LightShip Project
Status for use of FRP in Commercial Shipbuilding

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1 Introduction

1.1 Background

The LightShip project was launched to map the Danish status quo in commercial shipbuilding with FRP-based materials, and in attempt to find next steps needed to strengthen the Danish competencies and partnerships within this field. Background for the project was the belief that information is scattered and various initiatives not necessarily coordinated, so it was desired to get an overview of the current state and convey the available knowledge.

Through involvement of relevant stakeholders, the LightShip project seeks to map barriers and challenges for usage of lightweight composite (FRP) in commercial shipbuilding, and engage the same stakeholders in dialogue on how to possibly move forward. Main activities in the LightShip project is a desk study, a series of interviews, and a workshop. This Status Report and an Idea Catalogue are the main project deliveries.

The LightShip project is funded by the Danish Maritime Fund (DMF) together with Danish Fire, Security and Technology Institute (DBI), and partly the Danish Maritime Authority (DMA). The project is part of the societal partnership Blue INNOship's project portfolio, with DBI as project owner.

1.2 Scope

The LightShip project is a small non-academic project, where the 3 months duration reflects on the limitation in scope. The scope for the LightShip project in regard of FRP usage in commercial shipbuilding (in Denmark and the neighboring countries) is:

- Mapping of:
  - Stakeholders,
  - existing rules and status for coming rules or guidelines,
  - known research capabilities in the topic,
  - significant development projects the last 10-15 years,
- Identification and description of barriers,
- Listing of relevant ship types with current or likely coming usage of FRP.

The Danish flag is focus for the project, and below matrix shows considered ship types and usage:

Ship Category	Usage						FRP application		
	Conv.	HSC	Special personnel	Open Sea	Coastal	Port areas / protected	Hull	Super structure	Component / equipment
Cargo (incl. SPS)	X	X	X	X	X		X	X	X
Passenger	X	X		X	X	X	X	X	X
RO-RO	X			X	X			X	X
Cruise	X			X					X

1.3 Project Team

DBI participates in project with innovation consultant Carsten Møller and project manager Claus Langhoff. To run the project DBI, has contracted externally with naval architect and risk consultant Rikke Aarøe Carlsen from Ready? IVS, and ship surveyor Niels Brehm Nielsen from the DMA.

2 Stakeholders

Stakeholders are found in various groups, with shared and/or individual interests in the topic of using FRP in commercial shipbuilding. Interests are seen as spanning commercial, societal, environmental, legal, political, and scientific in character. General stakeholders are represented by the value chain (see below). In the LightShip project, contact has been made with many, but not all, potential stakeholders in Denmark and neighboring countries.

Prior to project start, some central stakeholders were approached and had agreed to serve as Advisory Group for the LightShip project team. Others were identified for interviews, whereof some also participated in the LightShip workshop. List of interviews carried out and list of workshop participant are found in Appendix I and II.

2.1 Advisory Group

The advisory group consists of stakeholders believed to be central to the topic which are authority, classification societies, and research and development institutes. Below is a table of the people represented in the LightShip project's Advisory Group by the following organizations:

Stakeholder Type	Organization Name	Person Title and Name
Authority	Danish Maritime Authority (DMA)	Chief Ship Surveyor Torsten Arnt Olsen
Classification Society	Bureau Veritas – Marine & Offshore	Surveyor, Sr. Naval Architect Alexander Bjørn Kleiman
Classification Society	DNV GL Group	Customer Service Manager Claus Bo Jenstrup
Classification Society	Lloyd's Register Marine	External Affairs Manager Valdemar Ehlers
Industry Association	Danish Maritime	Naval Architect Poul Erik Louw
University	Technical University of Denmark, Department of Mechanic	Associate Professor Christian Berggren
Development Institution	Danish Fire, Security and Technology Institute	Product Manager Dan Lauridsen

While the IMO and EU are recognized as significant stakeholders, they have not been approached directly in regard of the LightShip project. Their position on the topic is covered via the engagement from the Danish Maritime Authority (DMA).

2.2 Stakeholders and Value Chain

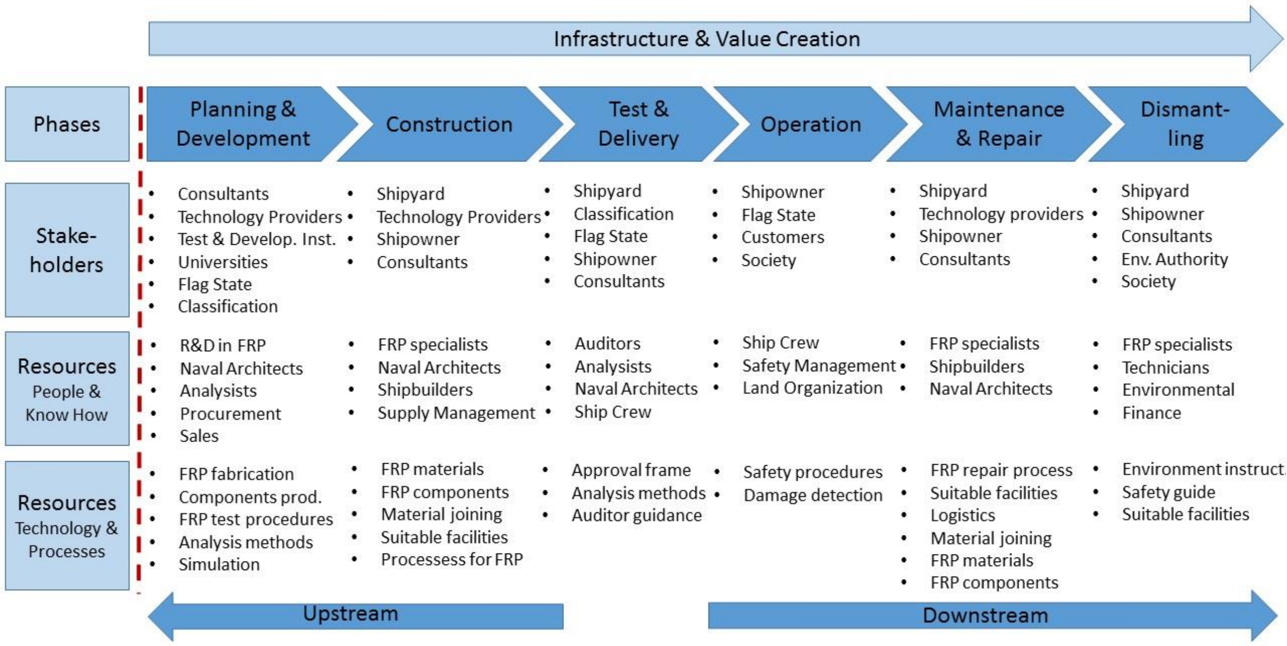
The various organizations with both shared and individual stakes in usage of FRP in commercial shipbuilding are:

- Authorities,
    - IMO (International Maritime Organization),
    - The European Union,
    - National maritime authorities, in Denmark the DMA.
- Classification societies,
- Shipowners,

- Shipyards,
- Technology providers, like
    - material producers,
    - component suppliers.
- Naval architects/consultants,
- Universities,
- Test & Development Institutions.

All of these are part of the infrastructure for the industry value chain, supported by their human and technological resources. Detailed value chain mapping and analysis around FRP in commercial shipbuilding, analyzing value creation and competence development for stakeholders and society, would be a time demanding plot, and outside the scope of this project.

