

Performance materials come in many guises and not just hidden away in sports clothing or protective wear. Whilst accepting that there are books dealing with this complex subject, what follows highlights just a few aspects of modern boat building.

Sea change in boatbuilding

The advent of glass reinforced plastic in the late 1950s transformed boatbuilding from a craft to an industrial process, bringing boat ownership within reach of a new, broad and modestly well-off generation with both disposable income and leisure time. Now, with the development of new closed mould production methods, glass reinforced plastic (GRP) boatbuilding is again undergoing major change.

Fanfares are customary at the Genoa International Boat Show. Italian boat builders in particular can be relied upon to strive to upstage each other on their home territory with glitzy launches of eye-catching, stylish craft. Last October's event, one of the largest boat shows in the world, was no exception.

The news being trumpeted by Azimut, based near Turin, and one of Europe's half-a-dozen largest builders of recreational craft, was of its new AZ 40 flybridge power cruiser. At 40ft this new boat is in today's terms a fairly modest affair. Production-built power cruisers these days rarely start below 30ft and can increasingly extend beyond 100ft in length. For Azimut the new 40 is at the threshold of a range of boats that extends in 13 model steps to 116ft. All of these are built in glass reinforced plastic (GRP). Although the very biggest are only built in single figures, perhaps every one or two years, Azimut builds ever larger motor yachts in its Benetti yards at Viareggio and Fano - on Italy's Ligurian and Adriatic coasts. These are the very limited edition 'megayachts' in aluminium or steel.

✔ DB ✔ DD



The Open 68S express cruiser, launched last year by Italy's Azimut, is the largest boat in the range built at the company's factory near Turin to have been moulded so far by the DIAB/Azimut core infusion process.

Azimut

Design or style innovations apart, what makes the baby AZ 40 a trailblazer is the method by which she is built. First of all, she is one of the few production powerboats built so far to be designed from the outset for resin transfer moulding (RTM). Moreover, she is almost certainly the first series-built power cruiser to have a GRP hull that is made of a sandwich laminate above and below the waterline, as well as a sandwich-laminate deck and superstructure.

As is obvious from the name, a sandwich laminate usually comprises layers of resin impregnated reinforcement material on either side of a lightweight porous core. The precise lay-up of the laminate varies according to mechanical properties demanded of the design and the price of the boat but, traditionally, it will be a combination of orthothalic (the cheapest) or isothalic polyester resin with chopped strand and/or woven glass matting either side of a core of end-grain balsa wood which is perpendicular to the laminate so that the resin can percolate through it.

Increasingly these days, however, rigid PVC foams are used as the intermediate layer, while reinforcement materials can be combinations of materials such as carbon fibre (where high strength and lightness are essential) or Kevlar, where torsional strength is required, as in load-bearing areas such as engine bays.

As for resins, polyester is still the most common, although vinylester is increasingly used because of its better resistance to osmotic blistering. Epoxy resin is also used to a limited extent to produce the best quality laminates in applications such as high-end racing sailboats. That, however, has the disadvantages of being difficult to work and chemically aggressive.

An inexact technology

In the mid 1980s boatbuilders began to consider alternatives when osmotic blistering became the great scare in GRP boatbuilding. Although it appeared in boats moulded by several builders, there was one with which it became particularly associated. To its great consternation

and that of its customers, France's Groupe Bénéteau discovered that certain of its mid-range sailing cruisers were breaking out in unsightly blisters and delaminating. Moisture was being drawn by osmosis through the gelcoat surface finish of the blighted hulls and into air pockets within the laminate. It transpired during protracted legal proceedings that the main culprit was the catalyst that Bénéteau used to cure its GRP mouldings. Apparently, the supplier had changed the formulation but failed to notify its customers. However, Bénéteau was also blamed to a lesser degree for failing to exercise proper quality control.

Although Bénéteau's reputation took a serious knock at the time, it does not seem to have suffered in the long-term, as today it remains the world's largest-volume boat builder. But its misfortunes over the 'boat pox' issue were an object lesson to the GRP boatbuilding industry at large and have been a spur to advances in the quality of hull laminates in general.

