

# Free Forming in Fiberglass

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Though I am at heart a metal boatbuilder, (actually I am meat and, unfortunately, too much fat, but you know what I mean) I have to admit that fiberglass is a very good material for boats. The main problem with building a fiberglass boat is getting a smooth surface. With conventional molds derived from male plugs, the smooth surface is achieved by hundreds of hours of fairing, filling and sanding on the plug. This is no exaggeration -- in 1986, my crew spent over \$40,000 in labor on a hull tool for a 26-foot rowing whaleboat. Over two thirds of the hours were sanding and fairing.

For a one-off fiberglass hull, this process is even harder because the relatively soft, easily faired materials used for plug construction cannot be used for an actual hull. On a one-off, you are sanding hard fiberglass.

One very interesting technique to get around this problem is fiberglass freeforming or direct female molding. Fiberglass freeforming is prevalent in the Pacific Northwest. A major yacht and ferry builder, Westport Shipyard, in Westport, Washington, has built dozens of very large yachts and commercial vessels by this technique.

Free-formed fiberglass gets most of the hull mold surface smooth without sanding, but at a cost -- you must use developable shapes for the easily faired surfaces.

Here is how it works:

First, build a smooth flat surface as large as the biggest panel you want. Westport Shipyard has a partial floor made of surplus store window glass with the joints carefully smoothed. I have used reject shower panel laminates. Some builders use sheet metal. You can use anything that is smooth, flat and cheap. You don't even have to be too careful about smooth joints, because hairline gaps between panels will become raised lines in the female mold and can be readily sanded off. Just balance the cost of finishing up the panels against the cost of the table.

Second, loft the hull, preferably by computer for precision and ease, and expand the hull panels to their flat shape. Obviously, it is good to be as accurate as possible, but there is more room for error than with metal or plywood construction. Also loft patterns for molds to fit OUTSIDE of the hull. These can be at normal stations or along the ruling lines. (The designer should leave the ruling lines on the drawings and tabulate them on any developable hull.) Molds on rulings will be straight lines, so they will be easy to build. Station molds will be a little harder, because they will be curved, but they will be vertical planes and therefore will be easy to set up. A combination of the two will allow good definition of the hull form for the easiest possible construction. You will also need some special molds for the lower stem, the forward sheer, and other places not well defined by stations.

Now, lay out an expanded hull panel on the table. You can mark the surface with grease pencil or dry erase marker or use Mylar or paper templates. The exact layout technique will depend on how you lofted the panels. If you are using a computer, you can mark the table itself with a grid and use the dimensions from the computer output, or you can use plotted full size patterns. Lay battens along the panel edges OUTSIDE the panel, and fix them to the panel. Usually big weights and duct tape are sufficient. Whatever methods you use make sure it doesn't mar the table because you will reuse the surface many times.

Next, coat the panel and batten edges with mold release and lay fiberglass over the panel pattern right up to the batten. Mat is the best for this process as it is cheap and easy to wet out. Mat also eliminates problems with print-through, so there is really no point in using roving at all. You can also use a chop gun if you have one available, because these parts don't have to be very strong. The panel will be the exact shape required because the battens formed the edge.

Remove the panel when it cures and you have part of your mold, already completely smooth except for the joints. There may also be an upstanding flange left on the outside of the mold. You can easily knock this off with a grinder, but in some cases it is useful for clamping the panels together. You only need to get rid of the flange if it makes the panels hard to bend. You may also want to lay marks in the panels for guidance in placing frames. Put colored thread or plastic tape down on the lines as you mold the panel.

You may want to flip the panel over to use to lay out the opposite side panel, but check carefully against the patterns to make sure the two are symmetrical. Then just make the rest of the panels the same way. You can use the same method to make fiberglass molds if you like or you can cut them out of plywood.

Stiffen the molds and erect them. If they are fiberglass, you can stiffen them by laminating half-cardboard mailing tubes or foam blocks to them. Set the panels in the molds, and tab them to the molds as well. It may be useful to notch the molds so that you can set full length wooden battens to help control the panel shape. Glass over these to stiffen the panels. You can also stiffen the panels with mailing tubes laid on the rulings. Finally, use fiberglass tape over the outside on the edges to join the panels. The amount of stiffening you need will depend on how many hulls you will pull from the mold, how big the boat is and whether you need to stand in the mold when you laminate. Your designer should be able to specify the mold stiffening required, but if not, the mold scantlings will need to be comparable to the boat you are building.

Now you have a female mold that is as smooth as your original panel everywhere except where the edges meet. Finish these with filler and sand them if necessary. You can now build your hull in any conventional method, but you have spent much less time and money than someone building a plug and a mold might have.

There are many variations on this process. One interesting technique is a "no-lofting" method that always produces a fair hull. Unfortunately, the hull may not have the exact shape you want, but that may not matter for you.

Make a scale model of the hull out of stiff material like hardboard (or for traditional steel boat lofters, "red paper"). Fit a panel to the bottom, make a pattern, and enlarge it by whatever method you like. Make the bottom panels and erect them, but support the edges so that you can move them. Make sure the two bottom panels come together all the way at the keel and adjust the edges until you like the shape of the bottom. When you are happy, stiffen the outside, especially on the rulings, and add some plywood molds.

