Mold Construction

Of all the advantages offered by composite materials, their ability to be molded to complex shapes is perhaps the most popular. When a shape needs to be reproduced numerous times, it is most efficient to build a tool or mold within which the part can be fabricated. Molded parts emerge perfectly shaped every time and require little post-finishing work.

Molding or "stamping" has been used for years to shape metal products like car bodies, home appliances, and industrial fixtures. Metal stamping dies are cumbersome and cost thousands of dollars to produce. Only large companies can afford to build, operate, store, or even move these tools. Composite materials offer a cost effective way for anyone to make even large production runs of identical plastic parts in molds they can produce themselves.

This brochure will describe the steps necessary to create accurate, high-quality, low-distortion molds for producing composite parts. It is intended to help novice through intermediate builders obtain successful results with their first project. While many of the principles described are the same as large-scale industrial techniques, the suggestions offered are meant to be used in small shops, garages, or workshops to help individuals produce BIG results! For this reason, the examples listed are intended to be scaled-down, helpful industrial hints.

Types of Molds

Male and female molds are the only two fundamental types of forms, but they yield significantly different finished parts. The least time consuming and cheapest method is the male or positive mold. This is a form that mimics the final shape of the part, but the part is fabricated over its outer surface. It is true that this type of mold is quicker to construct, but each part produced will have a rough outer texture which requires laborious finishing. The part will also "grow" during lamination. Usually this is undesirable, but if the mold is intentionally made slightly smaller the part will grow into the desired finished dimensions. Male molds should be used when fewer than 5-10 parts are being produced. Larger runs usually warrant the time and cost of female molds. The remainder of this brochure will deal mostly with construction female molds, but male molds can be made using the same materials.

Female or cavity molds are generally more costly, but they offer numerous advantages for medium for medium to large production runs. Finishing time is significantly reduced because every part emerges with a smooth outer surface. Female molds also lend themselves to use with core materials because the outer skin is always a smooth regardless of how inconsistently the core is used inside the part. Either type of mold can be used for vacuum bagging, but female molds are usually easier to seal while achieving good surfacing characteristics. If more that 5-10 parts which need smooth finished are being produced, female molds are worth the extra effort.

Compression molds are sometimes made by using both a male and a female form. These "matched" molds are excellent for producing precision parts. The molds are loaded with reinforcement and resin before they are closed and tightened. Excess resin is squeezed out, voids are reduced, and parts emerge smooth

on both sides. Compression molds can also be modified for use with resin infusion or injection. The key is to think about the intended use of the finished part and what type of mold will be necessary to build it. If this is considered in advance, there is no limit to the type of parts that can be produced.

Selection of Methods and Materials

Before beginning the construction of any mold, take the time to consider the desired end results. The construction of the mold will be a trade-off among the physical properties of the mold, cost of construction and time involved to build the mold. What you want in a finished part will have a direct bearing on these trade-offs. Careful consideration of these factors will enable you to incur the least expense to get the desired results.

When selecting mold-making materials and the method of construction, take into account such things as the length of the production run and the desired quality of the surface finish on the part. The time and materials put into the mold at the beginning will ultimately impact how many parts you can make and the quality of those parts. Other things to consider include technique specific modifications to the mold to aid in procedures like vacuum bagging and compression molding. Larger flanges are worth incorporating to make both these procedures easier. Locating ins along the perimeter flange should also be planned for complex molds with multiple pieces requiring precise alignment. Finally, consider how the mold will be held while in use. An egg-crate structure will add both support and manageability to molds with awkward shapes.

How you intend to release the mold from the plug and subsequent parts from the mold will also impact the overall design and construction. The first factor consider is the draft angle of the mold. This is the angle of the sides of the mold compared to its base. A mold with zero draft has flat sides perpendicular to the bottom. On a mold with positive draft, the sides are wider at the top than they are at the base. Parts will easily pop out of molds with positive draft. The sides of a mold with negative draft are tighter at the top than at the bottom. For obvious reasons parts are impossible to remove from a mold with negative draft. Shapes which have to be molded with negative draft must be made in multiple-piece molds. Each piece has positive draft for easy release, yet they all bolt together forming the negative cavity.

