Manufacturing of Tool-less Composite Hulls and Composite Superstructures

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1. Introduction

GFRP boats started to become available in the 1950's after the recent invention of polyester resin and glass fibers. From that moment on, there was a continuous growing trend of using composites in the construction of composites in boats, yachts and ships. The use of lightweight and other advanced material in the maritime sector is however lagging behind the potential. The transition from metal to composite goes slowly for three reasons:

a) The price of the current method of building composite ships, especially in case of one-offs is not competitive. Tooling costs are a major factor in this.
b) The lead-time of building composite ships is not competitive, especially in case of one-offs. The tooling development and the current building methods are a major factor in this.
c) SOLAS requirements are currently still stimulating the ship building industry to stick to metals.

Sailing yachts are the most successful segment in the marine market regarding the adoption of composites. For sailing super yachts, the development to adopt composite materials went extremely quickly. Carbon is the preferred material for sailing yachts since it provides a significant performance increase. The Wally Nariida ketch was in 1994 the first composite yacht at a length over 30 meter. In 2009, 60% of the sailing super yachts between 30 and 40 meter were already made from composites [1]. The largest composite sailing vessels made today are the Hetairos III (ketch of 66.7m), the Pink Gin VI (sloop of 53.9m) and the Doña Francisca (schooner of 52.5m). The transition from metal to composite for sailing super yachts has not evolved much further since 2009 however. Today (March 2019), all sailing superyachts of 45+ meter that are in build (still) have metal hulls [2].

Also the motor yacht market has adopted composites early. The Azimut Failaka was in 1983 the first composite motor yacht over 30 meters. Composites motor yachts became available in the mainstream since the 1990's. For motor yachts, fibreglass is the primary used material since a performance increase can more economically be established by using more powerful propulsion. Lightweight becomes more relevant high up at the superstructure since the weight saving improves the stability of the ship. However, similar as with the sailing yachts, all motor yachts of 45+ meter that are in build (still) have metal hulls [2].

The reason why composites are not commonly used in large watercraft has to do with the building method and SOLAS restrictions. Multiple initiatives such as RAMSSES and FIBRESHIP are working on solving these SOLAS restrictions and are briefly discussed in this paper. The primary objective of this paper is to present a modular building method that will disrupt the boat and yacht-building industry and will make it interesting to use composites for large (read 40+ meter) watercraft.

In this paper, we will provide/explain:

- The benefits of using composites over metals in the marine industry and the explanation for these benefits
- The reasons why the widespread use of composites is limited
- How reconfigurable tooling enable modular building methods and the benefits this brings to boost the widespread use of composites. Additionally, an overview will be given where we are today.
- An outlook to the future: the markets to launch this innovation and the markets that will follow next.

2. The benefits of composites

The primary benefits of using composites instead of aluminium is the significant lower structural weight compared to metal alternatives. This is not only related to the difference in specific mechanical properties but primarily by the fact that the metal alternative carries a lot of dead weight. Figure 1 visualizes that the metallic hull, which is constructed from single curved welded sheets, requires a lot of fairing compound in order to have a smooth and seamless hull. The composite hull on the other hand is released from the mould with the desired smooth and doubly curved shape and does not require the amount of filling that an aluminium hull needs. Furthermore, a metallic requires insulation while a composite sandwich hull has the insulation already integrated and forms part of the structure.

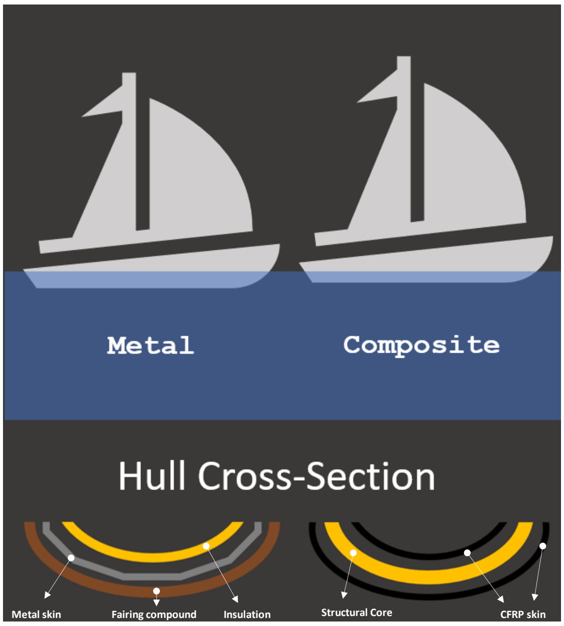

Figure 1: Illustration of the difference in hull construction between metal and composite hulls