For the purpose of pure illustration, and for further references to upstream and downstream stakeholders, an overall value chain, considering the most directly involved group of stakeholders and their resources, is sketched here:



3 Rules and Guidelines

3.1 Application and Operation of the Ship

The rules and guidelines for use of FRP in ships depends on the type of ship, the number of passengers and the area in which the ship is entitled to sail. The most general set of regulations is the SOLAS convention which allows a ship to sail worldwide as long as it holds valid SOLAS certificates. For a ship engaged exclusively in European waters the EU regulation for example for passenger ships 2009/45/EC specifies the rules and guidelines for ships engaged in trade inside the European Union. Finally a ship engaged in national waters has to comply with national regulation, and might be challenged if it, at a later stage, is decided to change trade permit area to another country. In addition to this the rules also depend on whether the ship is carrying up to 12 passengers or more making it either a cargo ship or a passenger ship which is two different set of rules. Furthermore, if a ship is certified under the HSC Code which implies certain restrictions on the operation of the ship, another set of rules will apply. Therefore, the rules and guidelines for using FRP in ships will depend on the application and operation of the ship.

SOLAS (Safety of Life at Sea Convention)

The use of FRP composites in relation to SOLAS regulations will be explained in the following section. The main barrier for using FPR composite is due to the material being combustible. In SOLAS chapter II-2 regulation 2.2.1.3 states that the use of combustible materials should be restricted. The term *non-combustible material* is defined in SOLAS chapter II-2, regulation 3.33 as:

"Non-combustible material is a material which neither burns nor gives off flammable vapours in sufficient quantity for self-ignition when heated to approximately 750° C, this being determined in accordance with the Fire Test Procedures Code (FTP code)."

Furthermore, certain divisions on board a SOLAS ship must be constructed of steel or other equivalent material, which is defined in SOLAS chapter II-2, regulation 3.43 as:

"Steel or other equivalent material means any non-combustible material which, by itself or due to insulation provided, has structural and integrity properties equivalent to steel at the end of the applicable exposure to the standard fire test (e.g. aluminium alloy with appropriate insulation)."

where the term standard fire test is defined in SOLAS chapter II-2, regulation 3.47 as:

"A standard fire test is a test in which specimens of the relevant bulkheads or decks are exposed in a test furnace to temperatures corresponding approximately to the standard time-temperature curve in accordance with the test method specified in the Fire Test Procedures Code."

Combustible materials used on surfaces and linings must also comply with SOLAS chapter II-2, regulation 5.3.2.2 to 5.3.2.4 concerning maximum calorific value of combustible materials, total volume of combustible materials and low flame-spread characteristics of exposed surfaces. These three requirements also apply to surfaces with non-combustible materials. The structural integrity of a ship must not be degraded due to fire and the purpose of SOLAS chapter II-2 regulation 11 is to prevent partial or whole collapse of the ship due to strength deterioration by heat. For this purpose the hull, superstructure, structural decks and deckhouses shall be constructed of steel or other equivalent material.

Another concern when using FRP composites is related to smoke generation and toxicity. In the FTP (Fire Test Procedures) Code Part 2.2.4.2 the average value of the maximum value of the gas concentration measured at each test condition shall not exceed the following limits:

- CO 1,450 ppm
- HCI 600 ppm
- HF 600 ppm
- NO_x 350 ppm
- HBr 600 ppm
- HCN 140 ppm
- SO_2 120 ppm (200 ppm for floor coverings)

For fire safety design and arrangements deviating from the prescriptive requirements of for example non-combustibility or the requirement for using steel or equivalent material, an engineering analysis can be made. Information about the analysis can be found in SOLAS chapter II-2 regulation 17, but the analysis should be based on the guidelines on alternative design and arrangements for fire safety specified in MSC/Circ. 1002.

HSC (High-Speed Craft) Code

For ships which can be certified under the HSC code, the use of FRP composite materials are more obtainable. In the HSC code chapter 3.2 it is stated:

"Materials used for the hull or superstructure and the other features related to in 3.1 shall be adequate for the intended use of the craft."

This is further elaborated in chapter 3.3:

"The structure shall be capable of withstanding the static and dynamic loads which can act on the craft under all operating conditions in which the craft is permitted to operate, without such loading resulting in inadmissible deformation and loss of watertightness or interfering with the safe operation of the craft."

In HSC chapter 7.4 concerning structural fire protection it is stated, that:

"The hull, superstructure, structural bulkheads, decks, deckhouses and pillars shall be constructed of approved non-combustible materials having adequate structural properties. The use of other fire-restricting materials may be permitted provided the requirements of this chapter are complied with and the materials are in compliance with the Fire Test Procedures Code."

For a ship to be certified under the HSC code certain requirements must be fulfilled. A high-speed craft must be capable of a maximum speed, in metres-per-second, equal to or exceeding $3{,}7\nabla^{0{,}1667}$ where ∇ is the volume of displacement corresponding to the design waterline, in cubic metres. Furthermore, the craft must at all times be in reasonable proximity to a place of refuge and more specific a passenger craft must not proceed on the course of its voyage more than four hours at 90% maximum speed from a place of refuge. For a cargo craft of 500 gross tonnage and upwards this limit is eight hours. The HSC code also includes requirements for readily availability for suitable rescue facilities and efficient facilities for rapid and safe evacuation of all persons into survival craft. In HSC chapter 4.8.1 it is stated that the provisions for evacuation shall be designed such that the craft can be evacuated under controlled conditions in a time of one third of the structural fire protection time (SFP) after subtracting a period of 7 minutes for initial detection and extinguishing action:

$$Evacuation\ time = \frac{(SFP - 7)}{3} min$$

The safety philosophy behind the HSC code is ships engaged on short voyages in protected waters with quick evacuation and coverage by an external rescue service.

3.2 International Discussions

At international level many different opinions are expressed about the use of FRP in shipbuilding[1]. Some member states are working towards the idea of having a ship or a component built in FRP, while a number of members have expressed concerns about the use of FRP in ships[2] because of the fire properties of the material and related fire safety requirements specified in SOLAS. This is also proven at the meetings held in IMO where it has not yet been possible to find a common ground, and a considerable amount of future discussion is to be expected about this matter[3].

3.3 Classification Societies

The classification societies act as Recognized Organizations (ROs) on the behalf of Flag, and are bound by international conventions like SOLAS and MARPOL and the national rules set out by the member states they are representing. Therefore, in the same way that different opinions are expressed by member states at the IMO, the classification societies will also have different opinions depending on which office you ask and in which member state this office work. The classification societies are progressive and innovative, but they are bound by the international conventions and the opinion of the member states they represent.

3.4 Upcoming Regulations

At the IMO sub-committee meeting on Ship Design and Construction (SDC 2) in February 2015, a draft *Interim guidelines for use of Fibre Reinforced Plastic (FRP) elements within ship structure* was agreed. The comprehensive interim guidelines are aimed at member governments, who are invited to apply them when approving alternative designs and arrangements for FRP elements in ship structures in accordance with SOLAS chapter II-2 regulation 17[4].

A concern expressed by certain member states is dealing with what is called implicit robustness. Implicit robustness covers, for example, the fact that at steel bulkhead can maintain structural integrity longer than the 60 minutes of fire that a standard fire test prescribes. The question is whether a FRP composite bulkhead will show the same strength and integrity after 60 minutes of fire. In regard to this due consideration needs to be given to deflection under load of a composite structure when subject to elevated temperatures with respect to whether or not it is truly equivalent to steel.