The point where the mold pieces join together is called the parting plane. This is the imaginary line or plane that divides the negative draft angle into two positive angles. Molds can be built with as many parting planes as needed for complete separation. The plane typically runs along the highest or widest crest of the plug. When first tackling mold building projects, it is helpful to draw the line on the plug with a felt tipped pen. This permits trial-and –error sketching until you are satisfied that it is located in the proper place. If further lessons are necessary, look at the mold seams on plastic children’s toys. They are often quite exaggerated and rarely removed. Quite a bit can be learned from their examples.

Large parts and molds have difficulty separating even once their edges break free. Slight adhesion over broad areas and even static contributes to the problem. Expect the worst, and plan ahead. Drill holes through the mold and bond an air fitting to the back. Use clay to fill the hole during molding so resin does not contaminate the air line. When the part is ready to release, just hook up the compressed air and pop! Try to locate the fittings in areas that will later be trimmed and removed from the part. That way the marks from the clay won’t have to be sanded and polished out.

In selecting the actual resins and fabrics, approach it from the standpoint of creating a mold for the lowest possible cost, given the application. Nearly all composite materials can be utilized in mold construction, but the part requirements often don’t justify the expense of more exotic materials. For many parts, a mold constructed with general purpose polyester resin and 1.5 oz/sq ft fiberglass chopped strand mat strand mat will produce satisfactory results. Mat offers quick build-up, along with uniform strength and stiffness, in a minimum number of layers (typically 8-10 layers.) Using a good tooling gelcoat sprayed at the proper thickness will also aid greatly in achieving a top-notch mold surface.

Some parts do require an extremely rigid mold for dimensional accuracy or longevity. Epoxy surface coats and resins, which experience little to no shrinkage, can then be justified. Mat cannot be used with the epoxies because it is not compatible. That is just as well since the woven fiberglass cloths are stronger anyway. Use carbon fiber for molds, which need the highest strength and rigidity.

Plug Preparation

One of the primary keys to success in mold construction is proper preparation of the plug, which is the "original" used to create the female mold. Any imperfections in the plug surface will be transferred to the mold, and then to future parts made from the mold. Recalling what we said earlier about beginning with the end in mind, the plug needs to have a finish AT LEAST as good as the parts you wish to produce.

The preferable surface finish for the plug would be a Class "A" finish, which means it would be a polished, high-luster finish free from any porosity or scratches. In order to achieve an acceptable mold surface and a long mold life, it is far more effective to remove defects from the plug surface than attempting to remove defects from the mold surface.

After the plug has been properly shaped and sanded, finish the plug with a high quality surfacing primer, such as Duratec Surfacing Primer . These materials can be readily sanded and polished to a Class "A" finish. The brochure Plug Surface Preparation and Mold Surface Maintenance goes into this process in greater detail.

Constructing the Mold

Once the plug has been prepared to a Class "A" finish, construction of the female mold can commence. First, a mold release agent will need to be applied to the plug. This is a critical step, since it will allow you to separate the mold from the plug once the materials used to construct the mold have cured. If the mold doesn't release properly from the plug, the mold and the plug could be damaged or destroyed, so follow these procedures carefully.

The two most common release agents employed are the traditional combination of parting wax and PVA release film, and the newer one-step, water-based release agents such as FibRelease . When working with parting wax and PVA, generally four coats of wax are applied with an hour wait in between the second and third coats of wax. After the final application has dried and been buffed, the PVA can be sprayed onto the plug. For best results, the PVA should be sprayed in three thin mist coats and allowed to dry for 30-45 minutes. In that time it should cure into a thin smooth film. 70 to 90 psi air pressure will help to fully atomize the PVA for a smoother finish. FibRelease, on the other hand, dispenses with the multiple coats of wax and PVA . The FibRelease is merely wiped or misted onto the surface and allowed to dry to a film-like state. After about a half hour, FibRelease is usually sufficiently dry to begin construction.

