protective coating.

Release Agent: Any of a number of materials applied to the mold surface before part fabrication, in order to aid in the release of the piece from the mold. These could be waxes, oils or specialty release coatings such as PVA .

Flange/Parting Dam: A temporary fixture attached to the plug when building multiple-piece molds. This generally creates a surface for materials to be molded against, perpendicular to the parting plane of symmetry. The flange aids in clamping or bolting the mold sections together, as well as serving as a mounting point during vacuum bagging operations.

Materials

Once you know the “key words” of composites, the next step is learning about the different resin and reinforcement options available when working with composites. The first portion of this section deals with the three main resins used for most composite structures, while part two deals with the most common reinforcements.

Part 1: Resins

A composite structure consists of a thermosetting resin used in conjunction with some type of reinforcement, such as woven fiberglass cloth. The three main types of room-temperature-curing resins used in composite fabrication are polyester, vinyl ester and epoxy resins.

Polyester resin is a general-purpose resin suitable for a wide variety of applications. Methyl Ethyl Ketone Peroxide (MEKP) must be used as the catalyst to begin the curing process. Catalyzation rates can be varied with polyester resins, environmental conditions. In thin laminations or when gel coat is sprayed as a topcoat, the surface may remain tacky and not cure properly if left exposed to the air. To get a complete cure, thin laminations or top coats must contain either styrene wax solution of have a coat of polyvinyl alcohol (PVA) solution sprayed over them to seal out the air. With the former, the wax “floats” to the surface as the resin cures, acting as a barrier to the air. Styrene wax must be sanded off after curing, but PVA can be rinsed off with warm water.

Epoxy resins are not as forgiving in their measurement as polyester resins, but epoxies provide a greater part strength and dimensional stability. They also adhere to other materials better than polyester resins. Epoxy hardener ratios can’t be varied, and adequate temperatures (at least 70 degrees F) must be maintained during the curing process. Epoxy resin systems tend to cost more than polyester resins, but they are a virtual necessity in some repair applications, such as with Sheet Molded Compound (SMC). Epoxy resins are also highly recommended for use with Kevlar® and carbon fiber.

The third type of resin, vinyl ester , possesses qualities that fall between polyester and epoxy resins for the most part. It excels above both, however, in the areas of corrosion resistance, temperature resistance (it’s good to 300 degrees F), and toughness. Common uses include boat hull repair, full tank construction and chemical storage tank linings. Like polyester resin, it is catalyzed with MEKP, but vinyl ester has as shorter three-month shelf life.

Part 2: Fabrics

There are many reinforcing fabrics available that are used with the resins discussed. The three types of reinforcing fabrics most commonly used are fiberglass, Kevlar® (Aramaids) and carbon fiber (graphite). Each possesses different qualities and advantages. All three are usually available at tows or rovings, veil mats and woven fabrics. Additionally, fiberglass is available as a chopped strand mat, which consists of short, randomly oriented fibers held together by a binder.

Carbon fibers costs the most to purchase, but it offers exceptionally high strength and stiffness, in combination with extremely lightweight. Kevlar® also offers lightweight, along with excellent abrasion resistance. It is, however, difficult to cut and wet out with resin. For finishing purposes, fabricators often use a surface layer of lightweight fiberglass cloth in Kevlar® laminates, because Kevlar ® is virtually impossible to sand once cured.

Most general-purpose applications utilize fiberglass cloth. Although it lacks the light weight and strength of carbon fiber or Kevlar®, it is considerably cheaper to purchase. Fiberglass cloth comes in a wide variety of styles and weights, making it ideal for many applications. High-strength weave styles are available, and these could be considered cost effective alternatives to the more advanced fabrics.

Mold Construction

The first step in mold making consists of plug construction and/or preparation. The plug may be constructed of nearly anything, as long as its surface can be finished well enough to give a suitable mold surface. As stated previously, the plug can either be an existing item or something fabricated specifically for the mold-making process. Some of the materials commonly used in plug construction include wood, plaster, metal and polyurethane foam. The latter comes either as pre-formed sheets or as a two-part “mix and pour” system that chemically reacts to form the foam. The “mix and pour” foam will conform to the shape of any cavity into which the ingredients are poured.

The surface of the plug must be finished at least as well as the desired surface on the part to be produced. In most applications, the preferred plug surface would be a perfectly smooth and polished class “A” finish. If a particular texture or pattern is desired on the finished part, it can be incorporated into the plug surface. A high quality, sandable surfacing primer such as the Duratec Grey Surfacing Primer (#1041-B), works well as the finish coat on the plug. Incorporate flanges and any necessary parting dams onto the plug at this point (see "Special Mold Construction Considerations.)