At the MSC 95th session in June 2015 it was decided to reinstate the existing output of the *Interim*

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[1] http://www.safety4sea.com/imo-sub-committee-on-ship-design-and-construction-outcome-23523
[2] http://www.lr.org/en/_images/213-35774_SDC_1_Summary_Report_tcm155-249133.pdf
[3] http://www.ifsma.org/members/IMO_Reports/IMO_Reports_files/6d0ffc8089cb25b680ae48cfdb2bbd7a-4.html
[4] http://www.imo.org/MediaCentre/MeetingSummaries/DE/Pages/SDC-2.aspx

guidelines for use of Fibre Reinforced Plastic (FRP) elements within ship structure in the agenda of SDC 3 taking place January 2016, since more considerations had to be given to the background of the fire safety objectives and functional requirements in Part A of SOLAS chapter II-2.

4 Known Research Capabilities

In this passage an attempt to map the known research capabilities in Denmark and neighboring countries has been made. It has to be noted that a lot of the challenges of FRP structures are universal and not only present in marine applications. In most engineering departments specialized groups exist dedicated to studying FRP structures and the challenges associated with these. From the aforementioned one might easily realize that a listing of all of the organizations involved in the field and a detailed description and assessment of their research and work is not easy.

In the following table special emphasis has been given to universities and R&D institutions, excluding R&D in businesses. That of course does not imply that R&D is not carried out on the business side – only that information on commercial R&D departments is less available.

The table has been populated primarily by the involvement in FRP, marine oriented projects, or related fields. The study field descriptions reflect some of the fields of research in these institutes.

Organization Type	Organization Name	Country	FRP study Field
University	Technical University of Denmark	DK	Analysis, modelling, design and testing of composite structures, adhesive bonding and interfaces, investigation of environmental temperature effects
Development Institute	Danish Fire, Security and Technology Institute	DK	Fire safety engineering, Fire testing
Development Institute	FORCE Technology	DK	Analysis, modelling and testing, Non destructive testing, adhesion and joining, environmental effects, recycling of composites, applications of composites offshore
Development Institute	SP Technical Research Institute of Sweden	SE	Fire testing analysis design, modelling and testing, recycling
University	University of Chalmers	SE	Analysis, modelling, testing of composites
University	Luleå University of technology	SE	Analysis, modelling, testing of composites
University	KTH University	SE	Analysis and testing of materials and processing
University	Aalborg University	DK	Analysis, modelling, design and testing of composite structures, processing
University	Norwegian University of Science and Technology (NTNU)	NO	Analysis, modelling, design and testing of composite structures, adhesive bonding,

Organization Type	Organization Name	Country	FRP study Field
			Non destructive testing
University	University of Southampton	UK	Analysis, modelling and testing, fire resistant composites, adaptive and smart materials
University	Aalto University	FI	Adhesive bonding Analysis modelling and testing
University	Delft university	NL	Analysis modelling and testing, Manufacturing; and Non-destructive Testing and Structural Health Monitoring
University	Ku Leuven university	NL	Analysis, modelling and testing, Processing
Research Institute	SWEREA	SE	Analysis modelling and testing, Manufacturing; and Non-destructive Testing and Structural Health Monitoring, processing, production
Research Institute	Fraunhofer-Institut für Fertigungstechnik und Angewandte Materialforschung	DE	Adhesive bonding technology and surfaces
University	Kaiserslautern University of Technology	DE	Analysis design and testing, Joining, processing smart composites
University	University of Stuttgart	DE	Analysis modelling and testing, Manufacturing, recycling
Research Centre	The Welding Institute	UK	Adhesive bonding, testing and non destructive testing
University	The University of Nottingham	UK	Processing Crashworthiness Recycling
Research Institute	Danish Technological Institute	DK	Testing Design Automotization of production
University	Newcastle University	UK	Analysis, processing, fire performance
University	Imperial College London	UK	Analysis, design and testing, adhesive bonding, non-destructive testing
University	University of Bristol	UK	Analysis modelling and testing, Smart composites

5 Development Projects

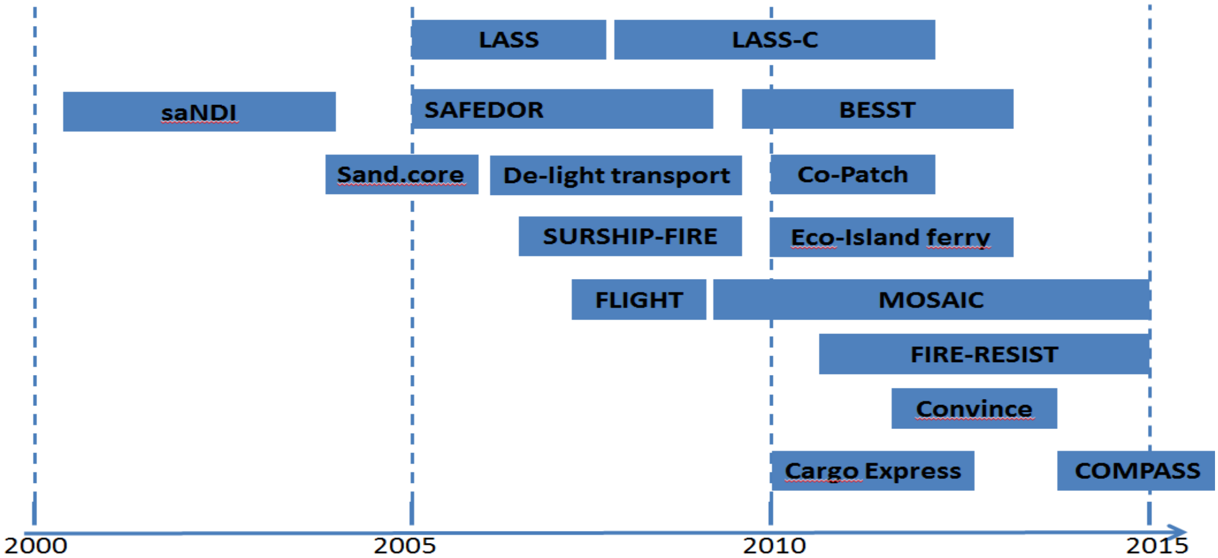
Mapping, description and high level conclusions of the last 5-15 years' significant development projects in the topic carried out or planned in Denmark and neighbor countries.

5.1 Projects found in LightShip Desk Study

During the LightShip project's desk study and subsequent interviews with relevant actors, the following development projects were identified:

- BESST (Breakthrough in European Ship and Shipbuilding Technologies)
- CARGO EXPRESS (Multipurpose cargo vessel with composite surfaces)
- COMPASS (COMposite super-structures for large PASsenger Ships)
- CONVINCE (Vulnerability reduction technologies for large maritime composite structures)
- Co-Patch (Composite Patch repair of metallic marine structures)
- De-Light Transport (Developing Lightweight Modules for Transport Systems)
- Eco-Island Ferry (Light weight ferry in CFRP composite)
- EUCLID (Survivability, durability and performance of naval composite structures)
- FIRE-RESIST (Marine application case)
- FLIGHT (Fast LIGht Hull Technology)
- LASS (Lightweight construction applications at sea)
- LASS-C (Lightweight construction of a cruise vessel)
- MOSAIC (Materials On-board Steel Advancements and Integrated Composites)
- SAFEDOR (Design, Operation and Regulation for SAFEty)
- SANDCORE (Advanced Sandwich Structures in the Transportation Industry)
- SANDI (Inspection and Repair of Sandwich Structures in Naval Ships)
- SCS (Composite Superstructure Concept)
- SURSHIP-FIRE (Survivability for ships in case of fire)

Appendix III presents a tabled overview of project participants and scopes. Timeline for projects carried out is depicted below:



Links to all the projects listed below can be found in the references list in chapter 8.

