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Preface

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1 Introduction

The marine environment is challenging for traditional engineering materials due to the corrosion of metals or the bio-deterioration of natural materials. Consequently, the use of fibre-reinforced polymer matrix composites in the seas and oceans has grown in diversity of components, the size of structures and production numbers. Composites consistently demonstrate good performance, with many technologies and developments only realised because of their use. This chapter introduces the book, signposts to the topics covered, and briefly considers some of the recent innovations not otherwise included in the text.

The incorporation of fibres (*e.g.* aramid, carbon, glass) into a polymeric matrix produces a composite material. With well-selected constituents, these fibre-reinforced plastics (FRP) can provide excellent performance in the marine environment while being resistant to the biological and chemical attack that can compromise other materials. For readers new to the area of composites, we recommend the following starter texts [1-4].

The use of composites in marine structures has been the subject of a number of earlier books [5-8]. This book seeks to provide a summary of some recent developments as a complement to Marine Applications of Advanced Fibre-Reinforced Composites (MAAFRC) [9], but is inevitably limited in its coverage as a comprehensive treatment would require a complete encyclopædia with the consequent costs. Over the past five years, there have been a number of review papers pertinent to the topic of this book, which complement the chapters of this text. Of especial importance are those addressing impact (Sutherland, 2018), durability (Davies, 2014), marine fouling (Myan et al, 2013. Yang et al, 2014) and the impact of plastics on the marine environment (Wright et al, 2013. Gall and Thompson, 2015).

For the purpose of this book, we define composites as fibre-reinforced polymer (FRP) systems which use continuous fibre reinforcements. Further, we define four categories of composite:

- monolithic composite material: all layers aligned parallel,
- laminated composite structure: orientation changes between layers,
- hybrid structures: more than one type of fibre (*e.g.* carbon/glass),
- sandwich structures: composite skins and lightweight core.

One additional chapter addresses a different form of composites as an essential foundation for effective implementation of offshore renewable energy generation.

2 What is in the book ...

This book comprises two distinct sections and many of the topics build on those covered within MAAFRC. In Part one, the focus is on the materials and the processes associated with them. Chapter 1 describes materials selection for marine composites, which leads to Chapter 2, detailing thermoplastic matrices for composites. The ability of composites to withstand hostile environmental conditions are covered in Chapters 3 to 5. Chapter 6 considers using composites effectively for marine structures, both in terms of acquisition cost and savings due to weight reduction. Whilst manufacturing sandwich structures was described in Chapter 3 of MAAFRC, this book contains a review of core materials for sandwich structures in Chapter 7. Composite manufacturing methods were described in Chapter 2 of MAAFRC and this is developed further in Chapter 8, dealing in particular with the techniques required to infuse large scale structures. Novel materials are discussed, be they smart materials (Chapter 9) or an innovative variation on existing, well known materials (Chapter 10).

Part two focuses on specific applications of composites. The marine renewables sector is dealt with specifically in Chapters 11 (foundations for offshore wind turbines) and Chapter 12 (marine renewable devices), complementing Chapter 9 of MAAFRC.. Chapter 13 considers the application and modelling of composite propellers, whilst chapter 14 describes composite marine hoses. Chapter 15 describes large yacht masts, as a complement to MAAFRC Chapter 12 on the use of composites within the yacht rigging market. Finally, the use of composite materials for mooring applications is covered in Chapter 16.

3 What is not in the book ...

The RAMSSES (Realisation and Demonstration of Advanced Material Solutions for Sustainable and Efficient Ships: www.ramsses-project.eu) project aims to produce a 70 m long glass fibre reinforced vinyl ester composite hull, then test the structure under real-life conditions on the high seas.

The new EU Horizon 2020 FIBRESHIP (www.fibreship.eu) research project aims to revolutionise shipbuilding by replacing steel with composite materials for the construction of light commercial vessels, passenger and leisure transport and oceanographic vessels over 50 metres long.

A partnership between the Oak Ridge National Laboratory (ORNL) Manufacturing Demonstration Facility (MDF) and the Navy's Disruptive Technology Lab has produced the first 3D-printed submarine hull.