Before starting the lay-up of the mold, parting flanges or dams must be added to the plug along all the parting planes previously described. This is the form, which divides the mold segments during construction. This form is removed once one side has been molded. Like the plug itself, these parting flanges are constructed of the lest expensive materials that will support the curing fiberglass later. Clay, masonite, waxed posterboard, thin sheetmetal, and playing cards have all been known to work. Typically, a "snake" of clay is rolled in the palm of the hands and pressed onto the plug along the parting plane. When the symmetry is simple, a silhouette cut-out can be made from masonite and attached with the clay. It is easier to use the posterboard, or playing cards on plugs with complicated shapes. Scissors can quickly cut the contours necessary before the dam is inserted into the clay. Use a mixing stick to scrape away the excess clay on the side that will be molded first. More elaborate fixtures can be constructed to do the same job, however this method will provide repeatable results.

At this point, any locating keys or dowels for re-aligning the segments of a multiple-piece mold should be added to the parting flange. If the flange is made of clay, these key-ways can simply be imbedded in the soft material. Masonite is also easy to add them to because it provides plenty of support for holding the dowels. When using a paper or metal dam, simply make a key from clay and stick it to the

surface. The key-way will be molded first, then remove the clay and the other mold section will be made with the matching key. Regardless of the materiel used to make the parting dam, spray or gently wipe o one final coat of release agent.

Once these steps have been completed, it's time to begin applying the surface coat. The polyester tooling gel coat is easily distinguished by its bright orange color. Although the surface coat can be applied with a brush, a more uniform result will be achieved by spraying it. Gel coats and other surface coat materials are too thick to be sprayed with normal automotive spay equipment, so a special gravity-feed "cup" gun must be utilized. Typically, cup guns accept disposable cups holding up to a quart of material. After mixing the proper amount of catalyst, you're ready to spray the surface coat. Once you start spraying, keep the material flowing; don't start and stop at the end of each pass like when spraying paint through regular siphon equipment. Exercise caution, though, or too much material will build up too quickly. Using a gel coat thickness gauge for testing, apply a uniform thickness of 20-25 mils over the plug. This is best achieved in three passes of 7-8 mils each. DO NOT allow any initial pass to tack-up before adding the next layer. All 20-25 mils must cure as a single film for best results. Epoxy surface coats be brushed on, and if mixed correctly are trouble free.

Once the surface coat has been applied, it's critical to stabilize it with the first layer of reinforcement within 1.5 to 5 hours. This will help prevent the surface coat from shrinking or lifting off the surface of the plug. The first layer of reinforcement is also the most critical layer in the mold to lay down without trapping air bubbles. All air pockets directly beneath the surface coat are prone to cracking. When the chips fall out after producing a part or two, the whole mold surface will become cratered and need resurfacing.

With the stabilizing layer in place, the mold could sit in that condition for days before being completed. The main advice here is to avoid spraying your surface coat just before bed and expecting it to perfect when you return in the morning. You will be time and money ahead if you wait and begin the process when the surface coat can be stabilized within the 5-hour window of opportunity. This advice may seem overly cautious to some, but it always works.

This also helps prevent heat distortion in polyester molds. After an hour the gel coat is cool to the touch. One layer of 1.5 oz/sq. ft mat and resin will heat slightly while curing, but not enough to distort the delicate surface coat. When the first reinforcement layer is cool to the touch, it can be sanded in preparation for more mat. The remaining layers can be added fairly quickly to this stabilized surface without much fear of thermal distortion.

If chopped strand mat is used, tear (don't cut) the mat into manageable chunks. The frayed edges blend well with one another without trapping air like sharp scissor - cut edges do. The flange areas will need some strips cut to the proper width to butt into the corner of the parting dam to exclude air. However, this is about the only area where they are needed. If coarse woven fabrics are used, they will lay easier over severe contours when they are cut off the roll on a 45-degree bias. Pre-cut much of the reinforcement so 2-3 layers can be added at a time before the resin starts to gel.

Using a natural bristle brush, pre-wet the surface with properly catalyzed resin, then place the mat on the plug. The reinforcement will soak up much of the resin, but white spots indicate more is needed. Once again, begin by butting pre-cut strips into the angles where the parting dam meets the plug. Then apply frayed patches on the main surface overlapping nicely onto the flange. A milled glass putty can also be spread into those types of corners to keep out air.

Roll the air out of the laminate at least every other layer. Begin using a bristle roller which will pop many bubbles within the mat. Next, switch to a grooved saturation roller to compact the laminate. Be sure to use a roller which contacts the entire surface. There are many shapes to choose from for this reason.