EUCLID (end of 1990ies)
Involved: 24 industrial entities from six countries

The **EUCLID** project looked at technologies for reliable, durable, lightweight and affordable composite structures for application in major naval ships. The focus was on a frigate with a glass fibre composite superstructure and a steel hull. In the project it was shown that a new improved design would have less than half the weight of a traditional steel structure. Together with distinctive features like stealth and multifunctional characteristics the final report suggests that composites can outperform steel in major warship applications. Another outcome of the project was that there was no evidence of significant permanent degradation from accelerated ageing test. However, the durability of the joint to steel hull was uncertain and a future focus should be on joint improvement.

saNDI (2001-2004)
Involved: Militaries of defence from Norway, Denmark, Sweden, Finland and the United Kingdom

The **saNDI** project investigated production defect and in-service damage types that arise in sandwich structures having fiber reinforced plastic (FRP) face sheets. More specific a damage tolerance approach was taken looking at inspection, assessment, and repair of defects and damages. This leads to a discussion of the challenges resulting from limitations in inspection techniques. The outcome of the saNDI project was a methodology for assessing the influence of production defects and in-service damage on the performance of FRP sandwich structures in naval ships as a basis for deciding on corrective measures. However, further work needed to be done to cover damage growth under repeated loading.

Sand.core (January 2004-June 2006)
Involved: 15 partners from Europe

The aim of the **Sand.core** project was to foster the application of innovative sandwich structures in the European transport sector especially the maritime ad rail sectors. This was done by benchmarking, harmonising and complementing previous research work and evaluating state-of-the-art knowledge and experiences. The overall objective of the project was to boost the applications of sandwich structures in several transport sectors. As a consequence of non-coordinated research, the general knowledge about the sandwich panels was widespread over the industry and other parties (research, classification societies, suppliers, shipyards). Therefore, there was a need to co-ordinate research, to conduct knowledge transfer and foster the application of various types of sandwich structures. Moreover, the current knowledge on different sandwich types varies, some were quite completely known (e.g. composite sandwich panels), while for others, like metallic sandwich panels, a lack of knowledge in several aspects still existed. The parties that were supposed to apply sandwich systems, particularly shipyards, were insufficiently familiar with the characteristics of sandwich structures and their integration in ship design and fabrication to apply them to the extent desirable.

One outcome of **Sand.core** was the production of a best practice handbook including a catalogue for sandwich structures, methods and test data. Risk assessment was also conducted and cost/benefit estimations were carried out.

LASS (January 2005-June 2008)
Involved: 29 partners from Europe

The **LASS** project looked at re-design of five existing vessels and one offshore living quarter using new lightweight composite and aluminium materials. Both a LCCA (Life Cycle Cost Analysis) and LCA (Life Cycle Analysis) were used to investigate costs and environmental impacts of using lightweight materials. On four of the five vessels investigated in the LASS project composite materials was used and a focal point was to demonstrate and certify fire safe composite construction elements for ships (deck, bulkhead, and door, window, and penetrations in deck and bulkhead). The outcome was that a dozen elements was tested and certified which made it possible to build a high speed craft in FRP composites in accordance with the HSC code. A weight reduction of over 50% compared to conventional steel design was shown and a cost analysis demonstrated possible pay-back times of 5 years or less for the lightweight material investment.

SAFEDOR (February 2005-April 2009)
Involved: Managed by GL and joined by 53 partners from European maritime industry

The purpose was to establish a risk-based regulatory framework that links performance prediction with risk assessment. The argument was that risk-based design, operation and regulation open the door to innovation, as radically novel and inventive design solutions become feasible. The intention was to incorporate safety into the design process as just another design objective, instead of being treated as a constraint. The integral elements of **SAFEDOR** was to use tools to determine the risks involved and to quantify the effects of risk preventing/reducing measures, and develop acceptance criteria. The outcome of the project was a number of public reports and manuscript including a guideline for approval of risk-based design and a book with the title "Risk Based Ship Design".

De-Light Transport (November 2006-November 2009)
Involved: 19 European partners

The purpose was to investigate and promote the design, manufacturing and use of lightweight sandwich structures in the marine, rail and freight container industries. This included design and manufacturing of prototype structures including deck and deckhouse structures for ships. Risk-based design principles were applied to ensure that the designs comply with existing regulatory frameworks.

The project had three goals. The first was a multi-material sandwich design tool which implements a more generic approach that would allow the evaluation and optimisation of a wide range of material and structural mixes. The second was a strategy for joining, assembling and outfitting of separate sandwich panels and/or subcomponents to produce finished structures. A third goal was to provide accurate and reliable methods for testing and validation procedures.

SURSHIP-FIRE (2007-2009)
Involved: Leader was VTT Technical Research Centre of Finland

The **SURSHIP-FIRE** project looked at survivability for ships in case of fire. One of the goals was to develop fire safety solutions of ships based on novel knowledge and computational techniques. This was done by dividing the project into four subproject namely materials, hazards, structures and evacuation. Results of the project was also divided in four related to the four subprojects. Results concerning materials were fire test data of some products commonly used in shipbuilding which was stored in a free-of-charge accessible database for the use of design engineers. Related to hazard a quantitative risk analysis of ship fire safety was performed.

The analysis looked at cabin fires in passenger ships and the probability for fire spread outside the cabin together with an evaluation of various measures for improving fire safety. The structure subproject concentrated on the effects of engine room fires on car deck structures.

These results clearly showed the need for total insulation of critical sections. Subproject four concerning evacuation had a special focus on the use of staircases and the movement of evacuees between decks, since this is an essential part of ship evacuation. A new staircase sub-model was created, verified and validated, which describe the complex staircases in egress simulation.

LASS-C (2008-2012)
Involved: Originally 9 parties from research and industry, but 6 extra parties joined later.

The **LASS-C** project was an extension of the **LASS** project. The aim was to look at the possibility of making the five upper decks on hypothetical Panamax cruise vessel in FRP composite. The project expands the concept of making lightweight structures to consider elements which were part of the hull girder that affected the ship's global strength.

The results shown that some parts of the construction had to be reinforced to compensate for the global stress losses due to the use of FRP composite, however even if it required additional 200-400 tons of steel the remaining weight saving for the new design would be substantial.

The weight savings could be used to add almost 100 cabins or a third of a deck. Other weight savings than hull construction weight for the five upper decks was also estimated for interior weight and glass weight. Furthermore a number of new materials were developed during the project including lightweight B-class material and lightweight wet-room module.

FLIGHT (Around 2009)
Involved: 7 partners mainly from the Netherlands

Integrate the fragmented knowledge of composite material suppliers in a well ordered and usable form for the ship/boat designer and builder. The project also looked at new material technology and structural joint solutions capable to withstand impact and cyclic loads, and how to make a more efficient production process.

BESST (September 2009-March 2013)
Involved: Leading EU shipyards, 20 research institutions and universities, five classification societies, and 31 industrial companies

Having in mind the comparatively high labour cost in Europa, the **BESST** project aimed at increasing the competitiveness of European built ships through decreased life cycle cost, drastically reduced environmental impact and improved safety. Focus was on cruise vessels, passenger ships, ferries (Ro-Pax) and mega yachts. This will be done by looking at new innovative technical solutions for certain ship systems to improve life cycle performance indicators like cost, environmental impact, safety and social perception. In relation to composite the project aimed at developing a reliable and long lasting joint solution between a steel structure and a composite structure. Solutions were also created to cope with stiffness requirements for a cruise ship. However, final results from the project is not yet public available.