As a result, the structural weight of an optimized carbon sailing yacht is approximately 45% lighter compared to an optimized aluminium equivalent [3]. This is estimated to result in an overall weight reduction of approximately 25% assuming that all other weight (systems & interior) are made to the same specifications. The increased freedom of shape and the weight reduction of 25% reduces the drag approximately with 25% assuming that the reduced weight is taken into consideration with the hull design and sail-architecture. A weight reduction of 25% results in a velocity increase of sqrt(1/0.75) = 15% since resistance (or drag) is proportional to the velocity squared.

These numbers represent rough order of magnitudes since there are many factors that determine the (maximum/cruising) speed of a sailing yacht. Nevertheless, when comparing a large population of aluminium sailing yachts and carbon sailing yachts built in the last 20 years, the estimates of 25% (weight reduction) vs 15% (velocity increase) match up.

Similarly, when considering motorized watercraft, a drag reduction of 25% reduces the energy (or fuel) consumption with 25% (for the same speed).

Besides the structural benefits which implies substantial fuel savings (aligned with Directive 2012/33/EU), composites are also:

- immune to corrosion which results in a better life cycle performance and reduced maintenance costs [4]
- Can offer additional advantages like an increase in ship stability and a reduction of underwater noise (Directive 2008/56/EU).

3. The limitations of composites (today!)

The state-of-the-art method to fabricate large load carrying composite shell structures (i.e. ship hulls) is by making them in a large mould as an integrated laminated structure. As mentioned in the previous section, composites are excellent for their structural efficiency and the integrated laminated structure takes full benefit of this property.

This in a large mould laminated shell also has 2 major restrictions:

1) A mould, as shown in Figure 2, is needed in order to create the composite product in the required shape. In case of small series production and especially one-offs, which is typical in yacht-building, the tooling creates many restrictions:
    a. **A long lead-time**. Tooling design and development and the fact that a hull needs to be manufactured before outfitting starts typically increases the lead-time for one-off boats or yachts of 30+meter typically with 1 year. These lead-times are show-stoppers for many private owners and are commercially not sensible for business-owners.
    b. **No flexibility**. Changes can no longer be made as soon as the mould is fabricated while the market is dynamic and the boat/yacht that the owner wants can change in the period that his product is manufactured.
    c. **High tooling costs:** The tooling cost are a significant part of the total cost of the product while it is not adding value to the product itself.
    d. **Storage.** Storage of the mould takes up useful/costly space. Furthermore, the mould needs to be protected in order to ensure longevity.
    e. **Handling.** Large structure, i.e. large composite ships become difficult to demould.
    f. **Waste.** The tooling weight is a lot more (typically a factor 2-5) compared to the structural weight of the boat. Many superyachts are one-offs and the amount of material that is wasted is irresponsible looking at the emphasis there is on the environment nowadays.
    g. **High Risk.** Fabricating large composite structures, especially one-offs are risky processes when this needs to be performed first time right in one shot. Multiple mistakes have happened in the past that have (almost) bankrupted shipyards since the material cost on composite materials for a carbon 50+m sailing superyacht exceeds 5 million Euro.

2) A second major restriction is that high quality boats/yachts require curing at elevated temperatures, typically at 80+ degrees Celsius. This means that tools are to be adapted to a rise of temperature and gigantic ovens are required for large high performance yachts, and

dedicated tools. These ovens are in average used for 1 to 4 times a years and are rarely used at full capacity which results in very high capital expenditures (CAPEX)

Figure 2: Demoulding the hull of the 34M superyacht (MM341) at Baltic. Courtesy Malcolm Mckeon Yacht Design

The best way to visualize these restrictions is by taking a real example; in this case the largest all carbon fiber sloop made until now: the *Pink Gin VI* by Baltic (Figure 3).

The *Pink Gin VI* has a length of 53m and took 4 years to build. The oven in which is cured was large enough to fit the hull of a *Boeing 787*.

The largest metal sailing yacht made up until today is the *Sailing Yacht A* (Figure 4). It is almost 3 times bigger compared to the *Pink Gin* and despite its size, it took ‘only’ 4 years to build. The reason why we can go larger with metals has to do with the manufacturing process.

