Composite colossus

The £33 million Mirabella V superyacht is presenting unique challenges to its designers and material suppliers

By this time next year, the largest single masted yacht in the world – the Mirabella V – should be making its way to the Mediterranean from the port of Southampton in the UK.

The yacht is currently being constructed – at an estimated cost of £33 million – by UK warship builder Vosper Thornycroft (VT) for US businessman Joseph Vittoria.

Mr Vittoria, former chairman and CEO of Avis car rental, has made plans to build Mirabella V largely from fibre-reinforced plastic and the project is requiring everything from new sailcloth and developments in rigging to captive hydraulic winches to be custom designed and built.

Gargantuan

VT, new to the 'superyacht' building business, received an international shipbuilding grant before securing the Mirabella V contract, but company spokesman Phil Rood said that did not play a part in Mr Vittoria's decision to employ the company.

"The reason Joe Vittoria came to us to build the yacht is because of our expertise in composite shipbuilding," he said.

VT has been building composite minehunters for the Royal Navy since 1970, and the 60-metre class was very successful in the Gulf War.

What will be the world's largest sloop-rigged yacht, designed by Ron Holland for Concorde Yachts, boasts truly gargantuan proportions.

It is 75.2 metres in length with a beam of over 14 metres and a full load displacement of some 740 tonnes.

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The composite superyacht is already presenting unique challenges to the leading designers and engineers involved in its creation.

Performance is a key demand, with special emphasis on windward ability, and its brief has called for a capability of exceeding 20 knots under sail.

Shell

Seven layers of Kevlar and E-Glass form the outside skin of the Mirabella V. Both of fabric consistency, the yellow, woven Kevlar provides high strength to the structure, while the white E-Glass is the bulking element.

The resin used to glue these layers together turns the E-Glass to a dark green colour. A core of PVC foam, pink in colour, was then fitted. This was then covered by another five layers of Kevlar and E-Glass to complete the hull shell.

Carbon fibre patching has been added to provide local reinforcement for areas of high stress such as keel, mast and rigging loads, etc.

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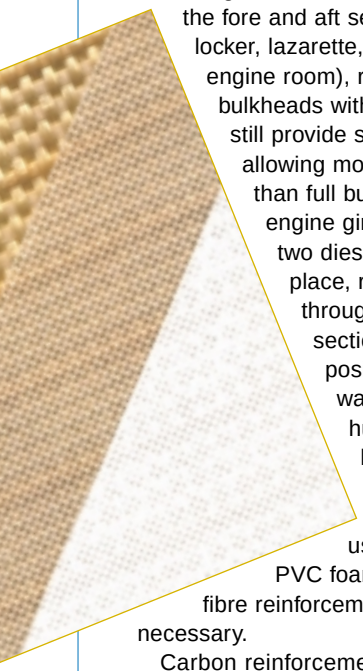

Fitted into the hull shell are bulkheads, positioned width-ways to add strength to the hull structure, and, in the fore and aft sections (sail locker, lazarette, or 'garage', plus engine room), ring frames – bulkheads with cut outs, which still provide strength while allowing more internal space than full bulkheads. The engine girders, to hold the two diesel engines in place, run length ways through the aft hull section. Hull stringers, positioned length ways throughout the hull, also reinforce hull strength. All of these structures have been made using E-Glass and PVC foam, with carbon fibre reinforcement where necessary.

Carbon reinforcements have also been added to the bulwarks for longitudinal bending strengths imposed by mast and rig loads.

Hull stiffeners

At only 18kg per m^3, Zotefoams' Plastazote LD18 polyolefin foam proved to be the ideal material from which to construct the formers in the boat's longitudinal 'ribs' or 'stringers' – the essential stiffeners for the hull. Weighing less than half the weight of its nearest competitor material, Plastazote was a natural choice.

Plastazote foam is manufactured by a nitrogen expansion process that enables very durable and lightweight foams to be produced without the use of potentially harmful and odourous chemical blowing agents.

The pre-shaped Plastazote foam lengths are attached to a laminated carbon pad (3-4 layers of unidirectional carbon) that has previously been bonded to the hull. They are 'filleted in' using a urethane acrylate, high impact structural filleting compound, and then over-laminated with between 5-6 layers of double bias E-glass, interleaved with up to 12 layers of 450gm unidirectional carbon.

Flexibility

The fact that the Plastazote has in-built flexibility simplifies its installation. It complies naturally with the complex curves of the hull, whereas if the formers had been made from a more rigid foam they would have had to be machined individually to fit.

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Plastazote foam has also been used extensively on the rear section ring frames, where again its compliant nature has removed the need for complex and costly machining. As the project progresses, it will also be used as the former material for the transverse deck beams.

Swiss-based Alcan Airex AG has also been involved in the project, supplying Herex C70 core material in different densities for the construction of the Mirabella V's hull.

Alcan Airex – formerly Alusuisse Airex – manufactures the Airex, Herex and Kapex brands of core materials for composite sandwich structures as well as Alucopan, Ecopan and Airsan sandwich panels for lightweight structures.

Sails

The Mirabella V has some 90 metres of mast, carrying almost 3,000 square metres of sail which is being supplied by Doyle SuperYacht, a division of Doyle Sailmakers, along with the specialist US weaver Warwick Mills.

OceanWeave is a new fabric designed by the two companies to increase longevity, and at the same time minimise the problem of mildew growth on advanced sailcoth.