MOSAIC (September 2009-September 2015)
Involved: Lead by CETENA (Italy) and 10 partners from 6 European countries

The aim is to investigate two novel ideas concerning ship structures. First, introduction of High Strength Low Alloyed Steels (HSLA) in specific structural details, and second the replacement of specific structural parts of the ship with composite materials. A special emphasis will be on steel to composite joints. The final goal of the **MOSAIC** project is to improve the structural response of the ship, reduce corrosion, reduce the lightship weight of the structure, and reduce maintenance and overall operation cost of the vessel.

Co-Patch (January 2010-December 2012)
Involved: 15 organizations from 8 European countries

The aim of **Co-Patch** was to develop a novel, effective repair and reinforcement method, also called composite patching, for defects in large steel structures to prevent crack growth and to extend the lifetime of the repaired structure. The hope was also to reduce maintenance costs. Focus was on marine structures and iron/steel civil engineering structures like bridges and transmission towers. A composite patch works as a crack arrestor by decreasing the stress in the area of the crack tip, and one of the aims is to investigate whether this is also true for cracks in the marine environment.

Eco-Island ferry (December 2010-July 2013)
Involved: MARKIS, Kockums, Aalborg University, SP Sweden, DMA, Swedish Transport Agency, and 2 others

The **Eco-Island ferry** is a fictitious ferry fully built in FRP composite, designed to replace an existing steel ferry with space for about 6 cars and 200 passengers. The project contains an engineering analysis as described by IMO/Circ. 1002 including a fire hazard identification process. A number of potential risks associated with FRP composite in load-bearing structures was illuminated and in particular were fire development on deck, and fire spread through openings and vertically along the outboard sides of the ship. In conclusion the base design was shown to pose a risk more than four times as high as the prescriptive design. A performance criteria with a safety factor of 50% provided three acceptable trial alternative designs. All three designs included an extinguishing system for the ro-ro deck and a redundant supply unit for that extinguishing system as well as for the internal sprinkler system. Furthermore they included an additional longitudinal bulkhead dividing the accommodation in two, and at least surfaces of low-flame spread characteristics on the forward bulkhead on ro-ro deck. Another outcome of the project was an LCA and an LCCA comparison between the fictive ferry and the existing steel ferry.

FIRE-RESIST (February 2011-January 2015)
Involved: 18 partners from 9 European countries

The main objective of this project was to validate and improve the fire performance of composite materials by developing new concepts for composite materials that are both lightweight and fire-resisting. Another objective was to develop multi-scale approaches to simulating the fire behaviour of composite materials, and to validate the performance of the materials through the design, manufacturing and testing of industrial case study components. One of the test involved replacing an A60 bulkhead on a superstructure with a triple cork core sandwich with furan laminates and intumescent coating on internal surfaces. The FRD60 test was made in accordance to part 11 in the FTP code.

The result was a temperature rise after 60 min on unexposed surface of only 6°C and the integrity was maintained until load bearing capacity was lost after 77 min (60 min is the requirement). Another test was made for reaction to fire according to part 2 and part 5 in the FTP code where heat release rate and gas concentration limits were measured and passed the test.

CONVINCE (2012-2014)
Involved: 26 partners from France, Italy, the Netherlands, Sweden, Norway and the United Kingdom

The **Convince** project assessed the potential use of composites in naval structures. The core investigations of the **Convince** project were structural materials selection for improved fire performance, proposal of fire risk control options, small coupon tests for fire, physical and mechanical properties, fragmentation tests, medium and large scale fire and blast tests on representative structure, together with simulations of fire and blast events. Weight and cost-effectiveness for enhanced performance are considerations that informed all activities throughout the project.

COMPASS (2014-2015)
Involved: lead by DBI and involving the Technical University of Denmark, Niels Hjørnet Yacht Design, and 9 other companies including Scandlines and Maersk

COMPASS is looking at composite superstructures for large passenger ships. The aim is to make the path easier for design and retrofit of composite superstructures for larger passenger ships especially for yards and design consultants, sub-suppliers, ship owners, and authorities. This is done by adopting a standardized approach through guidelines combined with (pre-) fire proven FRP structural standard components. It consists of four work packages including structural design, analysis and testing, and fire testing and analysis. Additionally the aim is to develop rule 17 guidelines for analysis- and testing procedures.

The **COMPASS** project is currently not finished so final results cannot be presented in this study.

5.2 Overview of Areas Investigated

Below is a list of the areas investigated in the 16 development projects mentioned above. The list is prioritized with the areas investigated in most of the projects mentioned first. It is also worth mentioning that 3 of the 16 projects have been military projects looking at naval ships. Furthermore a majority of the projects have been EU funded projects.

Area investigated:	Number of projects looking at this area:
Weight saving	6
Fire safety and test	6
Joints between materials	4
Risk based regulation	3
LCCA (Life Cycle Cost Assessment)	3
LCA (Life Cycle Assessment)	3
New materials	2
Structural design	2
Degradation of composites	1
Inspection of defects and damages	1
Certification of FRP elements	1
Global strength	1
Production process	1
Patch repair	1

5.3 Unsuccessful Project Applications (not included)

An anticipated insight was an overview of project applications that for some reason were not successful in receiving funding. This information, however, has generally not been available, wherefore the few instances made known are not included in reporting. This decision is made in order not to skew the picture of what may be reasons for applications not receiving project funding.

6 Relevant Ship Types

Below is a listing of relevant ship types and applications with current or likely coming usage of FRP. Based on the interviews with relevant persons in the value chain, the following categories were outlined:

- Type of ship or application:
  - High speed light craft, small ferry or craft, super-efficient vessel, standby vessel, work boat, crew transfer boat, wind farm supply vessel, passenger catamaran and special ship.

- Larger components:
  - Superstructure, deck house, hatch cover, cabin modules, bow door, scrubber system and funnel.

- Smaller components:
  - Ventilators, pressure bottles, propeller and ballast pipes

- Other areas:
  - Repair patching and replacement of aluminum onboard ships.

Superstructure was the single area mentioned most times among those interviewed, as a potential where FRP composite would be useful, since it would reduce weight and increase stability. A couple of the actors also proposed smaller steps for incorporating FRP in the shipbuilding industry by starting with components or equipment in FRP instead of the whole ship.

7 Barriers

In recent years there have been quite many statements in favor of using FRP in commercial shipbuilding, based on the materials' positive features and expected benefits like weight saving, no corrosion, design flexibility and low life cycle costs. Yet, the progress seen in actual Danish FRP ship projects has been less than hoped for. Therefore, the LightShip project focuses on identifying the barriers – not disregarding benefits, but rather aiming at describing the challenges. The aim is to present the status quo including political, legislative, technological and economic barriers and challenges.

In order to identify what seem to be the barriers for usage of FRP in commercial shipbuilding, the LightShip project team conducted a series of interviews. Together with the Advisory Group, a list was compiled of relevant people to interview from the entire value chain. While it was not possible to get to all, a good number of interviews where arranged. People being interviewed were asked which hazards they believed to be the biggest in connection with FRP on ships, and what they perceive to be the toughest barriers for using FRP in commercial shipbuilding.

The interviews will not be presented in resume format, but the findings are summarized here, as hazards ranking, barriers and challenges, and interdependencies. Generic topics covered in interviews are included in list form in Appendix IV.

Project findings were also presented at the LightShip workshop held at DBI on 1st June 2015, and participants' responses to project findings are considered in below overview. The workshop agenda was prepared based on project findings, intended to enable discussions to deal with topics that stakeholders themselves had identified as most significant. The Workshop agenda is included in Appendix V. The aim of the workshop was to focus discussion at potential steps to take to possibly overcome the barriers. This served as input to the Idea Catalogue that is concerned with how to proactively move out of the status quo situation described in this Status Report.