Before beginning construction of the mold, a release agent must be applied to the plug. This is the most important step in the process, because if the release agent fails to perform, the mold can't be removed without damaging it and the plug. A little extra effort at this point is better than hours spent trying to correct damage to the plug and mold. The release agent can either be a combination of parting wax and PVA, or a one-step release agent such as FibRelease .

When using wax, apply four coats, waiting one hour between the second and third coats. After the final wax coat has been buffed, spray three thin mist coats of PVA and allow it to dry for 30-45 minutes. FibRelease can be wiped or misted onto the plug, and allowed to dry for 30 minutes. Be sure to apply the release agent to the surface of any flanges and parting dams.

For most molds, polyester resin and 1.5 oz/sq. ft chopped strand mat yield satisfactory results. Mold strength and thickness can be built up more rapidly by adding woven roving or tooling fabric. With polyester molds, the first step in making the mold is the application of the tooling gel coat, which is distinguishable by its bright orange color. Prior to its application, be sure to catalyze the gel coat at the proper ratio. For best results, the tooling gel coat should be sprayed onto the plug with a gel coat cup gun in three passes of seven to eight mils each, building to a total thickness of 20-25 mils.

The surface coat should be stabilized with an initial layer of mat within one and a half to five hours, in order to prevent the gel coat from shrinking or lifting off the plug surface. Apply a coat of resin to the surface and lay the mat into the resin. Using a bristle brush, apply the resin to the mat, coaxing the mat into the various contours of the plug. A dabbing motion is much more effective than a painting motion, as long strokes tend to pull the mat around.

All trapped air pockets must be worked out so that the mat is tight against the plug surface, and it must be uniformly saturated with resin. Air bubbles and dry areas will appear milky against the tooling gel coat . Use a bristle roller to work air pockets out of the mat and a grooved saturation roller to help compact the laminate. Watch for bridging (lifting) of the fibers across sharp corners and in textured areas. Any air bubbles remaining after the resin gels must be carefully cut out with a sharp utility knife and a match patch laminated in place.

Once the initial layer has cured, lightly sand it in preparation for additional layers, following the same procedure as with the initial layer. Most molds utilize 8-10 layers, but do not apply more than three to four layers at a time to minimize heat generation (exotherm). After the third layer of mat, a layer of woven roving or tooling fabric can be added to more rapidly build thickness. In general, a mold should be a minimum of twice the thickness of the part it is to produce.

Allow the completed mold to cure for at least 24 hours before attempting removal. Any support structures should be laminated to the back of the mold prior to releasing it from the plug. Release wedges can be inserted around the perimeter of the mold, between the mold and the plug, and gently driven into place in a progressive fashion. Air injection wedges, which attach to an air compressor, can be used to coax stubborn sections apart.

Once the mold is released, wash off any residue from the release agent with warm water and inspect the surface. Any imperfections must be ground out and repaired. You're then ready to begin prepping the mold for part production.

Mold Maintenance

Before any part can be made in a new mold, it must be wet sanded and polished to a Class "A" finish. Wet sand the mold in a progressive manner, using 400, 600, and finally 1000-grit sandpaper. Be sure to change the water in your bucket and rinse the mold surface when changing to a finer paper to insure none of the coarser grit remains. For polishing Fibre Glast Development Co. recommends using a two step polishing compound and a high-speed buffer. The first stage removes the sanding scratches, while the second polishes the surface to the desired finish.

After polishing the mold, apply a release agent to it, following the procedures outlined for prepping the plug. A new mold is often given an extra coat of the release agent as added insurance.

In the event a part doesn't release properly and damages the mold, repair will be necessary. Any loose or damaged material must be removed by sanding or grinding, and new tooling gel coat applied to that area. A coat of PVA or wax paper placed over the repair will be necessary for proper curing. Once cured, the repair can be sanded and buffed as previously described.

Special Mold Construction Considerations

Part 1: Multiple Piece Molds

In some instances, the shape of the plug may require a multiple-piece mold so that the mold can be removed from the plug and subsequent parts removed from the mold. When making a multiple piece mold, start by constructing a temporary dam on the plug, along the desired parting line. This dam may be constructed of masonite or a similar material, and held in place with clay. A sharp corner without a radius must be maintained on the portion to be molded first. Any locating keys or dowels for realignment of the mold pieces should be added to the parting dam. With multiple piece molds, construct the entire mold before releasing any part of the mold, in order to avoid realignment problems. After the first portion of the mold cures, remove the temporary dam and use the completed portion of the flange to form the parting dam for the next half. Apply release agent to this surface before continuing the mold construction.

