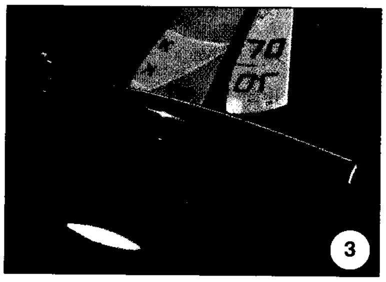
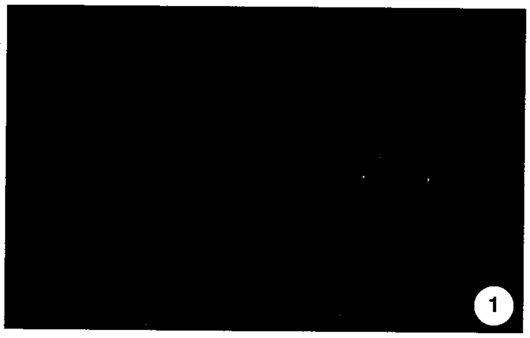
YACHTING

Yacht Lines

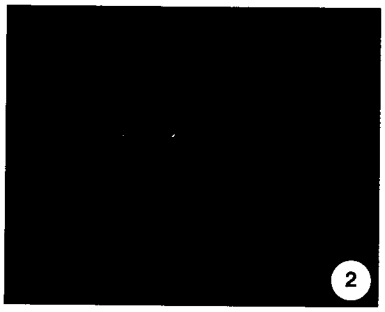
ANTHONY CORBETT

discusses fins





1: The new eye-bolt fitting from Sails Etc adapted with a thumb screw to allow easier adjustment but ...



2: ... be careful if your wish is for an adjustable jib sheet lead as the nut overlaps the track and could trap a sheet.

3 & 4: Although it is not easy to make comparisons on the hull shapes, the differences between the fins of the RM Enigma No. 70 and the Paradox No. 199 are clear to see. The Paradox fin is also considerably deeper although I have a feeling that No. 70 had two fins for use on different lakes.

5: The shape of the rudder is as important as the fins and the elliptical shape seen on this Shaft design is probably quite effective. The large profile would also contribute to the lateral resistance as well as improving directional stability.

6: Yes I know this shot appeared recently but it's the best one I have to demonstrate the need for a fin to resist torsion if the ballast is hung off centre. The rudder and fin shapes are also interesting as I notice that the Walicki fin seems to have moved away from the elliptical trailing edges of earlier boats.

Thanks Graham.....

The nice thing about model yachting is that even the biggest suppliers are able to give a personal service. Only a couple of weeks ago I discussed with Graham Bantock my need for a Sails etc. track slide with a thumb-screw rather than their standard fitting and low and behold, a scoop!; the first pictures of Sails etc. latest fitting - a track slide with eyebolt and adjustable lock-nut. Well not quite earth shattering stuff I know, but it makes rig changing on my latest One Metre a lot quicker (no I'm not going to tell you why!) and I'm sure a lot of you will think of a lot more applications. Just one word of warning, whilst having an adjustable slide might have an immediate application for a jib sheeting eye, the lock nut extends beyond the edge of the standard track leaving a nice place for the jib sheet to catch. Such problems are solvable and I've got what I needed, so there ...... Price is to be confirmed but if you're interested call Sails etc. on 01376 571437.

Fins, the introduction ....

As regular readers will know, I've been promising to have a look at building your own fin for what seems an age, however, during the past season several other issues have come up that have made me postpone the article. With the end of the year now upon us and with minds turning to new projects, perhaps now is the most appropriate time to go into print.

Those that have helped with the preparation of this article may well wonder why I didn't "knock it out" ages ago, however being one for researching a little beyond the realms of bar-room theory, I felt that it was necessary to write something that went beyond gluing a kit of parts together.

Now the newcomer to radio yacht racing may well wonder what all the fuss is about. Why should fins and their construction be an issue? To be frank, I don't believe that it is. But there are those who do, and have contributed to the argument about cheque-book racing and the development of with thinner sections which create less drag.

