CYLINDER MOLD MULTIHULL CONSTRUCTION

Cylinder Molded multihulls have come a long way in the last eighteen years. There are well over three hundred CM built multis out there building or sailing now. The original KAMANU, the first C.M. USCG certified charter catamaran has been sailing nonstop for nearly seventeen years. A couple of dozen C.M. cats are now USCG certified. Builders on all continents are finding out that Cylinder Molding can give them the very highest quality wood/epoxy multi hulls in less time than any other one-off construction system there is. Unlike other molding systems, CM lets builders get the hull shapes they need, not the ones the system allows. Here is how it evolved.

Many of my friends and clients share a curious dilemma with me; we crave sleek, high speed multihulls, but we cannot possibly afford them. Over the years we have developed a dodge to get into these fantastic boats at a lower cost and in much less time than usual. The dodge is a rapid hull construction system, usually called cylinder mold, though nothing about it resembles a cylinder. The hull sections that we use are conic sections like ellipses and parabolas, but not cylinders. I have been more accurately calling it vacuum-formed plywood, but the name "cylinder mold" seems to have stuck, so it will be used here .

Cylinder molding is an odd way to build boats. It is a process where vacuum pressure and epoxy are used to form thin sheets of plywood into thicker panels that are used to build hulls. Instead of the project progressing slowly in an incremental, linear, cumulative fashion, you start with the skin and work inward. Instead of being able to take continual stock of your progress, you will metamorphose raw materials into a hull in three major steps. Each major step will last only long enough for the epoxy to cure. Then, except for detailing and trimming, like it or not, it is done. So curmudgeons beware! Not everyone is suited to build this way. Instead of carefully following directions in a repetitive haze, a builder needs to make eyeball judgements, with confident calls. To help builders make those eyeball judgements, we offer a Construction Manual on Video. It is available to builders of CM multihulls.

"If you want curved plywood-curve plywood!"
Stig Hoffstedt
Sweden

THE NEED

I feel that multihull builders need a system of generating hulls, uncompromising hulls at very low cost and with far less work than usual. A fast building system that creates slow hulls is of no use. They would have to be of the most efficient round bilge shapes.
Also, I have always been curious about why many multihull designers force builders to work outside the nature of materials. Manipulating a blob of fiberglass resin into a smooth, fair, thin shape can only be done by applying many many hours. Cold molded plywood or Constant Camber ™ construction systems take thin, smooth, fair sheets of plywood and chop it into bits. Then they apply many many hours to convert it back to plywood again. Rough plywood. It makes no sense.
I strongly believe in using the high quality industrial materials all around us. To take fullest advantage of the quality, one has to stay in the nature of materials. For example, most CM hulls are made from 3mm Asian plywoods. These thin plywoods are fantastically smooth and fair. Hulls made from them are smooth and fair. Builders need a construction system that lets them take advantage of the industrial processes already out there. CM does let builders work in the nature of the plywood. The results are lower cost, fewer hours required, and better quality.
The technology of modern multihulls is changing very rapidly. A design that was called "state of the art" two or three years ago, is obsolete and overweight now. The implications are several. If you survey the common methods of hull construction, there are a lot of expensive wrong turns available to one, both in dollars and in product. Lets look at some of them.

Buying a very sophisticated multihull design, such as a **one-off composite** craft, will cost a great deal of money. Also, composite one-off multihulls are extremely time consuming to build. By the time an amateur builder finished, the design that was the latest state-of-the-art when he began might be obsolete.

Still, buying a less expensive boat, such as a **production run composite** boat, gets a product that is by definition obsolete. The accountants will still want to get as many boats as possible off of those ten year old molds.

Kit Panel™ or **KSS** boats by Kelsall seem to be rapid to build. In fact in one of the recent issues of a magazine, it looked like he had just discovered cylinder molding, but with fiberglass. At a recent Multihull design conference, in Miami, I watched several people working late into the night to build a little hull this way. By the middle of the second day they basically had a pair of panels done. That would be about 5 hours into a CM hull. Next I saw the chop saw come out and the hull panels got chopped along the keel into short bits. These bits were then bent into a profile and glassed over. The primary structure ws secondary bonded. Their basic premises, chopping the full hull length fibers, and depending on secondary bonding for primary strength, are contrary to modern composites practice. (see Professional Boatbuilder #66, page 78) The best study shows that a polyester secondary bond with a 12/1 taper ratio has about 20% the strength of the same thickness of original lamiminate. In Miami I saw no taper, so the strength must have been even less than 20%. The full length, properly oriented fibers, used with epoxy, that are so important to multihull rigidity and strength are ignored as I undestand KSS. The level of smoothness and fariness that I saw in Miami, especially below the waterline, would be utterly unacceptable in a modern boatyard.