7.1 Hazard Ranking

Ranking the hazards that stakeholders in total find the worst in connection with FRP in ships:

1. Fire *(No doubts on rank),*
2. Toxicity *(No doubts on rank),*
3. Structural Collapse / Loss of strength *(No doubts on rank),*
4. Ice sailing *(Rank pending interpretation – explanation follows),*

And outside ranking:

- Wrong Emergency Response (operational hazard, not ranked due to complexity – *explanation follows*)

It is evident from the interviews that fire is considered as the number one hazard for ships with FRP.
Of all the hazards discussed, fire always came out as the worst hazard. Related to fire was the toxic smoke from burning FRP, and most had that as second ranked hazard. Next in rank came

structural collapse – the material's loss of strength, whether the peril being fire or collision. When looking at findings from the interviews, the ranks one to three were clearly the order of worst considered hazards for FRP in ships for the largest part of stakeholders interviewed. Same certainty of ranking is however not to be stipulated for ice sailing. During the interviews some people mentioned ice as a barrier, while in other interviews the subject was brought up by the project team. Sailing in ice with FRP ships was mentioned by the project team to hear peoples' responses to it, as it is a topic that a group of stakeholders has big focus on. So for data scrutiny there shall be cautious interpretation; it might be a false finding in terms of rank.

Matters around the operational hazard of wrong emergency response came up repeatedly in the interviews, but not always formulated the same. The somewhat different form depends on and is influenced by the stakeholder's individual experiences and point of view. Operational hazards have a lot of complexity, broad variation, and inter-wired relations to perils. Discussions did not give strong findings to rank them, but for various reasons rather state it as a general concern of operational matters in responding to emergency situations with FRP ships.

When these hazard ranks and findings were presented at the LightShip workshop, the participants responded and reacted in line with the project team's analysis of project findings.

The top ranking hazards identified in interviews and discussed during the workshop is further elaborated in the following. In doing so, focus is slightly moving from the bare hazards into focus and perceptions on the risks related to them.

Fire Hazard and Risk of Fire

Fire is considered the greatest hazard among those interviewed in regard of usage of FRP in commercial shipbuilding. Along with that also the risks associated with heat and flame. While all stakeholders recognized that the fire hazard is always present, they did not as a group share opinion on fire when seeing it as a risk though.

An example that was referred to in several of the interviews was the fire onboard Norman Atlantic the 28th of December 2014. Norman Atlantic was a steel ship constructed to have a minimum performance within 60 min of exposure to a standard fire curve, which withstood a fire for 24 hours without suffering a collapse. This example shows that even though steel is only tested and proven to maintain strength and integrity in a 60 min fire it is capable of maintaining strength and integrity for a much longer period of time. This is also called implicit robustness. A ship made entirely or partly in FRP could probably not have sustained a fire, similar to that on Norman Atlantic, for as long a period of time, and could not have been its own best lifeboat. Then again, a ship with FRP would have been another design with another approach to fire safety. The different point of view presented in the repeated example indeed seems to be affected by the individuals' belief. Making it a picture of the current status in state of mind more than an illustrative example of anything else.

Findings from interviews can be detailed further into a technical aspect and a regulatory aspect.

The technical aspect concerning the ever present fire hazard is looking at ways to perhaps minimize the fire risk. Up to this point it is still uncertain whether it is possible to develop applicable non-combustible FRP. Even if the fiber material does not burn, the resin is likely to. While it is unknown what might be possible in terms of the material, the technical perspectives

gives rise to the question of possibly developing fire-resistant system solutions.
When looking at fire hazard one needs not only to focus on flammability, but also on heat release in the high energy levels in a fire. Concerning heat, there is both pros and cons in the use of FRP. Due to low heat transfer, a fire might be better contained in FRP sections than in steel sections, and it might be possible for example to evacuate through a deck above the fire as long as the deck does not collapse. However, because of the low heat transfer, it is less effective to cool FRP surfaces from the outside compared to metals. About the latter, steel hulls have a significant help from seawater cooling below waterline, which FRP hulls or sections cannot benefit from.

Stakeholders have very different opinions on the technical matters - not all necessarily substantialized by facts, it seems. An obstacle is the technology behind, so there is quite a ways to go with the material development before it can meet demands. Regulations and technology need to follow each other.

Concerning the regulatory aspects, the mere fact that there is not going to be a new SOLAS is the starting point of any discussion. Next is how to deal with chapter II-2.17; via risk analysis or comparative analysis to demonstrate sufficient safety level. It is important to distinguish between fire hazard, risk of fire and what happens in case of fire. According to the industry the regulatory bodies lack the necessary basis for decisions in the form of proven fire safety, while according to the regulatory bodies there are some fire safety challenges that has not been solved or shown how to handle. Due to this, many stakeholders stipulate the need of prescriptive rules on a material level. Though a key finding from the interviews is that it is difficult to make standards for the complex FRP nature and the broad range of combination options with the material.

Some stakeholders are quite opinionated on the regulatory aspect, for reasons that will be looked further into in the subsequent section of barriers and challenges related to them.

Due to it being on top of stakeholders' minds, fire matters in relation to use of FRP in commercial shipbuilding was included in the agenda as a discussion topic at the workshop. To set the scene for the discussion on fire in regard to FRP usage in commercial shipbuilding, there was a presentation of the COMPASS project.

Leading into the discussion at the workshop, some questions were highlighted already in the agenda. From the technical perspective, might it be possible to develop fire-resistant system solutions, for example by limiting the use of combustible materials for specific functions or sections on the ship?
From the regulatory perspective, are we within reach of adapting a Fire Safety Engineering approach to fire safety on board ships? Could fire safety become a widely accepted design parameter for future use of FRP?

Reference is made to the Idea Catalogue, for discussion on possible solutions.

A statement from the workshop, in terms of status, was the expectation that it will probably take another decade before something significant is recognized for usage of FRP in commercial shipbuilding. Whether this statement refers to a significant progress in terms of materials, a significant change of the rules or a significant change in the demand for FRP ships only time will show.

Toxicity Hazard and Risk of Toxic Smoke

Toxicity is regarded as the second highest ranked hazard among those interviewed. Smoke from burning FRP is toxic, and there is nothing suggesting otherwise. However, fire experts argue that all smoke is hazardous, so focus should shift to dealing with the risk of how to avoid exposure to smoke rather than focusing on the fact that the smoke is toxic.

Still, according to various stakeholders, there is an increased risk of the burning FRP material producing excessive amounts of smoke, toxic or not.

Structural Hazard and Risk of Collapse

Structural Collapse / Loss of strength were regarded as the third highest rank hazard among those interviewed. Whether the cause being a fire or a collision of some sort (either colliding, touching or grounding) the material's potential lack of sufficient residual strength poses a risk that stakeholders are generally concerned with.

Not ignoring the good structural features of FRP, in terms of flexibility and strength in all directions, these design upsides do not counter the issues in loosing strength as a consequence of for example elevated temperatures or deflection. Focus should then be of loss prevention and risk reduction, through other means that are not yet fully investigated.

Ice Hazard and Associated Risk

Ice sailing is regarded a high ranking hazard among those interviewed, though as mentioned not necessarily fourth, since the topic was brought in question by the project team to assess peoples' responses to it.

Ice as a hazard only exists if a ship operates in certain cold geographical areas. Whether it poses a bigger risk to a FRP ship compared to steel or aluminium ships, further depends on the operational mode and design criteria.