Although I suspect that it has gone unrealised in the general cacophony about cost and carbon fibre, it is the development of more accurate fin sections and new profiles, rather than hull-shapes, that has lead to the greatest performance gains in recent years. This is evidenced by the fact that GB won the 1993 RM Nationals by a convincing margin using a new fin section on a borrowed Enigma hull. The increase in stiffness, and hence length, in the M class has allowed the large increases in stability without an increase in overall weight (the mass is concentrated in the ballast) and this in turn has allowed the development of the narrow hulls (which are unstable but have low wetted areas and thus friction drag) seen on the modern RM and 1M. Whilst it is true that this development has been spurred on by the availability of cheaper and "expensive" carbon-fibre fins within the IYRU One Metre Class in particular.

The source of the problem really seems to rest with cost and I suppose there is some justification for this if one simply compares a timber fin costing around £15 with a moulded fin of £45. This comparison however is not like for like as a timber fin still needs a certain amount of trimming and finishing. I hope that the reader will not have missed my reference to a moulded fin, rather than carbon-fibre one, as it is the continual reference to high-tech materials and carbon in particular that is the most misleading part of populist theory. It is not carbon-fibre on it's own that makes boats go fast, or their fins more hydrodynamically efficient, it is the design of these elements in combination with the hull, ballast and rigs that brings success. The benefits of modern composite construction techniques have contributed to both process and solution by allowing significant reductions in weight whilst improving strength and stiffness. This has made it easier to build longer fins stiffer carbon-fibres in particular, there is nothing to say that if, for example, carbon had been banned from One Metre fins, some bright spark wouldn't have eventually developed a thin fin built from a timber material costing four times as much.

So what is it that we should consider in the design and construction of a fin? Whilst some of the theory needs to be discussed to help in understanding the more practical aspects of moulding a fin, I would like to cover this separately and in more depth as the second part of this article. In this part, I have decided to look at the process of construction as this will probably do most to dispel the more misleading statements one hears.

Firstly I must correct one omission in that no mention has been made of the rudder. Whilst most of us probably think of the rudder's only purpose being to steer the boat, it's profile and cross-section are as important as the fin itself. Neither should be developed in isolation.

The major restriction, apart from available skills, on the design and fabrication of the component parts of a yacht (whether it is two or twenty two metres long) is economically available materials. Knowing the properties of the materials, the designer can then apply his expertise in developing the most effective application of those materials within the known parameters. In our case, the parameters are the rules applicable to each of the MYA/IYRU recognised classes which, in most cases, carry their ballast at the end of a relatively long fin. This introduces a requirement for the keel to be both strong and stiff with a need for torsional rigidity if the ballast is hung off-centre.

The reader may also have heard a lot of references to "lift" generated by the fin but I'm afraid most of us laymen confuse lift and lateral resistance. Lateral resistance is a function of the profile of the fin, i.e. it's total area and distribution or shape. A fin pushed sideways in a fluid would offer resistance but no lift. Lift is generated by the cross-section of the fin moving through water in the same way as a plane's wing moving through air and the calculation of this lift is a function of the fins area. A bit of a conundrum then and something I will try to explain both in more detail in the next part of this article.

What a fin actually does is provide a means to balance the side force generated by the rig. Without the equal and opposite side force provided by the fin, the yacht would simply drift sideways. The keel and rudder should be designed with an optimum area and planform shape which balances the side force of the rig for a minimum drag caused by skin friction and form. In practice a greater or lesser degree of guess-work enters into the design process. Most fins on ballasted yachts are designed for an optimum performance to windward. As a boat sails further off the wind, the sideways and heeling forces reduce to the point where the fin becomes a hindrance.

So how can this best be summarised? The design of the keel and rudder need to be developed together. They need to be stiff enough to resist bending (and twisting if the design involves torsional loads) and have enough area to offer adequate resistance to leeway (without causing more than the minimum possible drag through friction). The section also needs selecting carefully to minimise form drag.