At the time of the great boat pox disaster the vast majority of GRP boat laminates were monolithic structures. Sandwich laminates with balsa or solid foam cores were fairly rare and almost the exclusive preserve of performance sailboat and top-end sailing cruiser builders. Lightness of construction combined with structural rigidity are far more critical to the handling and performance of such craft than powerboats, where extra mechanical power might compensate for 'overweight' mouldings.

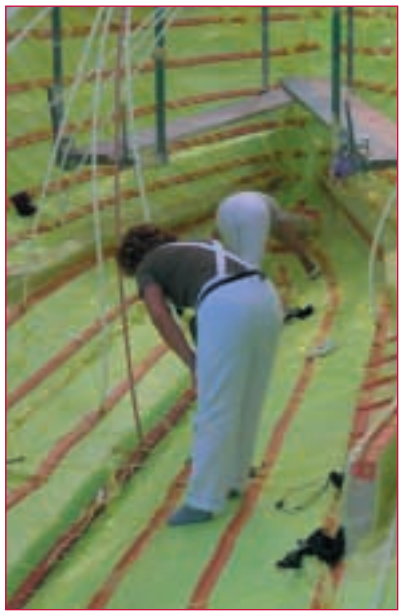
Also at the time, GRP boatbuilding was almost entirely a manual process, albeit one carried out on an industrial scale and lamination was very much the dirty end of the business. Laminating crews equipped with buckets, brushes, rollers and the occasional pneumatic spray gun discharging surface gelcoat or mixtures of chopped fibres and resin had the unenviable job of putting down layer upon layer of fibre mat in open moulds and physically rolling in catalysed resin. As well as working in often messy conditions, these operatives also had to put up with continually breathing in the high concentrations of styrene gas that used to give GRP laminating plant its characteristic pervasive sweet chemical smell.

Despite the difficult conditions the industry was turning out hundreds of thousands of boats this way. At the peak of the market in the early to mid-1980s the world's highest volume boatbuilder at the time, US company Bayliner, was producing more than 40,000 units a year by this process at its plant in Washington State.

Because it was then an almost entirely manual process (and still is today, albeit to a reduced extent) it was also an inexact one. Although many boats came out of the same sets of moulds, each would be slightly different because they relied on the skills and judgement of individual laminators.

Greater product conformity and repeatability were clearly desirable. Consumers were certainly expecting higher quality but it also made good production sense. In a labour and materials intensive business, where oil price rises are continually driving up the price of resins, the wastefulness of traditional wet lay-up is becoming increasingly unsustainable.





Operatives working on a hull moulding at ACT assist the flow of resin into a Pershing express power cruiser hull. While on the right a member of the laminating crew watches closely as resin starts to flow into the keel section.

ACT Group

Environmental pressure

But one of the greatest drivers of change here has been environmental legislation. In most countries now the maximum amount of styrene gas to which laminate workers can be exposed is 20 parts per million. In some countries, notably in Scandinavia, tolerances are lower still and there are further restrictions on venting the gasses to atmosphere. Handling these emissions can, therefore, be very expensive. One method is to provide individual breathing apparatus to laminators but that is burdensome and does not solve the overall problem of how to deal with high concentrations of styrene in the workplace.

As an alternative, air handling plant can be installed in addition to breathing apparatus, both to exhaust the gas or scrub and recycle the air, but that too can be costly. Bearing in mind that the air inside a factory may need to be changed as often as eight times an hour and that in cold weather that air has to be heated, probably by burning expensive fossil fuels, hard economic reality is also driving the search for alternative laminating methods.

Primarily, two alternative methods are rising to the fore. One is resin transfer moulding (RTM) using closed moulds. The other is using 'prepregs' – sheets of reinforcement material that come pre-impregnated with resin and catalyst which is activated on exposure to heat. Although prepregs have been around for a couple of decades, the latest and most advanced variants, such as SPRINT developed by UK company SP Systems, are now catching on in specialist, high-performance boat applications. In the broader boating market, however, it is RTM that has made the biggest advances so far.

