A “Fast Track to Approval” Process for Innovative Maritime Solutions

Stéphane Paboeuf¹, Arnold de Bruijn², Franz Evegren³, Matthias Krause⁴, Marcel Elenbaas⁵

¹Bureau Veritas Marine & Offshore, 8 boulevard Albert Einstein, 44323 Nantes, France
Corresponding author: stephane.paboeuf@bureauveritas.com
²Netherlands Maritime Technology, Boompjes 40, 3011 XB Rotterdam, Netherlands
³RISE Research Institutes of Sweden AB, Brinellgatan 4, 504 62 Borås, Sweden
⁴Center of Maritime technology, Bramfelder Straße 164, D-22305 Hamburg, Germany
⁵Damen Schelde Naval Shipbuilding, De Willem Ruysstraat 99, 4381 NK Vlissingen, Netherlands

Abstract. RAMSSES (Realisation and Demonstration of Advanced Material Solutions for Sustainable and Efficient Ships) is an Innovation Action project partly funded by the European Commission in the framework of the H2020 program. During the 4 years of the project, 13 demonstrators will be developed and realised to demonstrate the feasibility and efficiency of the introduction of innovative materials in shipbuilding. Objectives of using new materials such as composite materials and high tensile strength steel are to reduce the weight of the vessel and to increase performance compared to when using conventional material.

The role of the classification society Bureau Veritas Marine & Offshore in the project RAMSSES is to help and support shipyards, designers, naval architects and owners to reach the above objectives while achieving existing rules and international regulations.

The paper gives an overview of current international regulations and especially the recent IMO (International Maritime Organization) interim guidelines MSC.1/Circ.1574 concerning the use of Fibre Reinforced Plastic (FRP) elements within ship structures. The global survey scheme applied by classification societies is described and the material approval process is detailed in the scope of innovative material certification. An accelerated approval process called “Fast Track to Approval” (FTA), developed in collaboration with RAMSSES partners and leading to the certification of innovative solutions in ship construction is presented in detail. The goal of the FTA is to have a rapid and efficient methodology for the approbation of new designs or solutions involving advanced materials. This process is based on risk analysis, including model and demonstrator case tests performed during the RAMSSES project. Moreover, a materials database has been obtained from mechanical and fire test results carried out on innovative materials, which is utilized for the FTA. The FTA also makes use of proposed standard risk scenarios, standard tests and standard solutions, in addition to the database to look up reusable data. This will accelerate the process for approval of innovative maritime solutions for sustainable and efficient ships.
Keywords: Fast Track to Approval, composite materials, risk analysis, certification.

1 Introduction

Innovative and lightweight materials applied in ship structures have the potential to improve life cycle performance and to reduce the environmental footprint significantly. In recent years, considerable progress has been made in research and development, leading to the first commercial application, such as the car carrier SIEM Cicero, built by Uljanik shipyard in Croatia which is equipped with cargo deck panels made of composite material. However, the use of advanced materials in the maritime sector is lagging behind the potential. The Innovation Action RAMSSES, co-funded by the European Union, is aiming to tackle the most relevant barriers that hinder a broader and quicker technology uptake, thus to obtain recognition and an established role for advanced materials in the maritime industry. As Fig. 1 illustrates, RAMSSES is acting on three layers, each of them addressing at a particular strategic objective.

Fig. 1. Layer structure within the RAMSSES project and its main objectives (right).

The development and demonstration represents the bottom layer in the RAMSSES pyramid and includes 13 demo cases RAMSSES. They cover the entire range of innovative materials (metallic, non-metallic), ship types (from small work or leisure boats to big cruise vessels), types of structures (ship hull, components not contributing to global strength, major outfitting equipment) and volumes (custom made, standardised structures). Furthermore, the project is developing all the production, assembly and after sales processes which are required for successful technology introduction both in shipyards and on board. Fig. 2 shows a representation of a virtual ship in which all 13 demonstrators are implemented.