Although use is a function of availability, most of the successful skippers use fins that have evolved from the development put into the design of the Roar Edge and Paradox Marblehead designs. They have a thickness to chord ratio of about 7.5% although the profiles are very different (The Roar Edge is elliptical and the Paradox tapered). I have also seen a number of fins made with parallel leading and trailing edges but I have more cramming to do before I will understand whether this was a deliberate piece of design or simply an easier way of making a mould.

There is an awful lot of data available to those wishing to design their own fin, including the NACA profiles that most designers refer to. Again I will cover these in my next missive but for now, I will let the following piece demonstrate the contention that it is easier, and therefore cheaper to mould a fin than build one from timber.

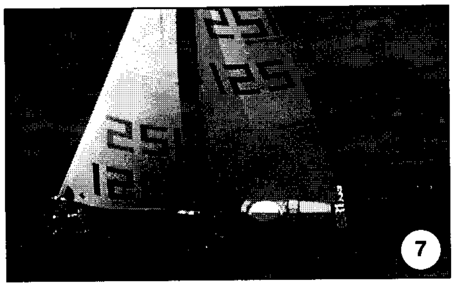
First Steps

The purpose of this article is to break down any preconceptions that moulding a fin is a dreadfully complicated process that involves high-tech or expensive materials. Whilst some may feel that the time, effort and skill is beyond them as individuals, there is really little to stop a group of club members pooling their resources to manufacture fins at a very competitive unit cost. Before going on to look at the process. it is probably sensible to deal with some of the basics. I don't intend to give you a blow by blow account of mix ratios, costs and the tools as all of this can be obtained from the supplier of the resin system you opt for. Our starting point will be the assumption that the reader knows little about moulding things.

Most of us have heard about G.R.P or glass reinforced plastic and I myself often refer to high-tech construction but what is it?

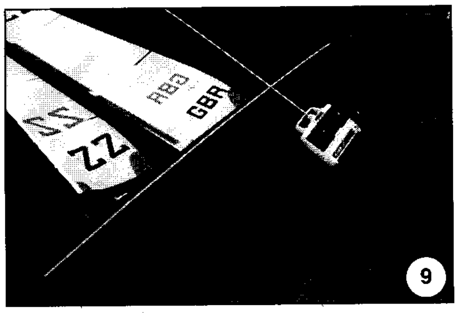
The material itself was developed during the war to the point where it became useful for day to day applications. GRP is now used in the fabrication of boats, architectural details, shop fronts, vehicles, visual displays, bus shelters and portable buildings. As a product, it has been commercially available in the high street for at least 25 years, so one can hardly describe the process itself as cutting edge technology.

The use of the generic term GRP is normally applied to a moulding formed by laying varying weights and weaves of glass fibre mat or woven cloths bonded together by the application of polyester resin. Like reinforced concrete, the constituent parts

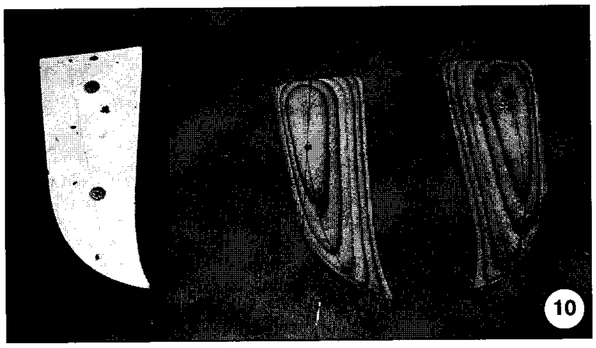


7: The design of a fin is influenced by many factors, but for an all round performance profile, the optimum is a balance between minimising leeway to windward and drag off wind.