Innovative and high-performance craft

A variety of innovative new vessels have emerged since the previous book, including:

- the 42 m carbon fibre composite hybrid-electric sightseeing vessel "Vision of the Fjords", designed by Brødrene Aa,
- the two near-identical 53m Latitude trimaran super-yachts "Galaxy" and "Galaxy of Happiness", and
- the 50 knot CFRP Princess Yachts/Ben Ainslie Racing (PY/BAR) R35 prototype super-boat with active foiling that promises to be one of the 'most exciting and revolutionary products' the company has ever produced.

In the context of high-performance:

- Multiplast used North Thin Ply Technology prepregs, (as described in Chapter 14 of MAAFRC [9]), lightweight glue films and Automated Tape Laying to build the Groupama Team France yachts, allowing optimised lay-ups and fibre orientations in the aft wing flaps and removing critical weight high up in the yacht's wing rig.
- In June 2017, the New Zealand NZ America's Cup boat flew on foils for 100% of race.
- In July 2017, the Transpac monohull course record was smashed by "Comanche" with an elapsed time of 5 days, 1 hour, 55 minutes and 26 seconds: over half a day off the previous record.
- In December 2017, François Gabart in the 30m trimaran MACIF finished his solo circumnavigation of the globe in a record time of 42 days, 16 hours, 40 minutes and 35 seconds.

Novel applications

Further novel applications have also been published. Acciona (Spain) and Huntsman Advanced Materials (USA) have created an all-composite (CFRP, GFRP and hybrids) lighthouse, completed in less than 20 days with only six hours for installation using a lightweight crane. Yu et al (2017] have reviewed the design and analysis of reinforced thermoplastic pipes for offshore applications. Weller et al (2015) have recently reviewed the use of synthetic mooring ropes for marine renewable energy applications. The US Naval Station Mayport took delivery of the first set of fibre-reinforced polymer (FRP) composite "camels" (floating structures designed to separate a large vessel and the mooring wharf) for berthing nuclear powered aircraft carriers

Marine renewable energy devices

An important potential market for composites is marine renewable energy where potential devices have been reviewed by Chen et al (2013) and Chen and Lam (2015). Ocean Renewable Power has deployed a second next-generation, commercial-scale ocean tidal energy power turbine generator unit (TGU) in the Bay of Fundy on the Canada-US border with helical composite foils and a hybrid carbon/glass fibre-reinforced composite direct driveshaft. Three composite rotor blades, manufactured by AC Marine and Composites, have been installed on the 1.5 MW AR1500 tidal turbine located in the Pentland Firth between the Orkney Islands and Caithness.

End-of-life

The market for marine leisure has expanded rapidly throughout the period since composites became the material of choice for such products. A recent estimate suggested there are about one million boats in France and 600,000 in the United Kingdom which will reach their end-of-life in the next decades. APER (www.aper.asso.fr) reported that only 20% of end-of-life craft are currently partly or totally recycled, with the other 80% buried or incinerated. ECONAV (www.econav.co) suggested that the construction stage of recreational boat represents only 20% of their carbon footprint. There is scope for the development of a circular economy to enhance the ecological standing of end-of-life boats (ELB) with potential for complementary disposal routes for other large composite structures (e.g. wind turbine blades).

A European Commission paper on nautical tourism [22], identifies that there is only a limited scale recycling and dismantling for ELB, reflecting the unfavourable economics of the business (high costs and few revenue opportunities). In turn, this discourages operators from providing facilities and boat owners from seeking appropriate means of disposal. A lack of boat owner registration systems makes effective monitoring, control and enforcement of ELB rules difficult. All stakeholders must become engaged to consider systems to collect and deconstruct these vessels and equipment, to process the waste streams, and to develop markets for the recycled materials.

A European Commission report [23] has recommended that any ship over 500 gross tonnage (gt) calling at an EU port would need to pay for a ship recycling licence. The ultimate ship-owner would be entitled to a proportion of the accrued Ship Recycling Fund if the vessel were recycled at an EU approved facility, but would forfeit the rights to this payment if the ship were scrapped at a non-approved facility. However, this is a consideration for the long term future given the current limited number of vessels (e.g. Royal Navy Hunt class Mine Counter Measures Vessels: 725 tons, Tripartite minehunters: 605 tons, Swedish Navy Visby stealth corvette: 600 tons) above the specified displacement, although composite components of larger vessels (e.g. superstructures on cruise liners and the 900 ton composite deckhouse of the US Navy DDG 1000 destroyer) would be implicated.

The technologies for ELB were reviewed in MAAFRC Chapter 8.

Enjoy the book!

Jasper, John and Richard.

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