Among the group of interviewed people, there were varying opinions on the usability of FRP in ice. There were also different opinions on whether it is really of interest to focus on. A group of stakeholders is taking a lot of interest in further studying the possibility for FRP ships sailing in ice, while others state that FRP vessels will never sail in ice, so focus should be on other areas.

This is not a conclusion, but a status of where discussions are concerning this matter.

Operational Hazards and Risks

Wrong Emergency Response and operational hazards in general, are regarded as high ranking hazards among those interviewed. Matters such as crew manning and external readiness were mentioned, together with the level of knowledge (or lack of) about FRP on ships both in operation and emergency situations.

Without it being further investigated, it appeared to be the general belief that crews are likely not well prepared to handle critical situations, such as a fire on board resulting in burning FRP material, or if in the vicinity of the fire there is an unfamiliar material like FRP. This can result in the situation not being managed correctly or the fire not being controlled in time, and hence evolving into a more serious emergency.

The cure for this – as is typical for operational risks – is likely to involve increased focus on communicating relevant information, design of suitable response procedures, followed by education and training. Future initiatives in this regard needs to make sure that actions to control operational risks goes hand in hand with technological progress to be achieved in R&D. Current status from interviews is that it is generally not in place, even though FRP is already in use in certain applications.

7.2 Barriers and Challenges

Listing the barriers that stakeholders in total find the worst, in connection with FRP use in ships is not in any order of rank, but simply mentioned as what was identified during interviews which are as *perceived* to be the toughest barriers with hardest challenges associated:

- Regulation,
- Parties' limited risk analysis experience,
- Functional criteria lacking, methods and standards lacking,
- Damage detection and repair,
- Conservatism and 1. mover risk avoidance,
- Tendering rules,
- Shipyards issues on size and FRP engineering,
- FRP technological challenges and uncertainties,
- "Noise" from to many points of view (?)

These are all too differing extent further elaborated in the following. A couple of them were used as discussion topics at the LightShip workshop. For these as well, participants' responses and contributions are taken into consideration when reporting the status quo.

Regulatory Barrier and Challenges

The round of interviews revealed, not surprisingly, (as already surfaced in previous conversations and debates) that many industrial stakeholders find rules and regulation to be an obstacle towards using FRP in commercial shipbuilding. For some stakeholders, this means just stating that rules formulations are not well reflecting FRP as an option (or even ruling it out) and difficulties with interpretation of rules for the area. Others evidently, have their own frustration surfacing and blame the approval system as being too rigid. Whether this critique is fair or not, is not up to the LightShip project team to decide, and therefore is merely mentioned as part of the status quo.

What was expressed in a majority of interviews with the industry was the perception that the maritime authorities were inexperienced with evaluating analysis made under Regulation 17, especially when it involves risk analysis, but also in deterministic approaches around FRP usages. The perception was that the maritime authorities, classification societies – as well as everyone else in the value chain – in general lack comprehensive information on fire safety involving FRP.

Risk Analysis Barrier and Challenges

Related to the rules barrier is the fact that the industry, in general, has limited risk analysis experience. This, of course, constitutes a tough barrier to putting regulation 17 to use. Along with that is that even with identifying the right resources capable of performing relevant risk analysis, the approach is typically considered too risky in itself, as no guarantees can be given up front, that performing risk analysis will necessarily lead to approval.

To that end, there is a hard challenge for using risk analysis as it has implicit conflicting purpose. On one hand, there are stakeholders having an interest in making more standardized methodologies in the risk analysis approach to make it less expensive – and not least less time requiring in a phase where even small delays are costly. On the other hand, there is the approval system requiring comprehensive analysis carried out if approval shall be considered – not being compelled to assume any risk of approving something that potentially could turn out to have dramatic implication on safety.

The Lack of Standard Barrier and Challenges

The above leads directly to the related barrier of lacking functional criteria, methods and design standards. There are more sides to this.

One important is that equivalence to steel is a hard demand, when not describing the functional side of what alternative materials such as FRP then must live up to.

Another issue is that the nature of FRP makes it difficult to build a standard for it, with all the possible combinations of fiber materials, textures, and reinforcements, together with the binding and coating in terms of material, the core materials, the resin to fiber ration, adhesives used, but also the fabrication process and lay-up schedules for the composite structure. Even with similar ingredients, different companies (even different people in the same company) shall be expected to have different characteristics.

Problems exist regarding the scope of approval that may be allocated to a fire test of an FRP structure due to the fact that it is extremely difficult to predict what affect any changes to a fire tested laminate schedule have with respect to its reaction to fire, hence each different lay-up schedule will in general require a separate test. This is obviously a challenge in terms of standardization.

Also, counter to the idea of standardizing is, that if deciding on some standard FRP it will compromise the flexibility in design; one of the valued features for the material.

Damage and Repair Barrier and Challenges

Damage detection and repair appeared to be of concerns to some stakeholders interviewed, while others did not think it constitutes a real barrier. This led the project team to think the problem possibly was down to lack of communication rather than technical. Therefor it was thought to be an interesting topic for discussion at the LightShip workshop, so it was made part of the agenda.

The topic was introduced as ship owners and consultants having expressed some concerns in regard of damages to FRP ships (detection and consequences) and how to get repairs, yet shipbuilders, suppliers, and some researchers believe it to be less of a problem. That damage detection and also repair is not necessarily harder to resolve than for steel ships – just different.

Part of the difference is the need for tighter controls with respect to matters like temperature and humidity in the repair environment, when compared to those conditions required for a successful repair of structures manufactured from metallic materials.

Looking for clarification some questions were asked to the audience:

Are worries possibly higher than needs be?

What are the actual issues?

Are there ideas/solutions readily available to set aside the concerns?

In discussing the workshop topics with the Advisory Group, it was agreed that DTU should present R&D work they have been engaged in. This was leading into the discussion along with the questions posed. Participants in the workshop appeared to know about repairs being possible, but were not surprised, however, that the interviewees expressed concern for this, and they are sceptic about it.

In the workshop it was said that we are far down the road to an innovative approach but we keep comparing to steel. But even here there are problems legally with commercial ships. The legal and insurance people need to be involved in the discussion too, as a ship will lose its classification and insurance coverage when damaged.

There is also an important logistic issue with repairs. There is a need for skilled people to make carbon fiber repairs, but it is uncertain how many repairs are really needed. With very few needs for repairs, it will be hard to make a solid business of repairing.

Reference is made to the Idea Catalogue for discussion on possible solutions.

Conservatism as Barrier and Challenges

The shipping industry is seen (and also recognize itself) as being very conservative. In regard to FRP the higher investment price is a barrier, even though lower life cycle costs might be expected. Often shipowners will chose to stay with known technology. The avoidance of being first mover with all the risks and uncertainties involved is reflected throughout the industry. Everyone wants other parties in the value chain to take the first steps.

This was a discussion topic in workshop with the working title "Universal Business Case". The project team and Advisory Group found it of interest to see what could come out of such discussion, even though it had a very loose frame.

To start discussion, it was pointed out that various business cases are seen from supplier side to create demand for delivered solution within FRP for commercial ships. Still, the risks and uncertainties often appears to high to the buyers – resulting in preference of known and more proven technology, despite otherwise compelling business cases for FRP.

Questions were asked to the workshop audience to prompt for discussing this virtual "global" business case. Not thinking of this a joint venture or a business model, but to see if it seems within reach to create needed momentum.

Is the industry ready to talk about shared possibilities and willing to joint forces?

Is it possible to formulate a common interest where involved parties perhaps can tune their own desired output to better match others' expectations – in terms of physical properties as well as economy?

Can risk and opportunity be shared by stakeholders in the value chain? How?