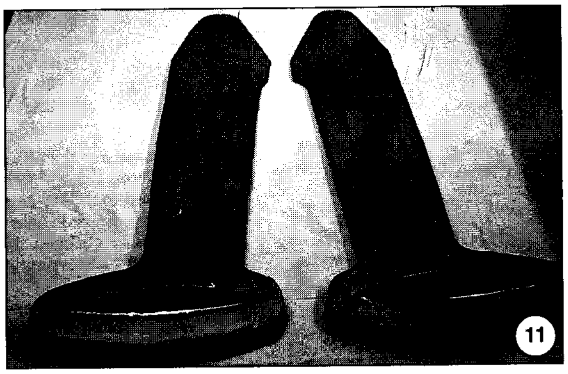
8: This fin was made by Paul Tickner from an experimental Roar Edge mould. It is typical of the elliptical profiles used by Roger and many other European designers. The same fin is supplied by PJ Sails, shortened for use on One Metres.



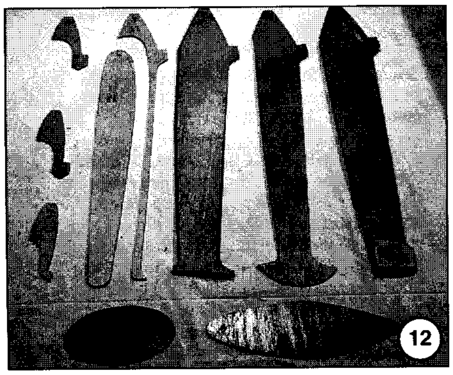
9: The fin fitted to the prototype Shaft RM had parallel leading and trailing edges, possibly for ease of construction.



10: This photograph illustrates Stollery's approach to making a plug. The ply is fixed to the melamine board by locating pins, the holes for which can just be seen. One can just see the lines on the plug which indicate the position of maximum thickness of the section and it's position relative to the chord width.



11: Gel coat applied to the two halves of the fin mould, which incorporates an integral ballast weight.



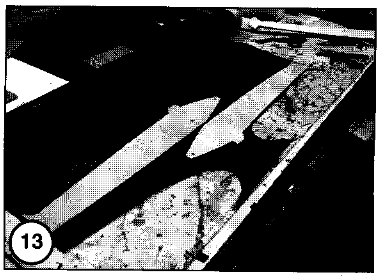
12: The dressmaking part. Patterns for the various cloths to be laid up in the mould.

have different structural properties, the resin being better in compression than in tension and vice-versa for the fibres. Their combination gives the most efficient strength to weight ratios, although strength can also be a function of the final shape. Glass fibres also have limitations in how they can be laid into moulds because they are inherently stiff and springy which affects the practicality of moulding particular shapes.

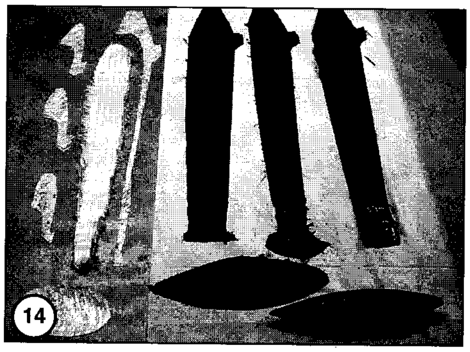
Polyester resin sets after the addition of an activator (also known as catalyst, hardener or accelerator) which triggers the exothermic reaction. The number of fibres and their direction in the weave of any particular cloth or mat affects the strength, so the fibres are sold by both weight and weave.

Over the years, manufacturers have developed a number of stronger materials, the most commonly known of which are Kevlar and carbon fibre. These fibres are considerably stronger than glass strands and when woven into cloth, can produce lay-ups with much higher strength to weight ratios than GRP. However Kevlar fibres do not bond as easily, so these are best used with a different type of resin known as epoxy. Epoxy resins are two part resins that also set by chemical reaction. They have better adhesive properties than polyester and are stronger in compression, however like polyesters, they can be comparatively brittle in their final moulded form. You will therefore find that a lot of manufacturers of light weight hulls use a two layer lay up of carbon fibre for strength and back this up with Kevlar to prevent splitting.