The new sailcloth features a filmless design that combines new weaving technologies using Celanese Vectran fibre in a patented biaxial compound.

OceanWeave's properties allow it to retain minimal stretch in multiple directions under extreme loads in a fabric that is lightweight, yet strong enough for a superyacht.

Designed for radial-cut sails, OceanWeave is a true woven, with a warp-oriented core impregnated with an integral woven bias. The new sailcloth does not use any of the film found in mylar-based laminates, which are prone to delamination. Instead it features a UV and mildew-resistant finish that permeates the woven layers, creating a fully integrated system that has the durability of traditional wovens and the performance of laminates.

In film-based laminate systems, fibres are adhered to the surface of a sheet of Mylar or polyester film. In laminates designed for superyachts, there can be as many as nine layers in order to get the amount of yarn required for the high loads. The flexing of the sail creates shearing forces that, over time, will break down the bonds holding the layers together. When the adhesive or film breaks down, delamination occurs, and negative things begin to happen. These negatives include increased stretch, decreased strength, and the formation of pockets where internal mildew can form. Ultimately the material can fail.

Modulus and tenacity

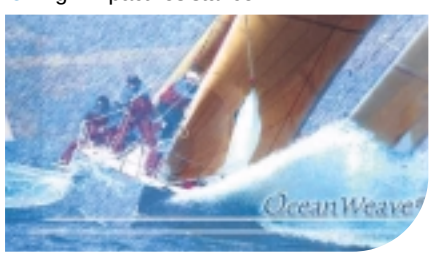
The best choice of fibre for sailcloth is one that has both high modulus and high tenacity while remaining flexible.

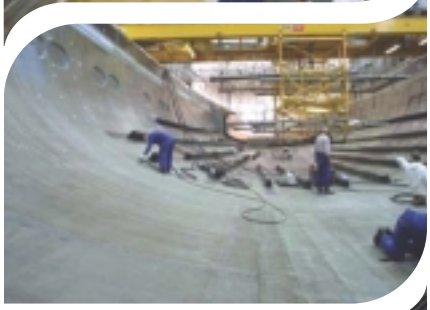
OceanWeave uses Vectran fibre, which provides all these properties.

Vectran is a high-performance thermoplastic multifilament yarn spun from Vectra liquid crystal polymer (LCP). Vectran is the only commercially available melt spun LCP fibre in the world, and exhibits exceptional strength and rigidity. Pound for pound Vectran fibre is five times stronger than steel and ten times stronger than aluminum.

The following properties characterise it:

- High strength and modulus
- Excellent creep resistance
- High abrasion resistance
- Excellent flex/fold characteristics
- Minimal moisture absorption
- Excellent chemical resistance
- Low coefficient of thermal expansion (CTE)
- High dielectric strength
- Outstanding cut resistance
- Excellent property retention at high/low temperatures
- Outstanding vibration damping characteristics
- High impact resistance





High modulus means it resists stretching or elongating when under a load. Tensile strength refers to how much load it will take before the fibre breaks. Flex life refers to resistance to damage when 'furling and flogging'. Vectran has a tensile strength that is three times that of high tenacity Dacron and a modulus that is 30 times greater, and it is extremely lightweight. Unlike DuPont's Kevlar, it can be bent and folded without becoming damaged, so it is an excellent choice for sailcloth.

The main goal of the OceanWeave project was to achieve high performance and longer life – therefore a woven system was required.

The result of more than 15 years of dedicated research and development by Celanese scientists and the establishment of over 130 US patents relating to liquid crystal polymer (LCP), Vectran fibre provides engineers with exciting material selection options and is available as Vectran HS, a high-strength reinforcement fibre and Vectran M, a high-performance matrix fibre.

The remarkable range of mechanical properties exhibited by Vectran fibres and their unique combination of properties permits them to be used for a variety of purposes. They are used in aerospace, ocean exploration and development, electronic support structures, the recreation and leisure industry, safety materials, industrial applications, ropes and cables, composites, and protective garments.

Abuse

"The abuse that wovens can take is legendary," says Charlie Howland of Warwick Mills. "The primary technical problem is developing a low-stretch, warp-oriented, bias-controlled weave without using film. Film is the weak link, so we made it filmless."

Traditional wovens have a super tight construction in order to make them stiffer on the bias. In OceanWeave, the crimp in the yarns has been held to levels below even the lowest stretch of fibre-reinforced nonwoven laminates.

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This result is achieved through the careful control of the fibre during the weaving process.

"By aligning the thread-line of the woven materials with the load directions, we've created a high-performance low stretch material with no compromise of durability," Mr Howland explained. "Unlike laminates, which use film for structure, a weaving pattern creates a structure that retains its strength as long as the fibre does."

When asked if he saw uses for OceanWeave other than for sails, Robbie Doyle commented: "For anything that has to be very strong with low stretch for its weight, this is an excellent choice. With its high tear resistance and ability to withstand the abuse of UV, flexing, and even chemical pollutants, plus last a long time, this fabric has a great deal to offer."

Warwick Mills is a leader in high-performance composite materials and is the world's largest manufacturer of Vectran wovens. The company created the Vectran crash bags for the successful NASA Mars Lander and also created flexible composite Vectran fabrics for CargoLifter, a blimp designed to be the length of four football fields and capable of lifting 160 tons. Warwick is a dedicated user of Dornier high performance weaving looms.

Mirabella V will be available for charter from Winter 2003/4 and among interested parties are the actor Tom Hanks.