

Composite materials offer commercial shipbuilders an enticing mix of benefits

Tom James, sales business development manager, Hexcel, examines the key issues with increased composite adoption and its current state in shipping

Composites have been used in recreational boats and yachts since the 1950s with both materials and production processes developing steadily since. They can massively reduce vessel weight, though these gains and the associated reduction in fuel costs and emissions are not the only advantage of composites. Increased cargo capacity, extended maintenance cycles, smoother hull surfaces, and in-built vessel health monitoring are all identifiable benefits versus metallic constructions.

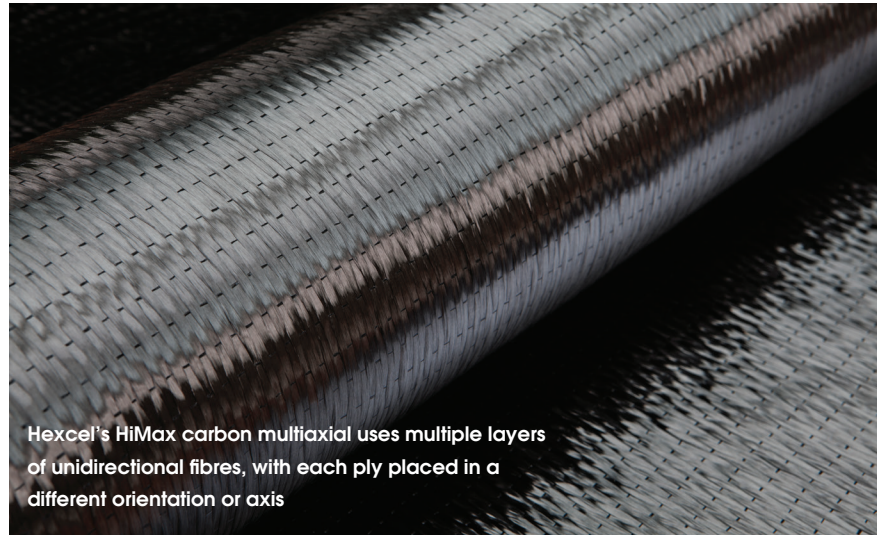
While larger military craft have sought to exploit the benefits of these lightweight, non-magnetic and corrosion-resistant materials, composites are not yet commonly used in large-scale shipbuilding.

Steel construction for commercial vessels is not just the industry standard, it was effectively the only option allowed by the IMO's SOLAS regulations until 2002. More recent amendments relating to composites offer guidelines for their applications and some concessions to the previous mandate on non-combustible materials, though regulatory hurdles remain.

State-of-the-art materials

Hexcel has supplied advanced composite materials to the marine industry for almost 50 years, manufacturing a comprehensive range of DNV GL-certified products for high-performance craft as well as commercial marine vessels. When we use the term composites, we are typically describing a material in which reinforcing fibres (carbon, glass, aramid or, plant-based) are used to strengthen a resin matrix, combined to produce a stronger yet light-weight composite material with improved properties.

Composites can be used to form monolithic laminates simply composed of resins and fibres, or complex sandwich structures where a foam or honeycomb core separates two thinner laminate skins, providing a higher stiffness to weight ratio than a monolithic layer.



Hexcel's HiMax carbon multiaxial uses multiple layers of unidirectional fibres, with each ply placed in a different orientation or axis

These materials can be supplied and used in several different formats and while they apply to large percentages of ship hull, deck and superstructure components, as well as ancillary parts such as communication masts, hatches, and even propulsion components, the optimum material solution depends heavily on the application and its unique requirements.

In terms of composite material formats, large composite shipbuilding demonstrator projects have often used dry fabric reinforcements, typically in the form of multi-layered textile products, where machine-laid fibres are orientated at different angles then stitched together to stabilise the fabric. These fabrics can then be combined with liquid resins (typically epoxy or vinylester) via moulding techniques such as resin infusion, where vacuum pumps are used to draw resins through fabric plies pre-positioned in a mold tool.

Prepreg composites use similar fibres, however, the catalysed epoxy resin systems are combined with the reinforcements on a production line before the materials are used, hence the name prepreg or pre-impregnated. After impregnation, the prepregs are chilled and stored.