Might this intercept the situation where players are looking to each other to make the first steps needed?

In the maritime industry, there is limited time and acceptance of unorthodox materials. It is important to consider it at society level and the risk Denmark is willing to make. We have safety scenarios, and civil engineering is researching this for society, but not ship-owners. However small the ship industry risks may in fact be in comparison to other risks assumed on daily business in other sectors, the society is not willing to take the same risks.

Discussions led to some findings, and some ideas for co-working in the future.

Reference is made to the Idea Catalogue for discussion on possible solutions.

Tender Barrier and Challenges

It has not been discussed at length, but it is seen as a fact from interviews, that tendering rules have new building cost as central for evaluation of bids. This is clearly a disadvantage for FRP ships due to higher new build costs, while life cycle costs – according to stakeholders upstream in the value chain – can be even significantly lower for FRP than for steel or aluminum.

Therefore it is a barrier for FRP that business cases reflecting also operating state of the new vessel is seldom part of requested tender material. Typically, such information may not even be volunteered, as it will make bid comparison harder for evaluation in the current set up.

Related to this issue is also investment challenges. Financing models to find capital for purchase of new building is found to follow similar pattern as tender processes.

Both regarding tender processes and financing applications it is also found that focus is on direct financial matters, and less on matters such as environment. Societal impact of the chosen technology is seen to be taken into account only on a smaller scale.

Shipyards seen as Barrier and Challenges

Some stakeholders claim that shipyards are not prepared to effectively handle FRP in commercial shipbuilding, and as such becomes a barrier to the industry getting accustomed to increased maritime usage of FRP. Stakeholders downstream the value chain are hesitant to engage in it, until the yards are seen as fully prepared. This relates very much to the barriers described for conservatism and first movers.

Especially for Danish shipyards it was pointed out (by other stakeholders than the shipyards), that yard and dock size are probably to small for building large superstructures, for example. Pending actual needed space, some yards perhaps can handle it in modules though. This is not investigated further in this project, so just stating it as part of status quo situation.

Lacking competences in FRP engineering is another issue at the shipyards (like with other stakeholders). Either educating (new) staff in FRP engineering, or subcontracting to FRP experts is needed to be able to build in FRP on larger scale, and the latter will not build competences. This is costly, and if order volume is low, there is not much incitement for yards to specialize in building and repair in FRP.

A strategic business decision with a broader perspective on markets and future has many aspects to consider. Amongst these are also the competitiveness between yards extending to build also in new material and those keeping business focus on traditional materials.

Technological Barriers and Challenges

FRP technological challenges and uncertainties with the material and how it might be applied are currently barriers preventing increased usage of FRP in commercial shipbuilding. As standalone technical material challenges as well as issues relating to specific use and approval criteria, as already described.

There is still a lot to be found out about the technology and its application in maritime business. The various qualities and how to enhance them and get the most benefit from it, without compromising safety.

Unlike other transportation sectors, the maritime industry as standard practice sends prototype designs sent directly into service. This is an issue, and not letting the business learn from experiments.

In regard of fire, experience is needed on how an FRP ship will burn and how long it takes. Currently, it cannot be stated with any certainty how different FRP is going to perform in a fire test.

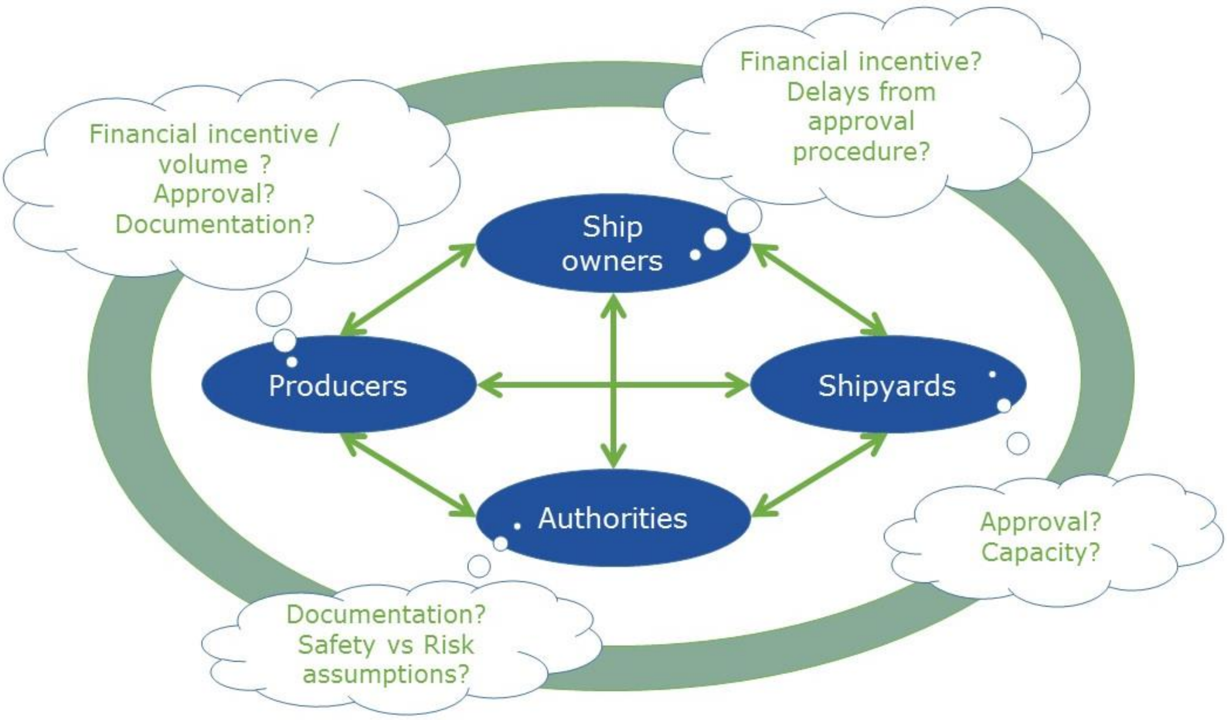
The “Many Points of View” Barrier and Challenge

As a peculiar finding from the interviews, it is seen that what might be described as “noise” from to many points of view, is somewhat clouding the message of overall benefits in using FRP. The many technical experts with individual specific knowledge and areas of interests are putting so many statements to table that it appears to have become a self-induced obstacle.

Even specialists that as a group are in favor of increased usage of FRP in commercial shipbuilding can find themselves almost opposite each other in subareas – partly because presenting arguments for own area of interest (and getting initiatives funded) becomes the driver behind discussions. Making it in fact counter to the purpose and the bigger picture, and therefore to some extent resulting in close down of topics that very well could be successful business ideas, if brought differently to the scene.

7.3 Interdependencies

Many of the previous barriers and challenges were said to relate to each other and be very interdependent. Right now many stakeholders are waiting to see if something happens elsewhere in the value chain, instead of taking (new) own or joined actions to move forward. There are a few exceptions to this, but generally the interviews identifies the isolated approach being the norm, with individual stakeholders pointing to others as needing to take the first steps. Barriers and interdependencies can be depicted as follows:



This picture of interdependency was discussed in the LightShip workshop. Participants agreed to its premises and said it to be a classical chicken and egg situation. What steps to take to possibly overcome the identified barriers and proactively move out of the status quo are described in the Idea Catalogue, the other main delivery from the LightShip project.

8 References

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9 Appendices

- Appendix I – List of interviews (not resumes, but names, titles, dates, form (visit/phone))
- Appendix II – List of workshop participants
- Appendix III – Table overview of development projects
- Appendix IV – List of generic topics covered in interviews
- Appendix V – Workshop agenda