The Future starts here

Just as Formula One car technology finds its way into the cars we drive on the road, the hull material of choice for race boats is being used to build Hanse cruisers. John Billings of SP Systems explains

Hi-tech racer *Patches*, a Transpac 52, built in SP Systems

This Hanse cruiser hull is built using race-technology epoxy

For many years production boats have been built out of the same materials: polyester resin with glass reinforcement. And for good reason – these materials are relatively cheap and on the face of it have ticked all the boxes. They have allowed series production in large volume and lowered the cost of boat ownership. It has become the accepted way of building a production boat to the extent that it is rarely discussed or challenged.

But as in everything, progress moves things on. Over time small changes and little tweaks add up to an idea, which leads to a more fundamental change – and we're now starting to see this occurring in production boatbuilding.

Nestling in among all the white polyester sailing boats at the 2004 Southampton International Boat Show was the new Hanse 461. The placard on the pushpit stated that this 14m (46ft) fast cruising yacht was built of epoxy resin and foam sandwich – a complete departure from the norm. So why has this primary European production boatbuilder decided to mould in epoxy?

Stronger and lighter

Developed for commercial use in the late 1940s, epoxy resin has been used in the aerospace industry among others because of its high strength. Popularised in the marine market by the Gougeon Bros (West) in the 1970s for use in modern wooden boat-building techniques, and introduced in the early 1980s into racing yacht construction by SP Systems in the UK, epoxies have evolved continuously through the years.

Epoxy resin is mechanically stronger than polyester or vinylester resins. This allows structures to be lighter in weight for a given stiffness, which is why virtually every 'one off' race boat produced these days is built using epoxy resin.

During the 1970s racing boats would have been built of either moulded wood or GRP foam sandwich. As the boats needed to be lighter to improve performance and become stiffer in order to resist ever increasing rigging loads, builders and designers started to experiment with more advanced materials such as carbon and aramid fibres. By the early 1980s, epoxy resin was allied to these new materials and became the resin of choice for race boat structures. It has remained so ever since, although the resins have continually improved and changed in their format over the years and the building processes have become far more advanced.

Performance

The need for a light, stiff hull that will give an extra hundredth of a knot is obviously not the Holy Grail for a cruising sailor, but an epoxy hull offers advantages nonetheless. If built in the conventional manner from polyester resin, for instance, the Hanse 461 would be approximately 1,000kg heavier. In a sailing boat lowering the weight/displacement is an effective way of achieving better performance in terms of speed through the water and responsiveness. But this saving in weight also gives you choices.

Seaworthiness

Some may say that lower displacement is not always a seaworthy option, but lowering the structural weight for the same strength can offer more options for a given displacement. For example, it could allow more ballast, thereby increasing stability without increasing the displacement. This, in turn could mean more sail area. It could allow more storage of water and fuel, or more equipment.

On a motor yacht a lower displacement could mean smaller engines, a greater range or generally more storage for equipment without loss of speed.

Hanse have used all these lower weight benefits to produce award-winning yachts that have been reported to have a good performance, are very responsive and have a fully fitted, well equipped interior.

epoxy by Green Marine

Farewell to osmosis

One characteristic of the epoxy resin family is that they are particularly resistant to the absorption of water, which over the years has been a problem with production boats.

Polyester resins are characteristically more water-absorbing than epoxies, and this higher absorption rate allows hydrolysis to take place – one of the fundamentals needed for osmotic action to get started.

Though it is generally accepted that osmosis is more of a problem of the past than with modern vinylester resins, it is interesting that some production builders who are using epoxy are offering long-term 'zero blister guarantees'.

In any case, most osmosis repair or prevention strategies involve using epoxy resins in the form of an epoxy coating. Those people wishing to leave their boats afloat all year round or are keeping them in warmer climates and leaving them afloat, should be considering an epoxy hull.

The nature and toughness of epoxies mean they also have improved resistance to micro-cracking and fatigue. In the practical use of a boat hull this means that if it comes into contact with a jetty or pile the epoxy laminate is tougher and can resist a bigger impact without fracture.

Boats are constantly being fatigued and where micro-cracking would normally develop on hulls built of more brittle materials, epoxy laminates are generally tougher and more robust.

Epoxy laminates have improved resistance to micro-cracking and fatigue and can resist a bigger impact without fracture

The cost

It has always been considered that epoxies are too expensive for high-volume use in production boats. As a general rule polyester resin is the cheapest boatbuilding material, followed by vinylester resin. Epoxies are three to four times more expensive than polyesters.

But the builders using epoxies point out that because epoxy resin is stronger you need a lot less of it, and because less material is going into the boat's structure labour costs will also be lower.

Despite this trade-off an epoxy boat will still be more expensive – but perhaps not by as much as you'd think. If you compare resin-for-resin costs, certainly, epoxy seems a great deal more expensive. But the resin cost is a small proportion of the overall cost of a complete yacht so percentages are not so much higher. On the Hanse models that offer a choice of polyester or epoxy construction, the epoxy version costs less than 5% more.

Design and build

The key to cost-effective series production in epoxy is firstly the structural design. The boat needs to be structurally engineered to make use of all the advantages of the extra stiffness and strength of epoxy resins. Skin thicknesses can be less, for a start, which means reduced quantities of resin. Because of its increased bond strength and reliable bond to foam cores they can be used over the hull with confidence. This in turn

allows great stiffness in the hull without having to resort to extensive internal framing, which again saves weight and build time. Foam cores also provide excellent thermal and sound insulation.