A series of test campaigns and life cycle analyses are performed in the assessment layer, with the aim to show that the suggested solutions are ready to gain regulatory approval and acceptance by customers. This readiness means that the innovative material have passed a process defined in RAMSSES for class rules application and alternative design for fire safety.
The paper at hand is concentrating on the top layer in Fig. 1, i.e. the integration and communication of project results into the industry and into the regulatory community. Particularly, this paper focuses on those activities which aim at developing and suggesting measures towards regulatory frameworks that support a quicker exploitation of new materials’ potentials, the so called “Fast Track to Approval”.

2 Motivations

There is a limited field history of FRP composite structures in commercial application on SOLAS [1] ships. Approval of the materials from a mechanical perspective requires a thorough testing procedure, and from a fire safety perspective it is not possible to refer to the prescriptive regulations in SOLAS [1] since the material is combustible. It is instead necessary to perform a risk assessment which demonstrates that equivalent fire safety is achieved. These procedures need to be done case by case and are often time consuming and costly. From a designer perspective, the general wish is a simpler and more straightforward procedure, with examples of often acceptable solutions. A guideline providing such recommendations would speed up the design and approval process in several ways, making it shorter and more efficient. From the approving authority perspective, it is also possible to improve the efficiency of the procedure and there is a need to harmonize in competence and acceptance of different solutions. Hence, “Fast Track to Approval” guidelines with recommendations on a more standardized alternative design and approval procedure for mechanical and fire safety, including examples of promising solutions, would work on different levels to make the design and approval of new material structure solutions less costly, less time consuming, more efficient, more harmonized and quality assured.
3 Global Survey Scheme

From class rules perspective on structural aspects, different schemes are generally used by the classification societies to assess the design of ship constructions with composite materials. All these schemes are typically based on the following steps of assessment:

1. Raw materials,
2. Structure design,
3. Coupon tests of FRP,
4. Manufacturing and inspection at works,
5. Final tests and inspections.

Each step of the global survey scheme is further described below.

3.1 Raw materials assessment

The first step of the global survey scheme is the assessment of raw materials used for the construction of ships, based on the two following steps according to typical classification society rules:

- Raw material approval: carried out by tests to check the characteristics of the material considered (resin, reinforcement, core materials…). These tests may be performed by the raw manufacturer, or a testing laboratory accepted by the classification society and validated on the basis of the minimum characteristics defined by the classification society or the raw manufacturer (these tests are generally based on ISO standards or equivalent). As a rule, after satisfactory completion of tests, a certificate is generally issued by the classification society to the manufacturer for the raw materials tested. Required mechanical tests for raw material assessment (sometimes called homologation) are given in Bureau Veritas rules NR546 [1].

- Works approval: based on the quality system (complying with ISO 9000 or equivalent) of the manufacturer and on recognition of the production and quality control processes in order to demonstrate the ability to consistently manufacture the raw materials according to the raw material approved. As a rule, upon satisfactory completion of the process, a recognition certificate is issued by the classification society to the manufacturer for the raw materials considered. The process is more detailed in Bureau Veritas NR320 Certification Scheme of Materials and Equipment for the classification of Marine Units [3].
3.2 Structure design assessment

The second step of the global survey scheme is the hull structure design approval, based on the hull structure rules of the classification society. These rules are generally ordered as follow:

- Definition of structure design principle: including general requirements about the hull structure general arrangements, definition of structure detail construction…
- Definition of design loads to be used for the hull structure assessment: Global hull girder loads and local loads
- Definition of structure calculation methodology: approach of structure computation similar to those considered for other type of hull structure (steel or aluminum structure for example)
- Definition of FRP approach for the scantling calculation based on:
  - Theoretical methodology to apply to the FRP material analysis
  - Breaking values reference characteristics of FRP material
  - Scantling criteria: Based on safety coefficients in relation to the breaking stress or strain values reference of the composite and the actual stresses or strains.