When required in production, the prepreg materials are defrosted and cut to size before being laid up in the mould, consolidated under vacuum, and cured in an oven or autoclave. Prepregs enable the highest structural performance for the lightest weight and are heavily used in aerospace, wind turbine blades, and performance yachts and boats.

At Hexcel, we usually advise that composite material, format, and process selection is decided on a case-by-case basis, and it is at this stage that our skilled composite engineers and material development teams add the most value, balancing cost and performance and guiding vessel owners and builders toward the most appropriate solution.

It is without a doubt that current state-of-the-art materials and processing technology are ready for composite integration into shipbuilding at the component level. Applications such as tween decks, hatches, wing sails, rudder flaps, and propellers have all been developed, approved for use and, in some cases, deployed onboard. The full composite >100m hull is still a development for the future, but the building blocks and technology to deliver it already exist today.

Large composite structures afloat today

In 2016, Croatian shipbuilder Uljanic completed the *Siem Cicero*, a 200m car carrier with a capacity of 7,000 vehicles. The vessel has 13 vehicle decks, with the topmost three decks featuring a fibreglass and foam sandwich construction that reduces deck mass by 25% compared to steel. In addition to stability benefits, a fuel savings of 4% has also been reported.

Japanese propeller specialist Nakashima has also developed a range of carbon fibre bladed propellers and thrusters. First deployed on the 64m chemical tanker *Taiku Maru*, Nakashima has since also equipped ferries and fishing boats with similar propellers.

Rotary and fixed sails for propulsion assistance are another interesting composite application onboard. Norsepower rotary sails have been fitted to several vessels since 2014, with the largest units to date being a pair of 35m tilting sails fitted to the 155m ro-ro *SC Connector*. Anemoi, Becker Marine Systems, and Wallenius with their *Oceanbird* sail-powered 7,000-vehicle transatlantic range transporter concept are all expanding rapidly in this space. Composites are well suited to such sails where lightweight (and strong) structures are required for stability considerations.

Industrialising composites production

With material solutions and production processes available, one might think that shipowners' desire to capitalise on the benefits of composites would be already driving the increased adoption of lightweight composites into new builds. As well as the regulatory complexities regarding fire performance mentioned earlier, there are some challenges associated with large merchant vessels that have not had the same impact in smaller vessels and other large-scale composite applications.

One such challenge is the adjustment required by yards to introduce composites at scale. Steel production environments are not always suitable for composite processing where controlled conditions are needed to ensure production consistency. Additional skills related to composite design, engineering, and manufacture also need to be fed into the mix.



Announced last year, the *Oceanbird* vessel under development by Wallenius Marine to build a 200m wind-powered ro-ro, with wingsails made from composites and steel

Fortunately, other industries have successfully industrialised composite production for very large structures. Composites are completely established in both aerospace (previously dominated by metallic constructions) and wind energy, with raw material supply chains, process automation, inspection, and MRO parameters all clearly defined. Shipbuilders will certainly adapt to new techniques, and with the current disruptions to the commercial aerospace sector, major composite industry players' opportunities may be well placed to support rapid growth in new high-volume composite applications.

Collaborative research projects such as FIBRESHIP and RAMSSES have been hugely important in generating industry focus on composite applications as well as providing the shipbuilders with design methodologies, validated production techniques, and a potential adoption pathway. Both of these multinational EU projects have defined specific demonstration cases that use composite construction throughout the vessel. Of particular interest for large vessels are the three composite vessel structural concepts detailed by FIBRESHIP. By presenting composite options for an 85m fishery research vessel, a 200m ro-pax, and a 250m containership, the project has illustrated how a staged approach could bring composites to full scale in commercial shipping.

Designing for composites with the full life cycle in mind

The FIBRESHIP and RAMSSES projects also included significant work on life cycle analysis (LCA) tools specific to composite vessels. Experience from other composite sectors provides valuable data, such as analysis including end-of-life considerations. Thermoset composites, such as the epoxy and vinylester structures previously described, are traditionally challenging to recycle. With millions of tonnes of composites in use globally in aerospace and wind, and with the first generations of composite aircraft and wind turbines approaching their end-of-life, the requirement for recycling options is paramount.

Fortunately, the composite recycling industry is accelerating in line with this need with several converters now able to recover glass and carbon fibres from manufacturing and end-of-life waste with remarkably close (90+%) properties to original virgin fibres. These recovered materials are not yet available in the same long length continuous fibres as in their original composite application but can still be used, either in non-woven mats or in new short fibre molding applications such as sporting goods.