In the boatbuilding industry RTM was pioneered in the USA by Bill Seemann, who introduced SCRIMP (Seemann Composites Resin Infusion Moulding Process) in 1990. This system, just like all adaptations that have since followed, involves laying dry packs of reinforcing fibres and, where used, core materials in moulds that will have been previously sprayed with the gelcoat that gives the hard shiny finish invariably associated with boat mouldings.

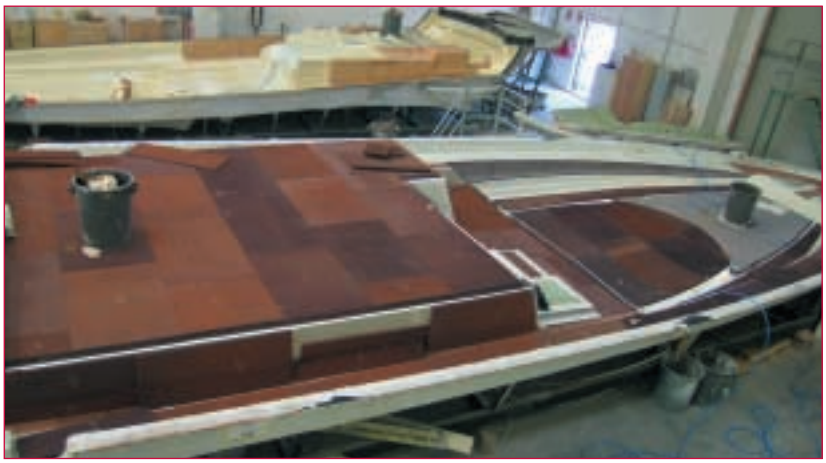
Depending on the size and complexity of the moulding (and often hulls are over 100ft in length, while deck superstructure and internal mouldings can be very complex) any number of vertical resin channels and horizontal offshoots thereof are laid in among the fibre/core materials packs to be impregnated. Once these are all in place, catalysed resin supply lines are connected and a polyethylene cover is taped over the mould. Starting at the keel and working upwards, taps to the supply lines are opened in turn, so that as vacuum close to 1.0 BAR is applied, resin is drawn into the mould where it impregnates the fibre/core material packs. Full impregnation usually takes between 45 minutes and a few hours, according to moulding size and geometrical complexity. Thereafter it is usually left to cure at about room temperature overnight.

Compared with traditional wet lay-up there are several advantages to RTM. For a start, it is environmentally cleaner. Because it uses a closed-mould system it is claimed to cut styrene emissions by 90%. But it can also produce a better-quality moulding. Gone are the vagaries of irregular impregnation of fibre/core substrates, so that laminators can be certain of uniform resin take-up. Any air pockets show up as lighter patches in the laminate and are treated by laminators with locally administered resin injections.

The irony in the system is that, although resin penetration of the laminate is far more regular and complete than with hand lay-up, less resin is actually used. Laminates can be thinner, lighter and, yet stronger with lower resin-to-reinforcement ratios. Typically with RTM methods they will use something in the order of 60% fibre and core materials to 40% resin, whereas with manual wet lay-up those proportions will be reversed. This means that the boats are lighter and can go faster or, alternatively, further with less fuel, or, in the case of sailboats, sail better than conventionally laminated boats. They are also stiffer which is particularly important in sailboat performance. Because there are few, if any, voids in the laminate the boats are at minimal risk of osmotic blistering.

Different route - same result

SCRIMP is now extensively used in the USA, primarily by Tillotson Powell International of Rhode Island. As well as J-Boat one-design racing yachts, Lagoon catamarans and Jeanneau and Pearson sailing cruisers, TPI uses the system to mould products as diverse as bodies for electric cars, wind turbine blades and components for lifts and swimming pools. In fact, the company now owns the patents for the system, which is also used in the aeronautical, military hardware and telecommunications industries by companies including Boeing, Northrop Grumman, Textron and Raytheon.