A **custom cold-molded** boat may be seen as a compromise between the two above choices. It may be more modern than the factory run boat, and less expensive than a composite one-off boat. However that compromise ignores one of the major reasons that multihulls are better now than they were three years ago, that is fiber orientation. The modern boats have the strongest fibers oriented with the lines of stress. The older designs are what is called quasi-isotropic, meaning for practical purposes, equally strong in all directions. But hull stresses do not run equally in all directions, so that would be an inefficient way to build. A triple diagonal hull would be considered quasi-isotropic. A double diagonal hull would be even less structurally efficient. It would have only a third the bending strength in the plane of plies, compared to a properly oriented plywood skin of equal thickness. For me, a cold-molded hull is too clumsy in its structural attributes alone, ignoring for now the large amount of work required to build it.

Strip plank or Duracore™ might be a good choice. Where complex hull shapes are called for I specify these. The face grains are oriented exactly right for global loads. It is again however more time consuming. A strongback must be set up, the station patterns lofted, beveled and lined up. Then the stripping material has to be beveled and scarphed to full length. Each of these pieces has to be individually epoxied on the joining faces. Then every piece has to be carefully fastened to the mold with structural bog spread between every piece. The excess bog is squeeged away and the whole thing is faired. Finally roving reinforcement is laid up on both side of the hull, and it is surfaced with bog and faired.

Note however that the strip pieces can't just be laid down. Since the hull gets skinnier at the ends, some strips have to be cut back at the ends. To resist those multihull global loads, the sheer and keel areas must be full length. That means that many of the pieces between have to be carefully fitted in. It is a fussy, time consuming job requiring lots of bog. For complicated or fat wood/epoxy hulls I usually call for strip plank foam.

Another choice might be **sheet plywood** hulls. Face grain oriented plywood could develop more structural performance than cold molded hulls but the choices are limited. They would have to be a "V" section, a chine hull, or a developed compound shape. A"V" section is absolutely out of the question. There may not be any other way to come up with less boat using more material. A chined hull has poor hydrodynamics, and enough structural discontinuities to be an unacceptable choice for an optimum hull.

Also, aside from the structure, even the simplest chine hull, even a "V" section will be noticeably more work than the same size cylinder molded hull.

The **developed hull**, compounded from sheet plywood, has the most promise; but there are difficulties here too. Boats bigger than daysailers need hulls of a certain minimum thickness. Thick plywood, however, is very difficult to compound. Imagine springing a full, high prismatic shape into a sheet of half inch marine plywood. It won't go. So the choices are to keep the skin thin,and consequently, the boat small, or work something else out. **Cylinder Mold Technology** is the something else. And it works out very well.

HISTORY

Cylinder molding is a relatively recent invention. It requires the simultaneous combination of several rather modern technologies:the use of plywood, of modern epoxy, and of vacuum bagging.

The earliest record that I find of this sort of boat construction seems to be by Uffa Fox with his tortured plywood hulls. While he did not use epoxy or vacuum bagging, our molding technology owes a good deal to his developed or tortured ply boats. (The Gougeon brothers book on boat construction has a very complete chapter on the construction of developed plywood boats.)

Certainly cylinder mold hull building was around before I began using it. The problem was, the panels that I saw being built didn't look like anything that I would want on my boat. They were made with rough, nasty veneers, and the section curve was the same for the topsides as it was for the bilge. I knew boats shouldn't look like that.

In 1980, when I got a high quote to build two new 30' amas for my tri, I decided that I had to find a way to get a pair of amas for a lot less money. They had to be good looking amas, and had to be built quickly.

I managed it, using cylinder mold technology. Now, between myself and other builders, at least 400 hulls later (maybe as many as 500) it can be called a very successful system. Here is what cylinder molding can do.