Carbon Conversions Inc., Hexcel's strategic partner in carbon fibre composite recycling, has successfully recycled some of the largest marine composite structures processed so far when they worked with

Team Oracle to reclaim carbon fibres from the hulls and masts of two of the team's America's Cup yachts.

Dispelling the myths about composites

Often perceived as high-performance lightweight materials from Formula 1 racing or aerospace, we do come across misconceptions concerning the suitability of composites for merchant shipping.

One common misperception is that composites can be fragile and fail suddenly in use. While it is true that modeling of composite structures is often more complex than for a metallic part, well-proven tools and simulations do exist from aerospace and other industries. Validation and test programs, coupled with tightly controlled composite material and component production, can provide extremely accurate predictions of failure mechanisms and operating limits.

Composites can also nearly always be repaired, even after suffering severe damage. Both the aerospace and wind energy markets have developed well-defined inspection and repair protocols to maintain composite structures throughout their life. Specific

maintenance and repair strategies may even reduce the workload required to keep marine structures operational in an environment that is hostile to steel.

As with all complex engineered structures, it is important to look deeper than raw material cost when evaluating the worth of new construction technology. Composite materials can sometimes cost more than steel, but a full life cycle analysis considering fuel savings and payload gains makes a strong positive case for composites in the vessels of the future.

Navigating a smooth path through the regulatory hurdles

Regulatory consensus and an approval pathway are key requirements to the wider adoption of composites, with FIBRESHIP and RAMSSES focusing heavily on this issue. The industry recognises the massive potential of composites and, with targets such as the IMO's desire to cut CO₂ emissions by 40% by 2030, the drivers to implement are present too. While these issues have not been completely resolved, considerable momentum has been created recently.

RAMSSES utilised a shorter-term fast track approval concept in its work with

Bureau Veritas, based on the definition of an approved material solutions database, fire risk cases, and a package of analysis and simulation tools. The FIBRESHIP approach was comparably longer term in that the project sought to develop an entirely new rule set covering fire performance, structural requirements and production alongside partners RINA, BV, and Lloyd's Register. Challenges remain, but by considering application areas across the vessel and overall fire systems present, a global safety equivalent with steel construction appears eminently achievable.

Hexcel expects to see a considerable increase in composites deployment aboard large vessels in the next decade.

With the correct design, engineering, materials, and production parameters in place, advanced composite materials such as those manufactured by Hexcel create lighter, cleaner, and more efficient ships. At Hexcel, we believe that it is a case of when – rather than if – the step-by-step adoption of full composite structures in vessels >100m in length goes ahead. [NA](#)

For more information, visit: www.hexcel.com

Action to decarbonise the shipping industry needs to happen now

Fuel agnostic clean technologies will play a vital role in getting to net zero emissions, argues Noah Silberschmidt, CEO, Silverstream Technologies

The decarbonisation debate is heating up: for progressive ship owners and operators, meeting the IMO's target of at least a 50% reduction in total GHG emissions by 2050, compared to 2008 levels, while maintaining economic viability in a competitive market, is rightly at the top of their agendas.

Much of the debate in shipping has, to-date, focused on the importance of establishing a clear range of alternative, low- and zero-carbon fuels to meet IMO targets. It is right that much of the attention is being placed here, because of the significant carbon reduction

potential of alternative fuels. However, to solely focus on these future solutions ignores measures for efficiency that are currently on the market and places emphasis on fuels that need considerable development, when action to decarbonise needs to happen now. This approach fails to consider the symbiotic relationship between future fuels and fuel efficiency.

In fact, industry leaders have already started to champion a change of mindset, with Maritime UK chair Sarah Kenny, stating in a recent webinar that "the conversation around tech should be more than just clean fuels, and using tech to get to net zero

emissions could help ships' productivity and efficiency as well as the environment."

To illustrate the scale of the fuels challenge, UCL estimates that US\$1.4 trillion of investment in R&D and infrastructure is needed to successfully commercialise a range of future fuels for shipping.

While no one can argue against the importance of future fuels in the decarbonisation of the shipping industry, the sector must also retain focus on efficiencies that can be delivered now, regardless of fuel or operational patterns.

Proven, available, fuel agnostic clean technologies, which can be retrofitted