Figure 3: Pink Gin VI from Baltic

Figure 4: Sailing Yacht A

Metal ships and yachts are build using the panel-block-assembly method as shown in Figure 5. In this method, plates and frames are prepared and given the required shape, they are welded according to the structural drawings prepared by the design department of the shipyard. The hull is divided longitudinally into blocks and each block is again divided into assemblies and sub-assemblies. This modular building method is a lot more flexible and allows to keep the hull fabrication and outfit installation processes in parallel. This reduces the building time and is called advanced outfitting.

Having a modular building method for composite yachts/ships would likewise reduce the lead-time greatly. The process to enable this is explained in the next section.

Figure 5: Illustration of the panel-block-assembly method

4. Manufacturing of Tool-less Composite Hulls and Composite Superstructures

All the restrictions that have been mentioned in section 3 can be eliminated when large ships/boats would be manufactured as COMposite Panel ASsemblies (COMPAS).

This idea is not new and this method has already been used and a lot of R&D initiatives have taken place to perform modular building methods on large composite structures. Existing examples and an overview of R&D activities is provided below:

4.1. Existing Composite Panel Assemblies

1) The Pink Gin VI as shown in Figure 3 was build as a composite panel assembly for pragmatic reasons as shown in Figure 6.

   In order to maintain easy access to the interior during the build of the primary structure, the topsides were constructed separately and joined to the hull bottom and bulkheads once the majority of the structure had been completed [5]. This modular building method is now commonly used at Baltic Yachts and has been implemented multiple times for large yachts together with the engineering support from Gurit.

Figure 6: Hull construction of the Pink Gin VI [5]

2) The Visby Class Corvette (Figure 7) is built in a modular way in the same way as metal yachts are built. This navy vessel is made from flat composite panels in order to maximise its stealth properties. The hull consists of four main sections, fore, mid, aft and superstructure (Figure 8).

Figure 7: The Visby Class Corvette (Wikipedia)

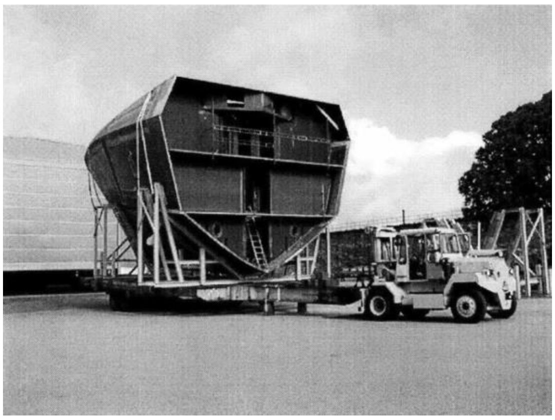

Figure 8: Bow section of the Visby-class corvette [6]

3) Privinvest have designed and built what is believed to be the largest modular composite superstructure ever made for the M/Y Yas 141m yacht.

Figure 9: The M/Y Yas [7]

The examples above are a selection of existing composite panel assemblies and demonstrate the feasibility of the composite panel assembly from an assembly and joining perspective. The Visby Class is a special case since most watercraft require curved geometries. Looking at the panel assembly of the Pink Gin VI, the issue of using conventional tooling and large ovens as mentioned in section 3 is not removed however.

4.2. R&D Activities concerning modular building methods

There is an increasing interest in using composites in the marine industry but there are still a few hurdles that need to be taken and it is for this reason that many research projects have been initiated in the previous 2 decades. The primary initiatives that have been undertaken for which a modular building approach will benefit are: FLIGHT, ADHESION, COMPAS, BONDSHIP, DE-LIGHT Transport, THROUGHLIFE, RAMSSES, FIBRESHIP and QUALIFY.

A description of all of these activities are provided at the back of this paper. All initiatives have contributed to stimulate the use of composites by investigating new innovative composite materials, defining new design and production guidelines and procedures, generate efficient production and inspection methodologies, and develop new validated software analysis tools. The technologies resulting from these initiatives will tackle the barriers of the SOLAS requirements and advance the transition from metallic to composite (panel assembled) hulls and superstructures.