Its PVC core materials pack exposed, a deck moulding awaits completion of the fibre reinforcement/core pack before vacuum bagging and resin infusion at the ACT lamination plant.
ACT Group

In Europe, however, the take-up of SCRIMP has been more limited, although on the boatbuilding side Europe's most important exponent has been the ACT Group of Mondavio in north east Italy. This company produces the mouldings for one of Europe's most prestigious brands of express power cruiser, Pershing. This flagship range of conventionally-powered and waterjet-driven sports yachts ranges from 50 to 115ft and is a subsidiary of Ferretti Group, one of Europe's half-a-dozen biggest producers of power cruisers and motor yachts.

Since its transfer to SCRIMP in 1999 ACT has produced more than 200 sets of Pershing mouldings using this system. While it is closely protected by copyright in the USA, TPI has not been rigorous in defending its intellectual property outside the US, leaving the way open for others to adapt the concept of vacuum moulding to suit their own applications. The motorboat builder that has adapted the concept and taken it further than any other boat builder in Europe is Ferretti Group's arch rival Azimut. At the end of 2002 it decided to collaborate with a Swedish GRP core materials producer, DIAB, in the development of an RTM system that goes beyond what has been achieved with SCRIMP so far.

At first sight the DIAB core infusion technology is more tidy than its RTM forerunners. For a start, the usual cat's cradle of resin channels, each fed by its own supply tube, has been considerably reduced. A 40ft hull moulding, for example, has just three longitudinal channels, with feeder tubes at 3m intervals. Most vacuum moulds would have far more as well as additional branches radiating from them at right angles.

The reason for the reduced complexity of the DIAB infusion system is that the company's rigid PVC foam core is itself a crucial component in the resin diffusion process. The core panels, which are cut by DIAB exactly to the dimensions

of Azimut models, are scored gridiron fashion and drilled through at regular intervals to conduct the resin as it is sucked through the mould to every part of the laminate.

A further claimed advantage for the Azimut/DIAB system is that there are far fewer disposables. Whereas with most RTM systems all feeder tubes, channels and polyethylene vacuum bags have to be thrown away after single use, with Azimut's application multiple use is possible. The tubes and bags, which were sourced from the food industry, are silicon coated so that any hardened resin residues cannot adhere to them.

The design also eliminates the need for a sacrificial diffusion mat, peel ply and release films. Indeed, the only things that need to be replaced after an infusion are the tapes that are used to fix the vacuum bag and feeder channels in place.