Secondly the build process has to be considered. There are various forms of epoxy products that can be used for construction from wet lay-up and elevated temperature cured pre-pregs, to resin film infusion systems. Hanse uses the wet lay process but, instead of using what is commonly known as the 'bucket and brush' method, the builders use a wet-out machine, sometimes called a resin impregnator. This machine takes the wetting of the glass reinforcement away from a labourer and presses the resin into the glass reinforcement mechanically. This ensures that just the right amount of resin is used to wet out the glass, and no more.

Quality control

The laminate's strength relies on the glass to resin ratio. In general the more fibre there is the stronger the laminate. Lower resin content can be achieved because epoxy bonds particularly well to the fibres so excess resin is not required.

After all the laminating is done it is consolidated by 'vacuum bagging' the laminate. This is where the builder covers the laminate with a plastic film sealed all around the mould and then the air is extracted from under the 'bag' via a vacuum pump. The pressure is very evenly applied and minimises the occurrence of voids in the laminate.

Once the hull is moulded and cured at ambient temperature it is then post-cured in a heat chamber to at least 50°C to achieve the full strength of the epoxy. Some builders also use resin mixing and pumping equipment to streamline the process further, enabling fast and accurate resin mixing. All of this provides a quality-controlled product.

Hanse produced its first epoxy hull for the 461 in 2003. Soon after that the flagship 531 was changed to epoxy, and at last year's Southampton show the company announced that its two new smaller boats – the 370 and 400 – could be built in epoxy as an option (these boats being designated the 370e and the 400e). Where this option is available approximately 50-60% of customers are choosing the epoxy version.

With boatbuilders wanting to provide better performance, more accommodation, more equipment and services in boats of all sizes, lowering structural weight by building hulls that are potentially more robust is seen by some as the way forward.

At the moment these builders are small in number and are dotted around the world. However it is good for the market place and the boat buyer to have a new, real alternative to consider, which has the potential for providing boats that could generally offer 'more'.

▲ The resin is applied to the glass cloth by the wet-out machine

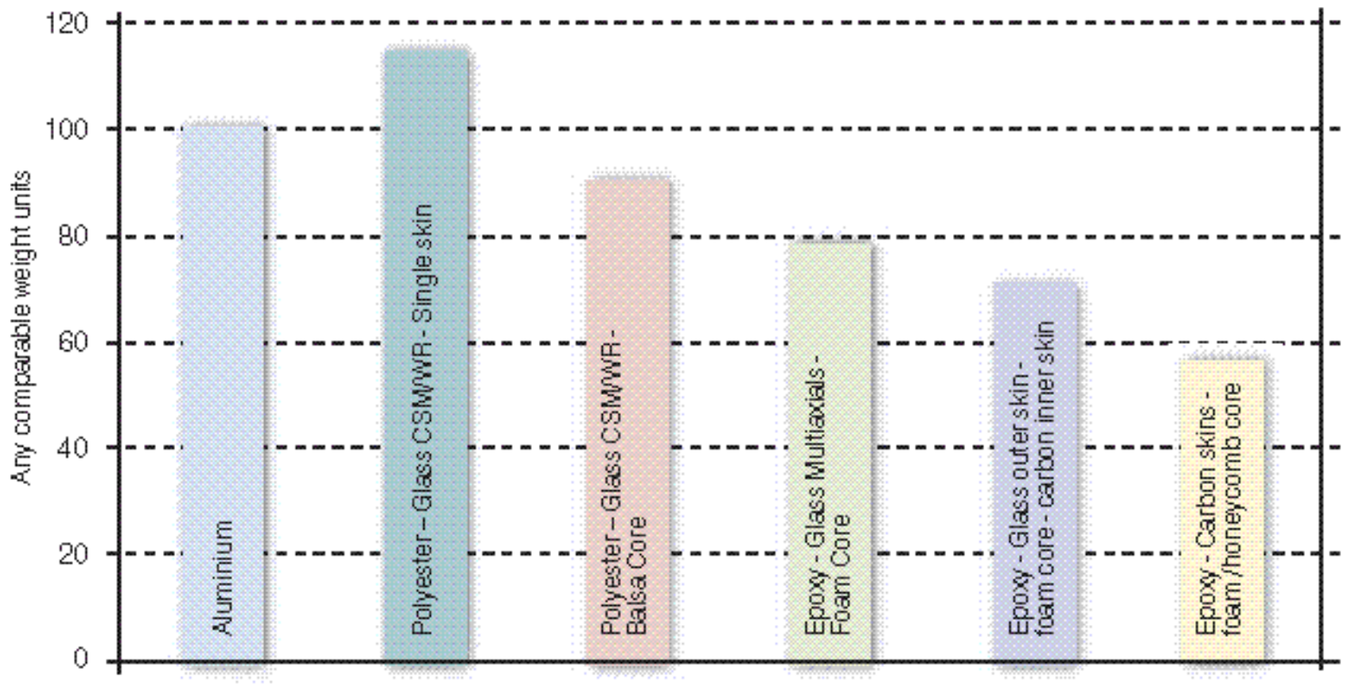
▲ The core material is added on top of the outer laminate layers of glass

▲ The inner wetted-out glass laminates are added over the core and then consolidated with a plastic vacuum bag

Comparison of structural weights

This graph, based on a paper presented at a 'lightweight materials conference' at the Royal Institute of Naval Architects, shows the relative weights for a given strength of the various building materials that are used today in boat construction.

The block on the far right is what current race boats (Volvo/Americas Cup boats) are built of and offers the lowest weight. As an example the Hanse boats use similar materials to the fourth block from the left. Conventional GRP boats are blocks two and three from the left so the weight saving can be seen as being approximately between 15% and 30% over conventional GRP depending whether the structure has either a solid laminate or a balsa or foam core.



CSM = Glass chopped strand mat
WR= Woven roving glass reinforcement
Multiaxials = Stitched glass fibre fabrics offering minimum crimp