The idea at Curve Works to manufacture tool-less composite hulls and superstructures originates from the involvement of F. Geuskens (*owner of Curve Works*) in the FLIGHT project in 2009 in which a more efficient production process was investigated using the panel/block assembly method. F. Geuskens concluded that there is not a good business case for this production process without the availability of smart or adaptive tooling.

Looking at the developments regarding the above mentioned initiatives, it is concluded that joining techniques and processes are investigated, optimised and professionalised but the manufacturing of panels on adaptive tooling is still not considered. As mentioned in section 3, this is still a major unresolved barrier for the advancement of composites in the ship-building industry.

Curve Works is founded to resolve this barrier and is the first company in the world that is a specialist in smart and responsible manufacturing of curved panels without the waste of tooling.

4.3. Hulls and Superstructures made as Composite Panel Assemblies using a reconfigurable mould

The foundation of Curve Works was based on the lack of a reconfigurable mould technology for the manufacturing of curved panels during the project FLIGHT. Reconfigurable tooling technologies are extremely old but the development of an industrial reconfigurable mould technology for the manufacturing of smooth doubly curved panels started with the foundation of the Danish Company *Adapa Aps* in 2010.

In December 2016, *Adapa* installed the most advanced mould to date at *Curve Works (*Figure 10*)*. The adaptive mould is used to create double curved shapes from 3D drawings with a high surface quality, fast and efficiently. The digitally adjustable surface is a pin-based-mechanism for generating 3D surfaces from a computer aided design (CAD) input (Figure 11). A rubber interpolation layer on top of the pins allow a smooth free-formed surface. The adaptive mould at *Curve Works* has a netto mould size of 3.6x1.56 m and can generate shapes up to a minimum radius of curvature of 400mm. The maximum travel of the actuators is 1m. Curve Works is the first company in the world to use this technology for the manufacturing of curved thermoplastic and composite panels

Figure 10: The adaptive mould at Curve Works

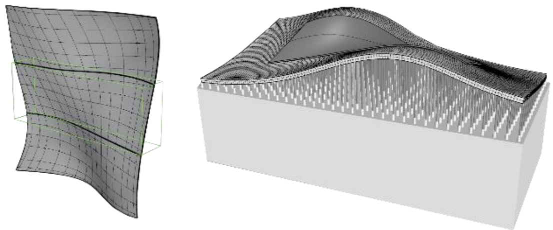

Figure 11: The mould is automatically configured in a 3D CAD environment

The equipment is used for multiple processes: Vacuum infusion of composite (sandwich) panels, curing of prepreg (sandwich) panels and thermoforming of plastic sheets and core materials. Furthermore, the adaptive mould is used in a highly advanced way since it is not only used as mould, but also as a manufacturing tool:

- Plastic sheets are for example prepared flat and shaped into the desired position as soon as the forming temperature is reached.
- Core materials are for example corrected for spring-back by 'over-shaping' the mould.

The current mould is dimensioned for general use and its maximum dimensions are particularly aimed for architectural projects (façade and wall panels).

Figure 12: Demonstrating the actuator deflection of the Curve Works mould

The adaptive mould technology will remove the barriers as mentioned in section 3 and allow for the manufacturing of 'large' high performance composite hulls and superstructures in a responsible and economical way. In the composite panel assembly as shown in Figure 13, the decks and bulkheads form the assembly jig. The outfitting can therefore occur in parallel with the mounting of the panels, resulting in an enormous reduction of lead-time. Regarding the architecture, it is proposed to:

- ensure that the doubly curved panels fit exactly in the pocket created by the deck(s) & bulkheads. Joints are in this way always supported by a structure underneath and are therefore not subjected to out-of-plane shear loads.
- Panels are arranged in a staggered way in order to optimize the load transfer in the seams where panels meet each other.

The architecture of the reinforcement and the joining method is based on knowledge that is already generated in previous research activities (section 4.2). To ease the preliminary design, Curve Works developed an excel-program that calculates the peel and shear stresses of single-lap joints based on the theory of '*Bigwood and Crocombe*'. A manual is created in order to use and interpret this program when evaluating double lap and stepped lap joints.