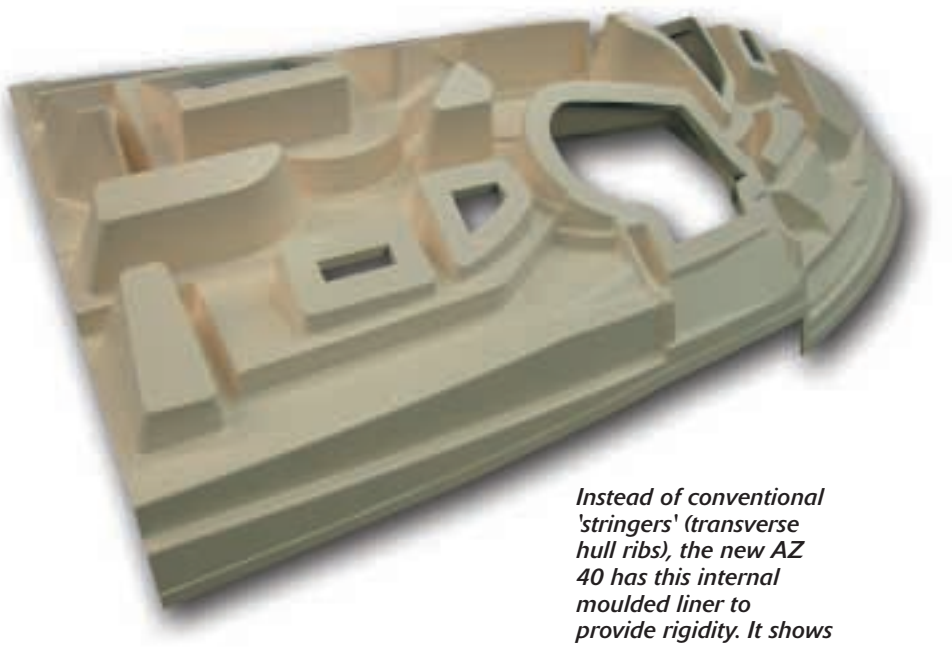
Construction-specific design

The new AZ 40 is remarkable in that it was the first to be designed for moulding by the Azimut/DIAB RTM method and that rigid foam core material is used throughout the hull. While core sandwiches are still unusual in the hulls of power cruisers, the AZ 40 applies the technology to the entire hull. Until now, the hulls of all GRP sandwich construction powerboats, and indeed sailboats, have all had solid GRP bottoms to take the slamming loads that they are subjected to and, in the case of sailboats, the stresses that are imposed on their keels.

According to Azimut, the hulls it now produces by the DIAB/Azimut RTM process are 35% stronger than their hand-laid equivalents and, using less resin, are appreciably lighter too. A good comparison is provided by its 55ft model which has been moulded both conventionally and by the new system. In a set of mouldings for its model the company says it can save between 150 and 200kg in weight. The laminates it now produces by RTM have a high-fibre content at between 65 and 70%; in conventional laminates, which are possibly less consistent and less strong, the main ingredient is usually resin.

Having reached the point where it is ready to go into full series production with the new system, Azimut will extend it to all models that are produced at its Avigliana plant near Turin over the next couple of years. At present it builds around 230 boats a year of up to 68ft there.

In the USA, where far larger numbers of smaller powerboats are sold compared with Europe, the technology of closed-mould GRP boatbuilding has been taken a step further by the world's largest independent boatbuilding group, Genmar. Its core business is outboard-powered open runabouts and recreational fast fishing boats of between 17 and 24ft. In 2000 it opened a new factory, now arguably the most advanced GRP boatbuilding in the world, at its site in Little Falls, Minnesota, where it builds its Glastron and Larson boats. There, it has manufactured more than 20,000 boats by the virtual engineering composites (VEC) process over the past four years.



Instead of conventional 'stringers' (transverse hull ribs), the new AZ 40 has this internal moulded liner to provide rigidity. It shows the geometrical moulding complexity that RTM is capable of handling. Such a moulding would be difficult to achieve by conventional hand-laid means.

Azimut

With VEC boats are formed in fully enclosed 'floating' moulds of two halves that are filled with warm water. The shapes of hull and deck mouldings are produced by polyurethane foam inserts which can be interchanged to produce model variants.

The moulding process begins with the inner surfaces of the moulds being gelcoated. On this glass reinforcement is laid. The two halves of the mould are then closed and catalysed resin is drawn in to the mould.

Then, after about 20 minutes the mould is opened and an almost completely cured moulding is lifted out for trimming, assembly and finishing.

By conventional hand lay-up methods it would take about eight hours to produce the same mouldings but with far greater mess and waste, considerable amounts of styrene gas in the work atmosphere and less certainty about the consistency of the end product. With VEC the variance between sets of boat mouldings across the first 1,000 boats produced by the system was barely 0.9kg. The laminators also benefit from hardly ever coming into direct contact with the boatbuilding materials and from barely detectable styrene levels in the workplace.

VEC works so well because of its digital control system. Sensors in the moulds enable remote computers to monitor continuously more than 500 variables affecting such parameters as the temperature of the water jacketing the mould, viscosity, flow rates, mass density, gel times and peak exotherms.

Unlike SCRIMP and its variants, which can be used in very small production runs of very large GRP mouldings, VEC requires far higher levels of capital investment and is more geared to mass production. Therefore, Genmar is looking to market the system outside the company and, indeed, outside the industry, where applications could include truck body panels, sound insulation capsules for generators and even jacuzzi baths.