Most Molds using chopped strand mat utilize about 8-10 layers. Heavier fabrics such as woven roving or tooling fabric can be added after the third layer of mat to more rapidly increase the build-up and strength of the mold. Consider alternat-

ing the fabric weave patterns between 0/90 and 45/45 degrees so the strength remains uniform. Do not apply more than 3-4 layers at a time so that heat generation, or exotherm, is kept to a minimum.

Once all of the layers are in place and have properly cured, the parting dam can be stripped of f the back of the new flange and discarded. Use clean rags to wipe away any excess clay that might remain on the surface. Take care not to scratch the plug while doing this. Apply fresh mold release agent to the newly exposed flange, as this will be the form against which its mate will be constructed. Once again, follow the sequence described above from surface coat to final reinforcement until all the segments of the mold have been built.

If eggcrate support structures need to be added, now is the time. Most are made from plywood or some other inexpensive flat stock. Make paper templates of the mold contour where the panel is to attach so miscuts are reduced. Cut the wood to shape so it fits well against the mold and any other pieces of the framework itself. Use the resin and reinforcement to bond it to the back of the mold. Join all other similar pieces to the mold in the same way, and attach them to each other as designed. Once cured, this will add even greater rigidity to the mold.

When all the portions are complete and cured, it is time to trim the mold and drill any final clamping holes for bolts. Drill the holes first so that if any part of the mold pre-releases while trimming everything will still line up later. Trimming is actually best achieved with a saw. Grit edge jig saw blades cut faster and with less effort than most air die grinders. With the perimeter entirely trimmed, construction is complete.

Releasing the Mold from the Plug

It is time for the moment of truth – releasing the mold from the plug! Release wedges can be used to help coax the mold off the plug. These plastic wedges should be used in place of screwdrivers and putty knives because they will not chip the mold surface. Why perform all these tedious tasks just to ruin it now? Insert the wedges around the perimeter of the mold and gently tap them into place, progressing evenly around the edges. Special air-injection release wedges , which attach to an air compressor, can also be used for stubborn parts. The pillow of air that is shot between the plug and the mold provides pressure where no wedge can ever reach. Slowly the two should separate. If problems still persist, light blows with a rubber mallet can send vibrations through the mold causing separation. Don’t get carried away. Heavy pounding can actually fracture the mold itself. These combined hints will safely release the mold sections.

Preparing the Mold for Use

Once the mold is separated from the plug, clean and inspect its surface. The residue of PVA mold release agent can be washed off with warm water. Dry the surface, and look for any serious defects. Critical problems will actually have to be ground out and resurfaced. Hinges, air injection ports, and any other accessories should be attached at this time if they are needed. If the directions were followed and nothing was damaged during release, the surface should already be very smooth. Typically, the mold release agents leave a slight texture behind, but this can be quickly removed while achieving a class “A” surface. Begin by wet sanding with 400 grit sandpaper, eventually moving to 600 grit, then 1000 grit paper. Rinse the bucket and the mold surface before moving to the next grade of paper, so any remaining grit from the previous sandpaper is removed. Once the sanding is completed, buff the mold surface with an appropriate polishing compound. Fibre Glast recommends a two stage polishing process for best results. For more detailed information on mold surface preparation and maintenance, see our brochure Plug Surface Preparation and Mold Surface Maintenance .

The final step before use is the application of he desired release agent. This is just as straightforward as it has been during the mold construction process. An unseasoned mold is often given an extra coat or two of the system just to be sure of its effectiveness. In fact, the first few parts made in a mold are sometimes constructed thin enough to be broken out in the event of a major failure. However, if the mold was designed correctly, there shouldn’t be any problems.

Congratulations are in order for all those who made it this far. You are now prepared to embark on projects, which can truly open the doors to new creations, even new careers. Following these simple instructions, accurate, high quality, distortion-free molds can be constructed for producing composite parts. This information combined with a bright idea offers the freedom to build structures many would consider impossible. Then, if the idea takes off, produce as many as necessary to fill demand. Hopefully, this brochure has instilled enough confidence and enthusiasm to get you started on your first project. Even if you start small, you can get BIG results!