Different general basic approaches are considered in the rules of the classification societies for the analysis of the composite materials:

- 1st approach: Approach based on the hypothesis that a composite laminate can be considered as a homogeneous material having mechanical characteristics (mainly young modulus and breaking stresses) defined taking into account the different reinforcement layers in the laminate: According to this theory, the hull scantling may be directly designed by thickness for plates and modulus for stiffeners.
  In this case, the reference values of breaking stresses are considered as a global laminate breaking stress.
- 2nd approach: Approach based on a ply by ply analysis, taking mainly into account the compression and tensile stresses or strains in the direction of fibres of the reinforcements.
  In this case, the reference values of breaking stresses are compression and tensile stresses of each layer.
- 3rd approach: Approach based on a ply by ply analysis taking into account the stresses in the direction and perpendicular to fibres, and the interlaminar stresses between layers.
  In this case, the reference values of breaking stresses are compression and tensile stresses in the direction of and perpendicular to fibres of layers, and interlaminar shear stresses between each layer.

As a rule, longitudinal hull girder strength and local strength are examined independently in the rules of the classification society. For large ship, it is reasonable to consider the stress combination between the effects of the global hull structure loads
and the local loads. It should be noted that such combination is not possible with the first approach defined here above.

The scantling check is based on the definition of safety factors equal to the ratio between the theoretical breaking stress/strain defined by the different methodology and the actual applied stresses/strains determined by the structure calculation. Even if it is difficult to directly compare the values of the safety coefficients taken into account in the structure rules of the different classification society (these values being dependent of the values of loads considered, the type of stress considered in the laminate, the theoretical breaking values considered…). Some classification society defined also a criteria based on maximum deflection values of the structure (plate and stiffeners).

3.3 Coupon tests of FRP

The third step of the global survey scheme is the mechanical and physicochemical tests on laminate panel produced by the yard in charge of the hull construction. The aim of these tests is to show that the mechanical characteristics of the laminates, produced with raw materials and production process used for the hull construction are at least equivalent to the theoretical mechanical characteristics considered during the structure design assessment.

The main mechanical tests, carried out according to ISO standards or equivalent, required by the classification society are:

- Tensile tests,
- Bending tests,
- Interlaminar shear tests,
- Measurement of density and content in fibre.

As a rule, the test panel may be taken from hull cut-outs or hull extension tabs or may be produced with the same process of the hull construction (same materials, layup, same process and cure system).

Specific process such as bond strength for the assembly of laminate or hull part may be required to be tested, see section 3.6.

3.4 Manufacturing and inspection at works

The fourth step of the global survey scheme is the manufacturing and inspection at works. The assessment of the manufacturer’s arrangement for production aims to verify that the hull construction is in compliance with the rules of the classification society.

As a rule, this assessment is based on:

- Periodical surveys carried out by a surveyor of the classification society during construction,
- Quality system used by the yard to ensure the conformity of the composite construction in relation with the hull structural drawings examined by the classification society.

3.5 Final tests and inspections

The final tests and inspection, within the scope of hull construction, are provided to confirm:
- The watertightness of hull, tanks and watertight boundaries (carried out by hydrostatic, hydropneumatic, air, hose testing or equivalent),
- The compliance of these tests and inspections with the rules of the classification society and the approved conditions.

Non-destructive testing may be used during the final tests (ultra-sonic testing, stereoscopy, radiography...).

Specimen tests are required on a case by case basis depending on the uncertainty. This kind of test is especially required for bonding assembly, “non-standard” joining technics, non-conventional design, new materials, etc.

In general, full scale tests are not required by the class. However, full scale tests can be useful to validate a structure in the framework of a research project for a scientific assessment. Full scale test may be required by the Risk Analysis.