POTENTIAL

In a reasonably equipped woodshop, you can expect to build a cylinder mold in six or eight hours. To build a 35' hull for example, you can expect to build a full length mold for seventy or eighty dollars. The mold for a full standing headroom hull will be just over a hundred dollars. On that mold you will be able to lay up a full length hull panel in two or three hours. Preparing for the layup will take up to a half day, depending on the size of boat. The panel for this 35' hull will be made from a dozen or so sheets of thin (usually 3mm) plywood. These sheets will be coated with epoxy, laid on the mold two or three thick, and vacuum-bagged together into a panel. The panel will become one continuous sheet of plywood, four or more feet wide and thirty five long, with the transverse curve already in it.

When the panels are compounded into hulls, they will have several important characteristics. The face grains will be oriented along the lines of greatest bending stress; the surface will be smooth already, and because the process of developing a hull treats it like a three dimensional batten spline, it will be automatically fair.

You can expect a two layer (6mm.) hull skin with the outside glassed, to weigh .9 to .95 lbs. per square foot. That is very close to a comparable cold-molded or composite hull weight using E glass. The hull costs will range from $2.00 per square foot for Asian plywood to $4 or more per square foot for Bruynzeel plywood. Cold-molded hulls will be in a similar cost range, but composite one could be double the price. A composite hull using high modulus exotic fabrics could run ten times that price per square foot.

A moderately experienced builder can expect to deliver a simple hull, an ama for instance, decked and glassed, at the rate of 12 to 15 minutes per square foot of hull. For comparison, a cold-molded oneoff hull will run between 2 and 3 hours per square foot, without decks. Paint ready requires the usual smoothing time, but the developed plywood surfaces are already several orders smoother than cold molded or composite surfaces. Fairing and filling will be needed at the keel area, but the large, flatter surfaces usually only need smoothing.

Using this evolution from Uffa Fox's fold up boats, one can build hulls, even large hulls, at labor and cost savings that are unattainable by other systems. At the same time the structural integrity is much better.

CONSTANT CAMBER

I am still asked if this is like Constant Camber™.

Except for the fact that we both use wood, epoxy and vacuum bagging, the answer is no. There is no similarity. Building the Constant Camber™ mold alone looks to me like a major operation. My sense is that the hulls made that way have more in common with cold- molded hulls. Just count the number of pieces, and what has to be done to them. In fact, over the last few years CC has been adopting many of the techniques that we started with, including full length molds, elliptical mold sections, and on one boat, full sheets of plywood. They still have not been using scarphs and proper fiber orientation.

Also, I have yet to see a CC hull that has a good modern hull shape. I'm not seeing the minimum wetted surface round sections that I like, and the nice wide transoms that dampen pitching and give powerful reaches.