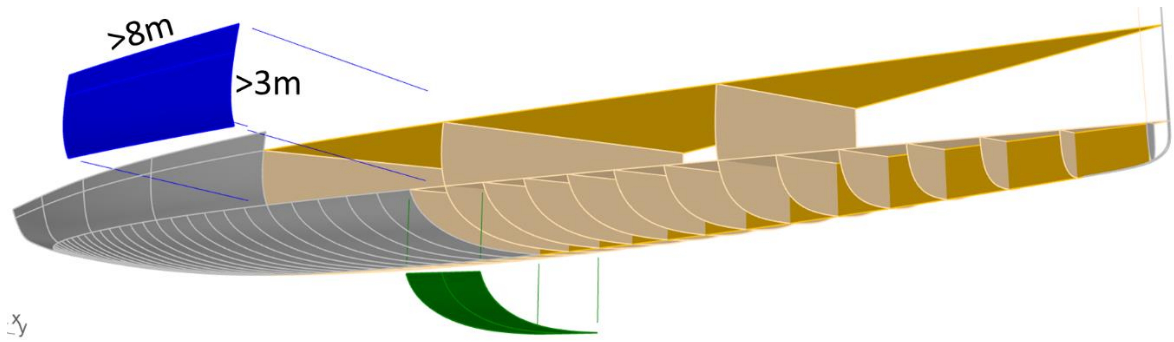

Figure 13: Illustration of the composite panel assembled mould

The feasibility study COMPAS 1 showed that the technology currently available at Curve Works needs to be upscaled for composite panel assembled hulls. The business case for composite panel assembled hulls starts to become interesting at lengths starting from 40m. Sufficient heritage and infrastructure is already available below 40m. The netto-area of the mould needs to be at least 3x6 meter in order to be interesting for tool-less hull structures starting from 40m. The preferred adaptive mould will become larger when yachts become larger. The composite panel assembly is the only sensible process for future concepts like the 300 foot composite Carkeek C300 (Figure 14).

Figure 14: Render of the Carkeek C300 Gigayacht concept

4.4. Other possibilities of the adaptive mould technology

The use of multiple production lines in composite shipyard is a growing trend, and industry try to minimise the construction time by producing in parallel principal vessel components.

As a general rules, in one-off production, main moulds which are shaped are those for decks and hull side shell, bulkheads being produced from flat moulds. Primary and secondary structures are produced onto the hull side shell once fully completed without any moulds.

For mass serial production, those parts are often produced using complex moulds in order to build up a complex "grillage" shape using a one shot process, thus permitting less production time. Then this "grillage" is fitted into the hull shell by means of assembly technics such as over-laminating or bonding.

The disruption brought by the adaptive mould technology in the composite shipbuilding industry, will need a change in the classical production process as the hull side shell is produced panel per panel. Assembly of panels might be done on a supporting structure such as bulkhead produced on basis of flat panel but also on stringers and frames which can be also produce using the adaptive mould technology.