### 3.6 Material Process Approval

The “classical process” for the testing of composite materials structure in shipbuilding can be represented by a pyramid as indicated on the Fig. 3. The test pyramid is composed on 4 levels:

1. Raw materials
2. Material coupon tests
3. Specimen tests
4. Full scale tests

![Composite material test pyramid.](image)

In general, tests are required by the classification society in the scope of the classification or certification. However, sometimes tests are also required by a risk analysis, especially in the case of an alternative design study.
4 Fast Track to Approval

The RAMSSES project is elaborating and testing a new approach to achieve a “Fast Track to Approval” (FTA) for innovative solutions, including new materials. This will be fed into the maritime rule making processes in the form of common positions and project guidelines. RAMSSES partners are also contributing to the development of cross-industry guidelines e.g. for new materials.

The “Fast Track to Approval” is to be:

- Simple,
- Generic,
- Readable by shipyards, engineering, naval architects, …
- Applicable to all RAMSSES demonstrator cases.

The FTA principle is based on the experience gained during previous research or commercial projects, by sharing knowledge with other industrial sectors, i.e. aeronautics, railway and automotive, by using existing database and by standardizing results.

The FTA is composed of two layers: one led by the classifications societies and one led by the shipyards, engineering or design offices, see Fig. 4. The FTA will be a first step to prepare an Approval In Principle (AIP), leading to the certification or the classification of a vessel or a part of the vessel. The FTA is developed in the RAMSSES project to propose an alternative to the prescriptive rules concerning the introduction of innovative materials in the shipbuilding industry. Fig. 4 resumes the process and gives the main steps of the FTA.

![Diagram](image-url)

**Fig. 4.** Fast Track to Approval, process overview.

The ambition is that the FTA will mainly be used for alternative design solutions performed in accordance with the circular MSC.1/Circ.1455 [4], see Fig. 5. In the
context of RAMSSES, several risk analyses are carried out to demonstrate the feasibility of new concepts, to validate different design options, to confirm the performance of innovative materials and to prove equivalent fire safety compared to conventional structures. All risk analyses will be supported by numerical simulations, such as Finite Element Analysis, Computational Fluid Dynamics, evacuation simulations, thermo-mechanics calculations, etc. Model or full scale test for the RAMSSES demonstrator cases, see Fig. 2, will be used to verify the assumptions in the assessment.

![Diagram](image-url)

**Fig. 5.** Design and Approval Process [4].
From the results of demonstrator case risk analyses, the FTA will propose standard risk scenarios, standard tests, standard solutions and a database to lookup for reusable data. The quantitative analyses are currently carried out on a case-by-case basis. The objective aims to develop standard risk scenarios covering a range of similar applications. These can be referred to in the future without the need to carry out extensive quantitative analyses or tests. The definition of standard risk scenarios will be based on the demonstrator cases developed in RAMSSES.

The standard risk scenarios will cover the following aspects:
- Fire safety,
- Stability, including damage stability,
- Materials,
- Structural arrangement.

For example, when evaluating fire safety for FRP composite structures, the encountered challenges are often similar. Standard risk scenarios developed in the project cover several applications and include scenarios defining suitable reaction to fire properties for external and internal surfaces as well as required fire resistance for internal and loadbearing bulkheads. As an input to the fire risk assessment, significant testing is often required to prove the functional properties. The second objective of the FTA is therefore the creation of a materials database, named RAMSSES Knowledge Repository, see Fig. 6. It is a web browser based platform on invitation access (https://repository.ramsses.eu/). In addition to descriptions of the maritime materials, it will define for example fire safety, mechanical and acoustic properties of materials tested standardized tests. A large number of tests, mechanical and fire tests, will be performed during the 4 years of the RAMSSES project on a multitude of materials, composites and metallic. The database of test results and pre-approved solutions, to be developed in RAMSSES, should avoid the necessity of repetitive tests if a simple qualitative risk analysis shows that relevant results and solutions are already available. In addition, numerical or statistical models will be developed during the project that may replace certain physical testing in the future. The approach will be documented in a project guideline, which may form the basis for future modified class rules. The feasibility of this procedure will be demonstrated in a showcase, using a RAMSSES demo case as reference, as presented in section 5.