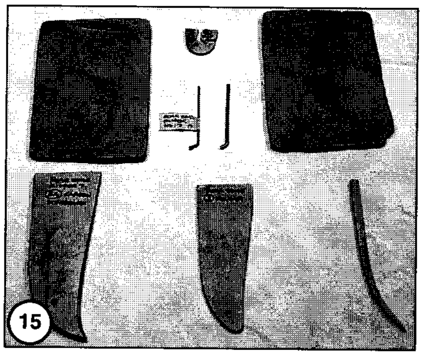
So if these material are readily available, why do they get referred to as high-tech? Well the answer probably lies more in myth than fact, although lightweight composites always seem to be associated with speed and sexy looking products. This might be because it is much easier to mould tighter curves and intricate shapes with carbon fibre, as well as the fact that lightweight composites are developed by cutting edge industries like aero-space and Grand Prix racing.



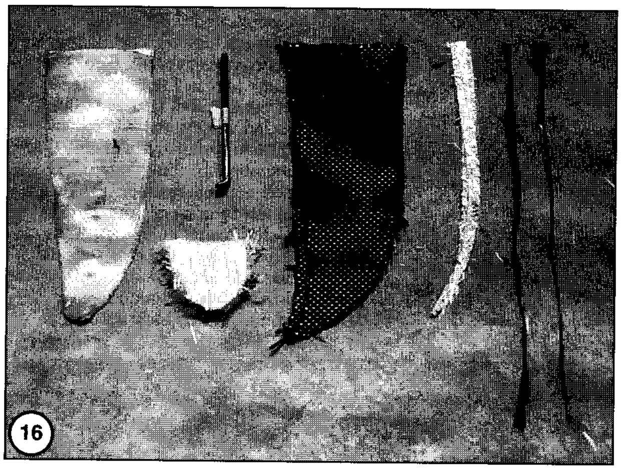
13: Cutting the patterns is fairly straight forward process which results....



14: ..... in the cloths that will be applied to each half of the mould (except the large glass fibre filler to the left of the photograph.



15: The mould and patterns for the rudder together with...



16: ...the cloth pieces applied to each half (except the shaft and spacer material).

17: Construction of the moulding starts with the bulb which...

18: ...is then wetted out.

Carbon-fibre as a material is more expensive than glass but it is much easier to use. It is a very soft fibre in use and lends itself to tighter curves than glass. It also stays in place once wetted out with resin. These attributes make it much easier and quicker to lay-up by hand than fibres such as glass.

The use of epoxy demands more controlled and cleaner conditions than is necessarily the case with polyester. Whilst I have heard epoxies described as carcinogenic and demanding of considerable care in use, apparently it is the phenols present in some epoxies that are particularly undesirable. Suppliers recommend using barrier creams in addition to special cleaners and disposable equipment. One should also note that any cloth, glass or carbon, will contain small fibres which float off into the air and which can be breathed in. So wear a mask and handle carbon with a lot of care as the splinters of the strands are far more painful than any piece of timber. Again we could discuss this in a lot more detail but there is plenty of technical information and advice available from the suppliers of the various products.

As for polyester, well although most of us would say that a tidy workshop is essential in any process, one will see from the photographs that hands seem to become an intrinsic part of the process, so cleaning is a relatively straight forward process allowing tools to be reused. The down side with polyester is that mouldings can be affected by heat build-up in the setting process. It also smells!