Part 2: Alternate Construction Methods

If durability and dimensional stability are important factors in mold construction, epoxy resin can be used in place of polyester resin . The procedure for this is much the same as with polyester resin, except that mat cannot be used with epoxy, as the binder that holds the mat together is not compatible with epoxy resins. Start with two or four ounce fabric to minimize prints through of the weave pattern. Then switch to a 7-10 ounce fabric. Be sure to place some layers on a 45-degree angle for good stiffness. Epoxy surface coats should be brushed onto the plug for best results. Because epoxies are less prone to shrinkage than polyester materials, immediate application of a stabilizing reinforcement layer over the surface coat isn't critical.

If exceptionally rigid molds are required, carbon fiber can be used in place of fiberglass cloth. We recommend using epoxy resin with carbon fiber, and a flexible rubber squeegee works best for distributing resin through the fabric.

Molding Parts: Selecting Materials

Once the mold has been properly polished and coated with a release agent, you can begin making parts! The first stage in the process of molding parts is determining which resin and reinforcements will be used. Having previously discussed the merits of the three main resins, we will concentrate here on the specifics of reinforcement selection.

After choosing the type of reinforcement to be used, the biggest factor becomes choosing the style (weave) and weight of fabric best suited to a given application. The three main fabric styles are plain weave, twill weave, and satin weave. In addition, fiberglass is available in ounces per square yard, with the exception of mat, which is expressed in ounces per square foot.

When fabrics are woven, the fibers are bundled into yarns running a 0 (warp yarn) and 90 (fill yarn) degrees. Plain weaves use an "over-under" pattern, while in a satin weave one filling yarn floats over three to seven warp threads before being stitched under another warp thread, and twill weaves are a "2x2" pattern. Plain weaves are the least expensive and are good general purpose fabrics, but they don't offer the strength of satin and twill weave fabrics, but it is equally strong in all directions.

The lighter the fabric weight, the easier it will drape over contours and the less resin it will take to wet it out. Lightweight fabrics are most commonly used for surfacing and radio-control (R/C) hobby applications. Medium weight fabrics are most commonly used in repair and fabrication work. The heaviest fabrics are generally used for rapid thickness build up, such as in boat hulls and mold making.

Fabrics are sold by the running yard, generally in widths of 38, 50 and 60 inches, although not every fabric will be available in all of those widths. For a given project, choose a width that most closely approximates the width of the part to be made. The idea is to use as few separate pieces of fabric as possible per layer. The amount of resin needed will depend on the weight of the fabric selected. Fabric to resin ratios for most woven fiberglass and Kevlar® are about 50:50, while carbon fiber is 60:40. Fiberglass mat will require about twice as much resin as woven fiberglass for proper saturation.Extra strength can be built into parts by means of sandwich core construction. This process involves utilizing a core material, such as end grain balsa wood , polyurethane foam, vinyl foam, or honeycomb, between to laminate skins. Some core materials come in a variety of thickness, depending on the needs of a particular application. The strength and stiffness of a part can be increased significantly, with very little extra weight added to the part.

Molding Parts: The Fabrication Process

With the fabric and resin selected, you're ready to begin molding the part. As stated previously, when using a mold for the first time, add an extra coating of release agent to insure a proper release. While the release agent is drying, take the time to cut the reinforcement to the proper size and number of pieces and stack the pile near your work area. If using mat, tear it into workable sized pieces instead of cutting it. The frayed edges of the pieces will intermix as they are placed in the mold, giving a stronger bond than when two cut edges are butted together. With woven fabrics, determine where the part's strength needs to be the greatest and orient the fibers accordingly. With plain weave fabrics, a more uniform strength can be achieved by alternating the fiber orientation between 0/90 and 45/45 degrees.

The part fabrication process is similar to the steps followed in making the mold. When working with a female mold, start by applying the appropriate surface coat to the mold surface. This step isn't absolutely necessary when fabricating parts, but a much better cosmetic appearance for the finished part will be achieved if it is used. Applying the first layer of resin and fabric directly to the mold surface can result in surface irregularities, pinholes, and print-through of the fabric weave pattern if a heavier fabrics is used. These blemishes can be corrected once the part is removed from the mold, but it will require tedious sanding and filling. Use of a lightweight fabric, such as two-ounce or four-ounce, as the first layer can minimize these problems if a gel coat or surface coat isn't used. As an alternative to gel coat, Duratec Surfacing Primer can be sprayed into the mold, providing a durable surface finish.

Polyester gel coats come in either white or clear form, which is pigmented to a variety of colors. Clear gel coats reproduce colors very accurately, while white gel coats yield pastel colors. Epoxy surface coat is white in color, and can also be pigmented.