The experience and procedures developed in RAMSSES need to be fed into the rule making process, with the final goal to implement the findings into new rules and regulations in the medium to long term. On the short term RAMSSES could deliver input to the evaluation of MSC.1/Circ.1574 [5]. Input to IMO and SOLAS needs to involve flag states, which are represented in the IMO. This will be achieved through consortium members working closely with their national authorities, like RISE (Sweden), Bureau Veritas (France), DSNS and NMTF (Netherlands). In addition to that, two other channels will be used: class societies, represented by IACS and shipyards represented by SEA Europe, have an advisory role as Non-Governmental Organiza-
tion at IMO. NMTF as a national shipbuilding association member of SEA Europe and Bureau Veritas as a member of IACS will serve these channels as well.

Fig. 6. RAMSSES Knowledge Repository platform (https://repository.ramsses.eu).

5 Shipyard perspective

Today, as in many industries, there is a drive for more durable solutions, CO2 reduction, reduction of lifecycle costs and reduction of operational costs. In the transportation industry this is almost always related to weight reduction (either over-all weight, or lower center of gravity). Composites offer weight saving as compared to traditional metallic solutions and reduce operational costs. Also composites could prolong lifetime as these structures do not corrode and, provided it is designed properly, can have a prolonged fatigue life.

For these benefits, composites have been a focus point for future ship structures for a long time. Though already commonly applied in leisure and fast passenger craft, the applications in large blue water vessels is lacking behind. The benefit from weight saving only really becomes evident if larger structures are being replaced from metal to composites. Then weight saving can result in a positive design cycle leading to less power required, leading to smaller and lighter propulsion further decreasing the weight, or allows adding for another key functionality set by our customers. In those cases composite structures are integrated properly in the overall design, offering a competitive advantage to our customers in Capex as well as Opex. Downside however, is that these larger integrated composite solutions, inevitably effect the overall design and need to be approved by classification societies. Despite significant improvements in the last decade, especially for fire safety, the legislation is still unclear, other than that the overall safety should be demonstrated at least to be equivalent to the original steel design.
This is where the importance of a fast track to approval comes in place. Yards can only offer large one-off capital products into the market for which the design is approved, or at least clear evident is available that the product, with integrated composite structure, can be approved within a well-defined functionality, cost and lead-time as set in the contract between yard and customer. The design appraisal should therefore be set prior to contract, giving time and cost pressure on the approval trajectory. This illustrates the importance of the “Fast Track to Approval”.

The Damen involvement in various EU research projects (De-Light, BESST, RAMSSES, and Qualify), and real commercial applications such as the composite waterbus, gives Damen knowledge and confidence that composites can be applied sensibly, and ensuring safety, at least equivalent to metallic structures. Recommendations from a shipyard perspective on how to fasten this process, especially prior to contract, are reflected in this paper. These may lead to recommendations what should be set prior to contract, and which issues can be dealt with after contract.

6 Conclusion

Any product design, material or production process in the maritime sector is subject to approval by supervising authorities, mostly based on prescriptive rules and regulations. This may partly be attributed to a certain conservative attitude in the sector. However, this approach is duly justified by the extreme operational conditions and long life times under which maritime products need to survive, the difficulty of human emergency interaction at sea, and the potentially extreme consequences of the failure of maritime products on human life, maritime assets and the environment.
The proposed “Fast Track to Approval” respects the need for a thorough evaluation of safety of the design while avoiding the necessity of repetitive tests if a simplified qualitative risk analysis shows that relevant results and solutions are already available in the database. The intention of RAMSEES is to define and apply a smart and efficient approach while never compromising safety.

During the next phase of RAMSEES project, this approach will be applied on the demonstrator case developed by DAMEN in order to demonstrate its feasibility and efficiency.

References

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