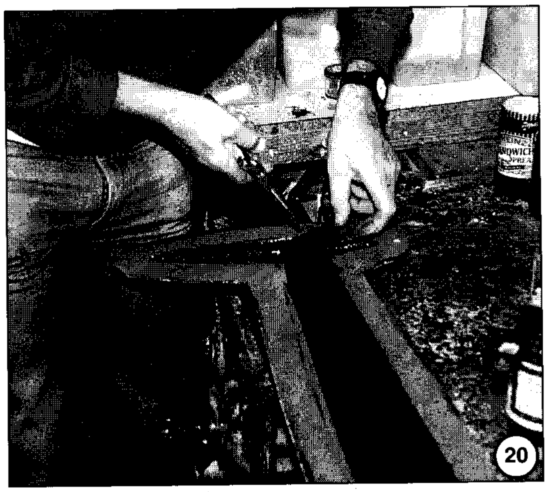
At the end of the day whatever resin you prefer to use, the objective is the same. We are looking to fabricate a light and strong structure that can be reproduced, with the additional benefit of reduced finishing time. Apart from the careful selection of cloths and lay-up, I would also add that the objective must be to use the minimum amount of resin as this is the major contributor to the weight of the finished product.

We have already looked at the concept of design but I felt it might be useful to add some of Roger Stollery's thoughts on the matter as he has a wonderful way of keeping things in perspective.

Obviously Roger is well known in model yachting circles as one of the innovators in both vane and radio yacht racing. Roger is an Architect and regards himself as a student of yacht design and a builder of boats, so I was interested to find out about his approach to fin design. It is when one visits his workshop and talks about the various yachts gathering dust on the walls and ceilings of the room that one can see the process of development and only two wooden fins to be seen! Roger himself describes his ideas as evolutionary and empiric, always searching for ways of making things both quicker and simpler.

Apparently, Roger didn't take the design of fins sections too seriously until David Hollom tested various fin and hull sections and it was found that Roger's TOP design didn't measure up. Roger concluded that the

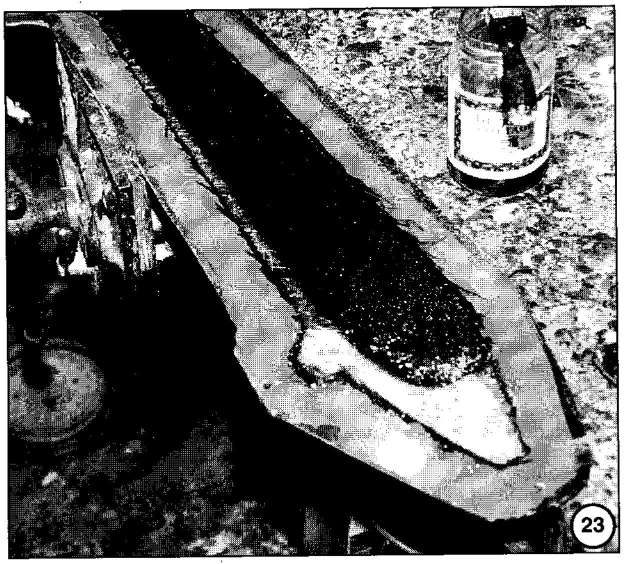
19: The unidirectional carbon cloth is then laid in the mould...



20: ...it's end spread into the bulb to strengthen the connection...

21: ...followed by wetting out with resin and finally...

22: ...rolling, to ensure the material is fully saturated.



23: The first layer is followed by two others as described in the text and finished by the application of the GRP mats to fill the top and leading edges.

24: The flat edge illustrates the section of the moulding.

problem was the fin and this in turn prompted him to take advice and start designing fins to particular NACA 00 sections. Just as importantly, he started to make more effort to build them accurately. This immediately and dramatically improved performance. It resulted in winning events and allowed Pitstop to be the highest placed UK yacht in 3rd at the 1991 RM European's in Finland. Improved fin design was a high priority for both Graham Bantock and Roger in developing their boats for New York at that time.

The Plug.