Use a stiff material (red paper again) to take off the upper edge of the bottom panels. While it is up, determine how wide the next panel will have to be to reach its upper edge. Put a series of sticks against the pattern, flat against it (which helps support the pattern material) and measure or mark the sticks at the height of the next panel. Also mark the line of each stick on the pattern material. Lay out the panel on your smooth surface, leaving some excess at the top. You can also leave some excess at the bottom, as well, because the panel can lap down over the edge of the bottom.

Make the next panel, fit it up to the bottom temporarily, shape it as you like and mark it. Lay out the upper edge by sighting along a batten fastened to it and mark that edge. Drop the panel down, cut it to shape and use it as a pattern to lay out for the other side. (This ensures the boat is symmetrical.) Repeat this process until all panels are made and up. You end up doing more work full scale, which I think is harder, but if you are uncomfortable with lofting, this method may work for you.

A few builders have made hull panels directly, rather than a mold. This is also feasible, but requires much more care. Shaw Boats; in Aberdeen, WA has made high tech racing sailboats with cored panels incorporating Kevlar and carbon fiber laminates. The cored panels are laminated flat, cut to shape, then bent up to form the hull. However, Shaw Boats uses epoxy as a laminating resin, which is a much better adhesive, and uses very careful quality control. The boats they build are also very carefully engineered specifically for this technique.

The most important problem with joining separately molded panels is that the critical joints are secondary bonds. Secondary bonds are made after the basic chemical bonds forming the laminates have cured. They are notoriously unreliable unless scrupulously made, especially in polyester or vinylester laminates. You will probably have to very carefully grind the panel surfaces to a controlled roughness to prep them for joining. Some builders use "peel ply"

or other materials to prevent the final cure on a surface that will later be laminated to another part, but even this technique is not really reliable. You should also use high performance adhesives and reinforcement fiber at the joints.

You will also need to talk to your designer about the structural requirements of the joints. The chines and keel are heavily loaded in shear as well as bending. This is caused when the whole boat bends in waves or under the headstay load. The bottom stretches and the top compresses (or the opposite, depending on the type of load). The joint material has to keep the two panels from sliding relative to each other. This is not a trivial problem in fiberglass and requires that the fiber reinforcement be oriented in the correct direction. Your designer has to be aware that you intend to build the boat in this fashion and engineer the joint accordingly.

You should build some sample panels and test them to failure. Make sure you record all of the variables of each procedure very carefully so you can duplicate them later and achieve the same strength.

If you are using cored panels directly, there are two more problems. You have to ensure that the required bend in the panel can be achieved without either causing a premature core shear failure or local buckling on the inner skin. This generally will have to be calculated by the designer. You can minimize these problems by only laminating the outside skin on the table and laminating the inside skin in the cored hull. This will also improve the quality of the panel joints, since they will be primary laminate, not a secondary joint.

The other problem is differential shrinkage. The process of curing induces shrinkage in the fiberglass laminate. The core will not shrink like the laminate. The laminate on the side away from the laminating table will also shrink differently due to the difference in thermal conduction and other variables. This variation causes the panel to warp or bend. This is obviously more severe with single-sided laminates because there is no laminate on the opposite side to balance the shrinking forces. A single-sided cored laminate also will generally warp the wrong way, cupping outwards.

A final problem with or without core is that the process of making the joints results in significant areas of unfinished outer hull laminate. There will be several inches each side of each joint to be finished by sanding. (However, this is still not as much work as finishing the whole hull surface.) You must also avoid compromising the hull strength by cutting away too much joint reinforcement when you finish the joint.

For this reason, when you cast the panels, it is a good idea to plan for the additional thickness of the joint reinforcement. You can lay down seat belt material (which can be bent edgewise to some extent without buckling) or some other thick material inside the panel boundaries to provide a sort of rebate. Cover it with plastic film, wax, and mold release.

If you want a round bilge hull, you can use direct female molding as well. Just put patterns within the developed hull mold in the double curved regions, glass over the patterns, fill and fair. This is more work, but still less than sanding a whole plug, and of course it saves the material cost of the plug. You could also make a partial male plug, just for the double curved areas, and join them to the developed panels. Make sure your designer knows you are using this method and uses as much developable surface as possible. You obviously will also need more detailed hull shape information than usual for this technique.

If you intend to fair the inside of a curved surface, watch a crew installing a swimming pool and examine their tools and techniques first. They are very good at this kind of fairing. There are also techniques used for steel ships that are very useful for defining and lofting the double curved plates conveniently. (Most steel ships are mainly developable or even flat surfaces joined with a very few double curved plates.)

No matter what specific method you use, fiberglass freeforming will save hundreds of hours and much material cost compared to building a plug. It will also be much easier than direct hull construction, though you may spend a bit more in materials. Even if you are doing just one boat for yourself, and want a fiberglass hull, this method is a clear winner. You may even be able to recover some cost by selling the mold when you are done. If you are building more than one boat, such as two friends working together, or for a local one-design class, there is no better method.