CONSTRUCTION

The Mold

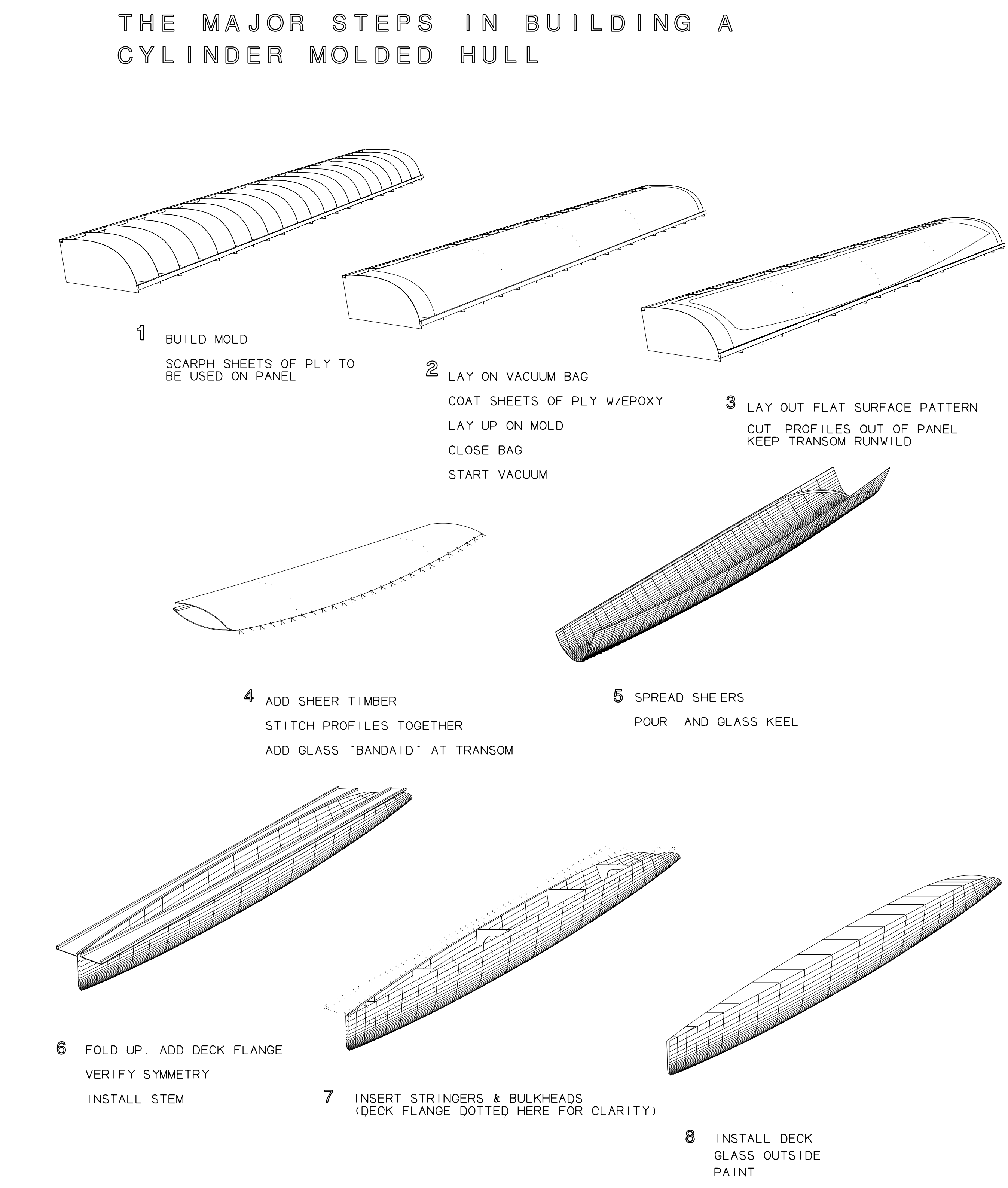
Lets take a run through the stages of hull construction. We can build that 35' ama as an example.
I will not include the very significant time required to set up your shop, or the time required to collect materials. There are too many possible differences between builders and situations.
Building the mold will be done first. To do that, cut out enough identical mold sections to allow one for every two feet of panel length. Locating the sections at exactly two feet is not necessary, but making the sections identical is. Once they are cut out, from plywood (CDX or worse), stack them together and compare them. If they are at all different from each other, a grinder will make them all match. A lumber cleat is added top and bottom to finish the mold. The first major step is to build panels. Each hull will have two full length panels, port and starboard. A scarphed edge must first be put on every thin sheet of plywood to be used on the entire hull. That is easy. Stack the sheets in an even 8 to 1 step back, using a grinder to give them identical scarphs. It will take about an hour. Consider that every piece in a panel will be both lapped and scarphed to the others near it.

Apply Plywood

A vacuum system must be set up to bag a panel. I usually use a shop vac. It can both clean your shop and suck a vacuum to make panels. For the bagging material we use 4 or 6 mil polyethylene. For the bag edge seal, storm window snap bead has proven to cause the lowest grief at best cost. It can be used a dozen times, is clean, rapid, and not bothered by wrinkles and dust. As a diffusion layer inside the bag, bubble pak is best.

I have laid up panels by myself, but it is many times faster to have a helper or two. Enough sheets of 3mm plywood to build a panel will be coated with epoxy on the scarphs and mating faces only. When this is done, the sheets of plywood are laid on the mold. Finally close the bag and start the vacuum pump up. To build their last panel of the 36'KAMANU, Schooner Creek Boatworks spent only 38 minutes. It takes me an hour or two working alone. Remember again that every sheet of thin plywood forming a panel is both lapped and scarphed to the others. The result is a panel that behaves, when compounded, like the huge, fair, batten spline it is. Naturally that will make a stronger hull. After the bag is checked for leaks, the vacuum pump must run long enough for the epoxy to cure, usually eight or ten hours. If you have not done vacuum bagging before, it is quite amazing. Your own mild mannered shop vac will suck enough vacuum that you cannot physically lift the bubble pak off of the panel.