Once you have determined a profile for the fin, then the first step must be to make an accurate plug from which the mould will be taken. You will see from the photographs that Roger fabricates his plugs in two halves using 1.6 mm birch plywood cut to an exact profile. As the two halves have to be joined for comparison and fabrication of the mould, it is essential that locating pins are positioned precisely. Roger does this by drilling through the base on which the plugs are built. The ply is then sanded away to match the shape of the buttock lines (vertical slices) set at 0.53 mm centres on the drawings, the different ply layers giving an accurate indication of the shape and fairness. Once the plug is shaped, it is faired then waxed and positioned on the building board of melamine faced chipboard to form an accurate centre-line. It is also worth noting that the port side moulding is slightly smaller than the starboard half to allow for an extremely fine taper on the trailing edge of the fin. Those that have cut their hands on the back edge of a new RM fin know just how fine an edge can be achieved but this does raise some practical issues as sharp edges are prone to damage and difficult to repair. Whilst the sharp trailing edge is the ideal, the alternative is to make a fin or rudder with a squared off edge. Avoid rounding off trailing edges as this generates a lot of drag.

After applying the initial coloured gel coat, a second coat of a different colour is applied as a warning when sanding later. The first structural layer of the mould is applied using a light glass-fibre tissue. After this one builds up the layers so as to produce a strong mould that will resist bending or any deformation. It is worth noting that any hollows in the plug can be removed by sanding the bumps created in

25: *The process is repeated for the starboard half to which the spacer is added. This is...*

26: *...followed by the ballast and...*

27: *...finally the bolting together of the two halves.*

28: *The rudder follows a very similar process, although the need for...*

29: *...strength is reduced. The lay-up is changed to one layer of carbon...*

30: *...followed by one of Kevlar.*

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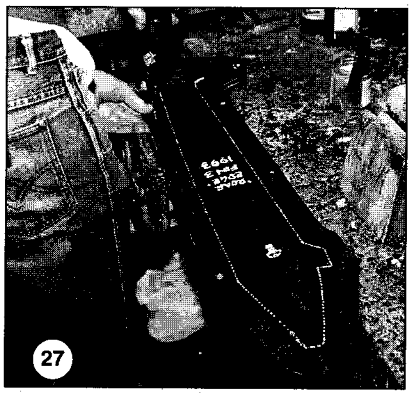

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the mould. However all bumps and other flaws should be removed at the early stages. Once the mould is complete and before it is separated from the plug the two halves are aligned by using the locating pins between each side of the plugs mentioned earlier. The moulds can then be drilled and bolted at their flanges. Then, with the plugs removed, they can be sanded using fine grades of wet and dry, followed by polishing to produce an extremely smooth surface. This is the most labour intensive part of the operation as there is no short cut, the finish improves with effort.

However if this all seems a bit too much for your first project, Roger is prepared to lend a moulded GRP plug to clubs for the construction of the fin and rudder moulds (details at the end of this article).

Producing the moulding

Having made the moulds, it is now time to make the product and this starts with more preparation of the moulds by wiping on a release agent or polishing with a product like original Simoniz wax.

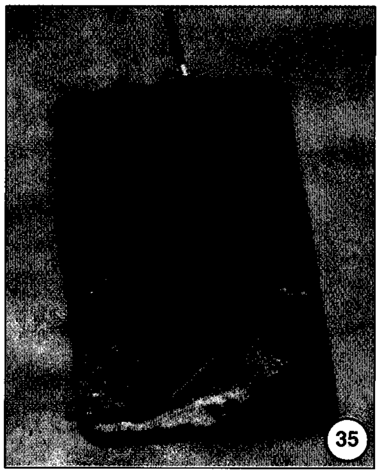
Roger uses polyester resin as he finds it very easy to use with plenty of tolerance to temperature conditions. The first job is to apply what is called the gel coat to the mould, which for hulls is normally coloured to give the finished surface. Roger suggests that producing a moulding is a combination of dressmaking and painting, so the Gel coat is applied by brush ensuring that the mould receives an even layer that totally covers the surface. The moulds are then set aside whilst the gel coat starts to set. Fortunately polyester is not quite as demanding to use as epoxy, so Roger uses this setting time to cut out the various cloths used in the lay-up.