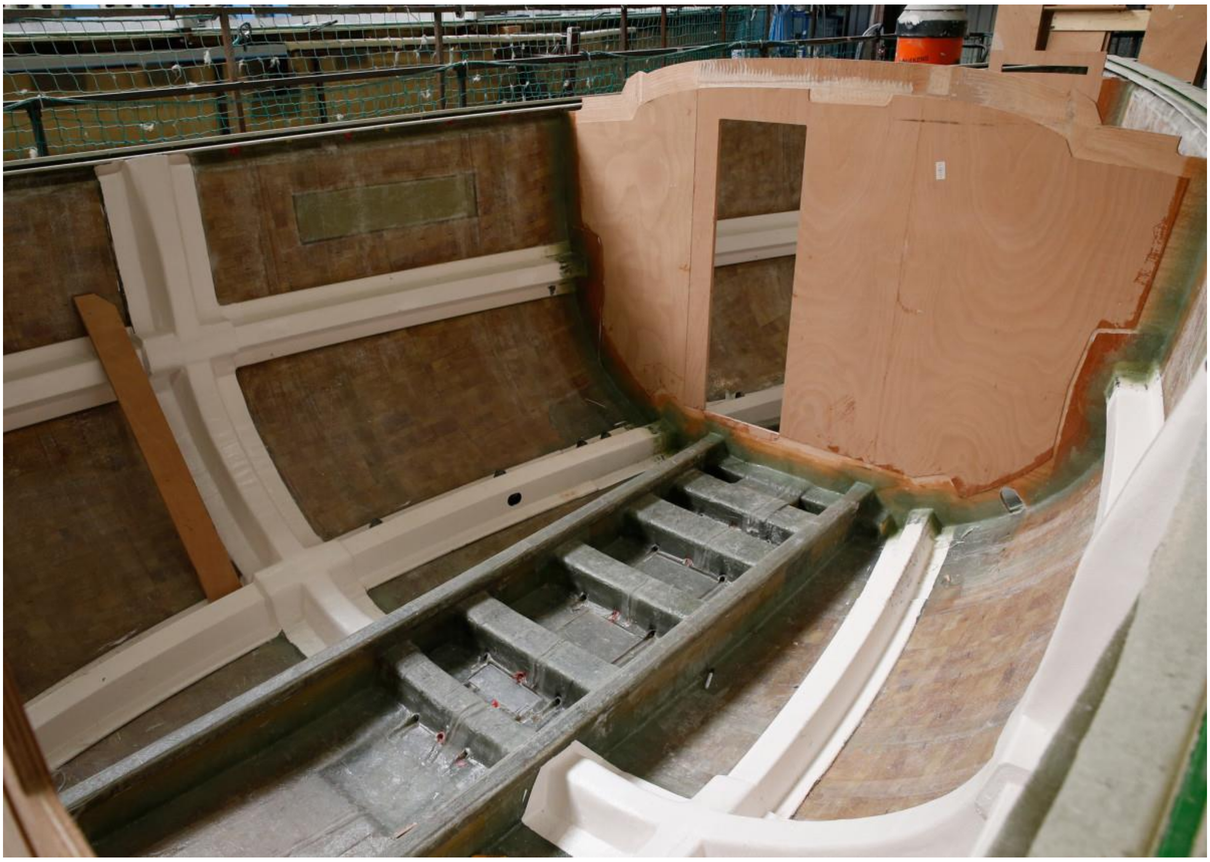

Figure 15 Typical stringer grid system fitted on sailing ship.(source: https://www.sailmagazine.com/diy/know-core-principles)

In such case, structural continuity of shell panels but also the one of the longitudinal structure are to be ensured, thus imply shift in over-laminating / bonding of connections.

5. The market for composite panel assemblies

Curve Works is focussed on changing the way large composite yachts and ships are built. In contrast to the industrial focus of projects like RAMSSES, FIBRESHIP and others, *Curve Works* aims to launch this technology in the private sailing super yacht industry, for two reasons:

- Sailing super yacht owners prefer composite over aluminium
- Prestige is valued high in the private yacht industry where yacht owners want something that nobody else has. This is directly opposite to the needs of the industrial market. Starting in the private market will therefore result in early commercial success.

The industrial market is more complex. Many factors play a role in in the trade-off between metals vs composites like a) the intensity of the use (fuel-cost over a lifetime), b) initial investment, c) rules and regulations, d) lead-time, e) performance, f) customer perception and g) maintenance. There is a clear trend to use composites in superstructures but the growth of composites in the motorized one-off market is going slowly. It is expected that the industrial market will follow soon after a successful launch in the private sailing yacht market, especially since it is shown [4] that the lifecycle costs for composite ship structures are lower.

An additional boost for composite ship structures will occur when electric propulsion will become increasingly popular. The energy density of batteries compared to fuel is one order of magnitude lower. Changing to electric propulsion will from a commercial perspective require very efficient (lightweight!) designs.

Additionally, an interesting market is the defence market. Performance requirements are in this market more important than budget requirements. Furthermore, the defence market can deviate from rules and regulations which the industrial market cannot.

6. References

[1] The Yacht Report, 2009

[2] Superyacht Intelligence, d.d. 26/03/2019

[3] Dubois E., “Superyachts”, Sailing Yacht Design Practice edited by Claughton, Wellicome & Shenoi, 1998

[4] Throughlife: Project Final Report

[5] PINK GIN VI - BALTIC 175, Case Study, GURIT.COM

[6] Use of Fiber Reinforced Plastics in Ship Construction, DIMITRIOS-ALEXANDROS ZISIMOPOULOS, 2015

[7] Yas Magazine

Appendix: Overview of R&D Developments enhancing the use of composite (panel assemblies)

Dutch Funded Initiatives

FLIGHT 2009-2012:

The ambition of Flight (*Fast LIGht Hull Technology*) was to advance the state-of-the-art composite material technology knowledge for prominent Netherlands maritime industrial and research organisations, hereby securing competitiveness within their respective market/activity fields. FLIGHT innovative issues were:

- Integrate the currently fragmented knowledge of composite material suppliers in a well ordered/well organized and usable form for the ship/boat designer and builder
- New material technology: a limited selection of high performance hybrid fibres in combination with newly available resins. This will also improve the safety factors of elementary layers in composites
- Structural joint solutions capable to withstand impact and cyclic loads
- More efficient production process using panel/block assembly besides vacuum injection

Partners: *TUDelft, DSM, Teijin Aramid, Bureau Veritas, Damen Shipyards, Lightweight Structures BV*

ADHESION (2008-2012)

The objective of the ADHESION project goal was to gain information and implement technology for certified adhesive joints in shipbuilding practice. The project resulted in a firm knowledge base about requirements that a bond needs to fulfil to survive in a marine environment. The conditions at the shipyard proved to be suitable for bonding and employees from the yard were trained in bonding practices. A large number of specimen tests were performed, which showed that materials that are sensitive for corrosion are problematic regarding adhesive bonding. A corrosion resistant primer system that is strong enough to result in cohesive failure has not been identified yet. Bonding of metals is therefore used for low risk applications and composites need to be considered for primary structures.

Partners: *Airborne Composites, Amels B.V., Bureau Veritas, CMTI, Damen Schelde Naval Shipbuilding, Damen Shipyards Gorinchem, Henkel & Co Gmbh, MTI Holland BV, Netherlands Maritime Technology, Lightweight Structures BV, Lloyd's register EMEA, TU Delft (Adhesion Institute, Design and Production of composite Structures, 3ME)*

COMPAS (2017-2018)

The objective of COMPAS (*COMposite Panel ASsembly*) was to investigate the manufacturing of composite hulls and superstructures using composite panel assemblies that are fabricated on adaptive/smart tooling. The results of this study have lead to this whitepaper and are used to initiate COMPAS 2. The objective of COMPAS 2 is to be market ready in 2022/2023 regarding the development of tool-less composite hulls and ship structures
Party: Curve Works

European Funded Initiatives

BONDSHIP (2000-2003)

The objective of bondship was to introduce adhesive bonding for joining lightweight materials. This objective is achieved by:
• Studying the structural behaviour of bonded joints, including long-term performance in a marine environment
• designing, building, testing and repairing prototypes involving superstructures of patrol craft, secondary attachments to cruise ship superstructures and load bearing connections in superstructures
• preparing guidelines for use of adhesive bonding in such applications. The main results are guidelines for the design and modelling of bonded joints; acceptance tests and criteria; inspection methods; documented application cases and joint designs; production and repairs procedures.

Partners: *DNV A/S, ALUSUISSE ROAD & RAIL LTD. DÉLÉGATION GÉNÉRALE POUR L'ARMEMENT, FINCANTIERI - CANTIERI NAVALI ITALIANI SPA, FiReCO AS, JOS. L. MEYER GMBH, NDT SOLUTIONS LTD, SIKA SCHWEIZ AG, STENA REDERI AB, THE ITALIAN SHIP RESEARCH CENTRE, UNIVERSITY OF SOUTHAMPTON, VOSPER THORNYCROFT LIMITED*

DE-LIGHT Transport (2006-2009)

DE-LIGHT Transport objectives were to develop new solutions, methods and tools for the design, production, integration and testing of complex modular lightweight structures in ships, inter-modal transport containers and railway vehicles. Focus was given to the development of multi-material modules with a higher degree of pre-outfitting, as compared to the optimization of structural components which was mainly done in previous projects. Results were used and demonstrated in large scale prototypes for six application cases.

Partners: *CMT, 'Ovidius' University of Constanta - Center for Advanced Engineering Sciences (RO), Uljanik Brodogradiliste (HR), University of Zagreb Faculty of Mechanical Engineering and Naval Architecture (HR), Meyer Werft GmbH (DE), Institut fuer Holztechnologie Dresden GmbH (DE), Schelde Naval Shipbuilding (NL), APC Composit AB (SE), SICOMP AB (SE), Anthony, Patrick and Murta Lda (PT), Bombardier Transportation (FR), Det Norske Veritas AS (NO) Fraunhofer (DE), BALance Technology Consulting GmbH (DE), University of Newcastle upon Tyne (UK), Teknillinen korkeakoulu (FI), Riga Technical University (LV), Technical University of Gdansk (PL), Noske Kaeser (DE)*

THROUGHLIFE (2011-2014)