After completing the two panels (port & starboard) necessary to build a hull, a pattern called the flat surface profile is laid out on each panel. Cutting along the pattern lines gives two identical half hulls. Identical sheer timbers are next



glued to each profile.

The reflected profiles are wired together along the keel. The sheers are spread to the distance noted on the plans. At the bow area we install a composite stem. The stem unit allows one to keep the stem area under control, a condition that was a bit lacking in previous developed hull schemes.

The next major step is the keel pour. The hull halves will now be fully joined. We build the keel from a mixture of epoxy

Vacuum Bagging

and fillers, under biaxial roving.

To create the proper developed fullness, and to insure that port matches starboard, a temporary deck flange is to be built. The final major step in hull building is when the deck flange is set in place. The bulkheads and stringers may now be added. Since the hull skin has already assumed a smooth fair surface, the bulkheads must be fitted lightly. They should be a little under size to keep from deforming the hull skin. With proper planning, the inside of the hull may coated at the same time that the bulkheads are coved in and the stringers are pushed in through the open transom. If the entire job is done in one "wet out", no inside sanding or bonding preparation is needed. I like that.

The best decks seem to be built with composite cores bagged onto thin plywood. There is some time saving over using plywood stringers, and the cored decks reduce the microfissuring that often occurs on the underside of epoxied plywood/stringer decks. After the bilge wires are removed, and the edges trimmed, the keel has a layer of biaxial tape added to the outside. Any necessary filling is done at the sheers or keel, and the hull is sheathed with a layer of 4 oz. or 6 oz. glass cloth.

Panels

A light, high performance hull can be built very quickly at low cost. This technology should give one more of a chance to finish a boat before it becomes outdated, or the money runs out.

This is not to suggest that cylinder molding will make boats inexpensive. Hulls are only a small part of the cost of a boat. Multis that are almost all hull will see big savings. Bridgedeck cats for example will see smaller relative time and cost savings from rapidly built hulls.

PROBLEMS

Every building system has limitations. CM is no exception. There are some restrictions on the possible hull shapes. To keep building time down, CM hulls should be simple curve sections. Flares, steps, and hollows are not easily possible.

These hulls must have slenderness ratios 10:1 or thinner at the waterline if they have reasonable amount of rocker in the profile. Within these constraints however, virtually any hull shape is possible.

Also, as a designer, I cannot locate things in a cylinder molded hull with absolute certainty. For instance, I could specify that a seat be located

14" below the sheer level. I could not also state that it would be some exact distance up from the keel. I can come close, but there is still some uncertainty. Two hulls built from identical profiles but different plywoods might come out slightly different. You could not see the difference, but a tape measure might show it. It is eyeball boat building, with 'make port reflect starboard' being the dominant rule. If you must have exact accuracy in all aspects, this is not for you. I'm happy to design boats for you to be built in other construction systems. We do many composite boats for clients where time and cost are less important.

CM hulls are better suited for some types of multis than others. I see CM as being ideal for hulls such as tri amas or charter cats where interior living in the hull is not needed. I see CM as having the least advantage in hulls such as livaboard cats where interior is everywhere in the hull and the structure must be carefully finished.

Finally, one must be careful about which plywoods to use. Some types of excellent plywood might be too stiff to compound. With the great number of useful plywoods out there, that does not need to be a problem.

THE FUTURE

The system is moving toward unprecedented dimensional certainty as I collect an ever increasing body of data from the boats that have been built. A mature CADD system makes that even easier. In fact CADD (computer aided design and drafting) is a natural fit with CM. Changing the length, beam, or freeboard on a building project is as easy as a rescale is on the computer. Adding eighteen more inches freeboard on a 40' tri main hull panel was done in about three minutes, by simply sliding the flat surface pattern up 18". About the same difficulty as a drawing rescale on the screen. All KHSD multis are drawn using CADD now.

Experiments with strategies to allow fatter length/beam ratios on boats with larger amounts of rocker have turned out very well. The result has been higher displacement cylinder molded cruising boats than we ever thought possible years ago. At this point as we keep exploring the envelope of possibilities, I must repeat, it looks like virtually <u>any slender, positive curve hull shape wanted is possible.</u>

CONCLUSION

This construction system, developed by people too poor to deserve boats, got us into sleek, high speed multihulls that would be out of our reach otherwise. They are also the highest quality boats we could have chosen. Cylinder Molded hulls may be the best possible choice for many builders of multihulls.

Smooth and Fair Hulls