As one will see from the photographs, RS has a number of patterns from which he marks out the shape of each layer onto the cloth for cutting. The lay-up of a fin is probably the most difficult part as the mix of different weights and weave of cloths produces composites of very different strengths. I have mentioned in previous articles that Graham Bantock and his colleagues at Sails etc. actually produce sample panels of various weights and combinations which are all tested to give an indication of their strength and stiffness. For the rest of us mortals the process is probably more trial and error, although a quick lake-side chat with either Graham or Roger will probably save one disappearing down a blind alley.

For the Edge's fins, Roger uses a mix of carbon fibre, Kevlar (rudder only) and glass mat plus an interesting glass product which expands acting as a spacer between the two sides of the moulding. You will also note that the keel mould includes an encapsulated lead which makes completion of the boat very straightforward.

This is where we return to the construction process as with all our various patterns cut out (better illustrated by photographs than words) we check that the surface of the gel-coat is now tacky and lay in the first bit of cloth (190 g/m2 plain weave carbon cloth) within the mould for the ballast. The keel lay-up starts with the first layer of 190g/m2 uni-directional hi-modulus carbon followed by a similar weight diagonal weave cloth which increases torsional stiffness. Each layer is applied dry then wetted out by applying resin by brush. One has to balance the need to apply resin thoroughly against increasing weight, so after applying the resin, each layer is rolled to ensure that the resin saturates the cloth. It is in this part of the process that the more specialist manufacturers gain an edge by developing building processes such as vacuum moulding that ensure minimum amounts of resin are forced through the lay-up. The carbon lay up is finished by the third layer of plain 190g/m2 plain weave with all the lower ends of the patterns being cut and spread out into the ballast capsule to ensure a proper connection. This half of the mould is then completed by the laying in of the leading edge and fin top reinforcement of patterns cut from 300 g/m2 chopped glass mat.

The process is then repeated for the other side, except that the ballast and spacer are now introduced, wetted out and



31: Again, a GRP filler is added to the trailing edge and...

32: ...the head is filled with carbon off-cuts in resin (sounds like something from a deli'!)

33: The process is repeated for the other half except that the GRP spacer and rudder shaft are now fixed and...

34: ...the two halves are bolted and screwed together in the same way as the fin.

35: Once the resin has set (over lunch if my memory serves), the moulds are separated and your left with a sexy looking fin, with...

36: ...only the resin flash to sand-off before it can be fixed to the yacht.

the two halves of the moulding brought together, when they are bolted and clamped. The "low-tech" alternative to the material spacer shown in the photographs is to use a balsa (grain on end is good in compression), spruce or foam (closed-cell) central spar but be careful of resin absorption, which can inadvertently lead to weight increases.

The rudder is built in a very similar way, although the lay up is different and the mould allows for the building in of the rudder shaft. It is also worth having a bucket for all the threads and off-cuts from carbon cloth as these don't get wasted. Roger chops them up and uses them for reinforcement at the head and trailing edges of the rudder, as well as in various fittings.

Well I hope that my jottings and photographs are an adequate response to any misgivings the reader might have in taking on a project like this.

One only has to look at the lay-up of Roger's fin which is very simple in comparison to something like the Paradox fin manufactured by Sails etc. (this is made up of three mouldings including a corrugated core which are then placed in a compression mould to produce a hollow but extremely strong and light fin). It maybe a little less structurally efficient but this simple approach will yield major performance gains at little extra cost in comparison with the timber profiles that some seem so attached too. The refinements of the Paradox fin come at more cost in terms of time and effort although it is true to say that the technology is not all that complicated. I also doubt that the retail cost really reflects the intellectual effort that has gone into the concept, however what this article is really about is demonstrating that you don't have to win the lottery to build a boat that can compete with the best. If you wish to take advantage of Roger Stollery's offer of the loan of a plug, then he can be contacted on 01483 421801.

My next article will take a closer look at the theoretical side of design. Until then I'd like to firstly express my heart felt thanks to firstly Roger for all his time and help in the preparation of this article and secondly to Graham Bantock, who once again kept a close eye on the technical content. Finally, I close by taking the opportunity to wish you all a very merry Christmas.