When applying gel coat to the mold, the best results will be achieved by spraying unthinned gel coat with a cup gun , in much the same manner as tooling gel coatis applied in mold construction. Slowly build up the gel coat in three passes, to a thickness of 15-20 mils. A gel coat thickness gauge is the best tool to use for determining the thickness. Check in several locations on the part to make certain an even coat is being applied. Too much of too little in some areas can cause wrinkling or distortion when the gel coat cures. When using an epoxy surface coat, it should be brushed into the mold.

Adhering to the guidelines in the mold construction section of the brochure, follow the gel coat with an initial stabilizing layer of reinforcement. If you've pigmented the gel coat and want the same color throughout the part, the resin can also be pigmented to match.

When laying up the reinforcement, try to utilize a single, uncut piece of fabric for each layer. Unfortunately, this is not always possible. Sometimes a part is too large to be covered by as single piece of fabric, so two or more pieces must be used. When two separate pieces must be joined together in a mold, it is best to overlap the pieces by one-half to one inch, as opposed to butting the pieces tougher. Butt two pieces together to form a seam only when maintaining constant thickness is necessary.

The contours and shapes of a part may also make it difficult to get good adhesion using a single piece of fabric. Indentations and sharp angles, in particular, present this kind of problem. Composites can be formed into many shapes, but it is very difficult to achieve sharp angles (90 degrees or sharper) with continuous pieces of fabric. The fabric will tend to lift in these areas, resulting in air bubbles and weak spots in the laminate. If a sharp angle is required in a part, the best way to approach it is by butting two cut pieces of fabric together at the turn. For added strength at these butt joints, mix a small amount of resin with milled glass fibers to form structural putty filler. Apply this to the joint before lying in the fabric. With indentations, it's better to cut a smaller piece of fabric to fit the indentation rather than trying to force a larger piece of fabric down into it.

As with mold construction, use rollers and squeegees to thoroughly saturate the fabric, work air pockets out of the laminate and compacts the layers as much as possible. This will help avoid weak spots and delamintion problems into the finished part. As the layers of reinforcement fit into the mold, pay attention to the orientation of the fibers if using woven cloth, alternating the orientation by layer to increase part strength.

If a sandwich core construction is going to be utilized, determine which type of core material best suits the application. Polyurethane foam is very rigid and doesn't conform well to contours, whereas vinyl foam can be heated and formed to a variety of shapes. Balsa, which generally consists of small end grain blocks held together by a scrim of fabric, can conform to mild curves. Honeycomb core materials are very flexible and will bend to a variety of shapes.

Several steps must be taken to prep core material, in order to get a strong piece. After cutting and shaping the core material to the contours of the part, bevel the edges of the core's perimeter to a 45-degree angle to smooth fabric transition. Mix a portion of resin with glass microspheres to a slurry consistency, and use this to fall any gaps, as well as splice multiple pieces or core material together. Pretreat open-celled foams and honeycomb cores with this slurry mix, in order to fill the open cells with something lighter than pure resin. Once these steps are completed, the core can be bonded in place.

When dealing with multiple-piece molds, almost always assemble the pieces of the mold before laying up a part. Laying up a part and then assembling the mold pieces will make it difficult to get a good bond between the pieces and a smooth cosmetic finish. The exception to this rule would be an enclosed item, such as a fuel tank, which would be impossible to lay up if the mold was assembled in advance.

If a compression mold is being used, the other half of the mold can be clamped to the first half once all of the reinforcing layers are in place. If a compression mold is not being used, but a smooth surface is desired on both sides of the part, a surface coat can be applied over the final layer of reinforcement. When the laminate reaches the "leathery" semi-cured stage, trim the edges with a sharp utility knife. Doing this now will significantly reduce finishing time and dust generation down the road.

Once the part has cured, remove it from the mold in much the same manner as the mold was removed from the plug. Any residue from the release agent can be rinsed off the part, and it can be finished in whatever manner is necessary. Finishing usually involves sanding down any seams and sanding the edges of the part.

Inspect the mold for any damage or dulling of the mold surface. If everything is fine, reapply the release agent when you're ready to build the next part. If repairs or buffing are necessary, carry out those operations as previously described.

By carefully following the guidelines in this and our other brochures, you can produce molds and finished parts that meet or exceed your expectations. If something does go wrong, nearly any damage or problems can be repaired. Remember that working with composites is like any other new skill you learn: the more you work at it and practice honing your abilities, the better the results will be. Once you have mastered the basics, and then refined those skills, nearly anything is possible.