Fuel and environmental legislation are considered to be the major future cost drivers throughout a vessel´s lifecycle according to a survey among yards, ship operators and other stakeholders in the maritime industry carried out by the ThroughLife project. In order to cope with these future challenges, the respondents agreed that increasing the energy efficiency through applying new technologies is the most promising measure. However, the survey identified barriers concerning the technical reliability of new technologies and incalculable costs. With the goal to overcome these barriers, the ThroughLife project developed new approaches for through-life asset management to optimise the economic and ecological lifecycle performance of vessels.
One of these technologies was the implementation of composite structures for which it was concluded that the introduction of composite material in the ship structure has shown its potential in terms of weight, and in terms of lifecycle costs.

Partners: *MEYER WERFT GmbH & Co, APC-Composites, Aalto University, TNO, BMT Group Limited, Swerea SICOMP AB, Fraunhofer IFAM, Shipbuilders and shiprepairers Association (UK), D'appolonia SPA, Balance Technology Consulting GMBH, CMT, CESA, Uljanik Brodogradiliste D.D., Safina Limited, BIBA, Metalship & Docks S.A.U., Balearia Eurolineas Maritimas SA*

RAMSSES (2017-2021)

The use of lightweight and other advanced material in the maritime sector is lagging behind the potential, despite the European initiatives such as BONDSHIP, DE-LIGHT Transport, ThroughLife and ADAM4EVE.
The reason for this situation is manifold and complex. The European Innovation Action RAMSSES is addressing the most relevant problems that hinder a broader and quicker technology uptake. RAMSSES consists of a large European consortium and has the objective to accelerate market implementation by developing 13 market driven demo cases.

Partners: *Cetena, CMT, Aalto University, Airborne Composites BV, Aimen technology centre, BALance Technology consulting, Baltic workboats AS, Baltico GmbH, Becker Marine Systems, Bureau Veritas, Chantiers de L'Atlantique, Composites Evolution, Coventive Composites, Damens Schelde Naval Shipbuilding, Centrale Nantes, Ensta Bretagne, Evonik, Fincantieri, Cardama Astilleros Shipyard, Fraunhofer IFAM, Galventus, Hutchinson SA, Infracore Company BV, Jules Verne Institute, Marine Engineering and Consulting (MEC), Meyer Turku Oy, Meyer Werft Papenburg GmbH, National Technical University of Athens, TNO, Naval Group SA, Damen Shipyards, NMT, Swerea/Sicomp, Uljanik d.d.*

FIBRESHIP (2017-2020)

The main objective of the FIBRESHIP project is to enable the building of the complete hull and superstructure of large-length seagoing and inland ships in FRP materials by overcoming the current technology gaps. In order to achieve this objective, the project will develop, qualify and audit innovative FRP materials for marine applications, elaborate new design and production guidelines and procedures, generate efficient production and inspection methodologies, and develop new validated software analysis tools. Clear performance indicators will be designed and applied in the evaluation of the different solutions developed for three targeted vessels categories. Finally, the different technologies generated in FIBRESHIP will be first validated and then demonstrated by using advanced simulation techniques and experimental testing on real-scale structures.
Partners: *TSI SL, Compass Ingeniería y Sistemas SA, TWI, Ateknea solutions, Bureau Veritas, Lloyd's Register, RINA, iXblue, Navrom Shipyard, Fundacion Soermar, TuCo Marine Group, CIMNE, University of Limerick, VTT, Anek Lines, danaos, foinika shipping companyne, Instituto Espanol De Oceanografia*

Qualify (2017-2020)

The advancement in composite materials allows building primary maritime structures traditionally made of steel, e.g. ship superstructure. Steel and composites can be bonded together using adhesives, forming a hybrid (steel-composite) joint. Despite of the many benefits of composite and hybrid joints, the lack of correct guidelines for approval and design has prevented their uptake by the maritime industry, limiting their usage to secondary structures. This is partly because the long term behavior and failure of hybrid joints is not yet understood. The goal of the EU funded QUALIFY project is to fill this knowledge gap, enabling the development of such guidelines, with the correct objective promote the use of hybrid joints in primary structures in a marine environment.
Partners: M2I, *Bureau Veritas, Lloyd's Register,Cambridge University, Damen, TU Delft, Ghent University, Com&Sens, Parkwind, WMC, BAE Systems*