RAMSSES - Realisation and Demonstration of Advanced Material Solutions for Sustainable and Efficient Ships

Work Package 16 - Composite superstructure module on a steel deck for multi purpose vessels

WP leader: E. BILLAUDEAU
Naval Group
Content

Overview of the H2020 RAMSSES Project

Introduction to WP16

• Objectives
• Description of the demonstrator case
• Work program

Technical progress: Presentation of the work done so far

• Design and structural analysis of the demonstrator case
• Experimental campaign on coupons and assemblies

Work to be done

• Next steps and 1-year timeline
OVERVIEW OF THE H2020 RAMSSES PROJECT

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Realisation and Demonstration of Advanced Material Solutions for Sustainable and Efficient Ships

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European Commission

FibreShip Workshop: June, 2019; La Ciotat
RAMSES WP 16 – Composite superstructure module on a steel deck for multi purpose vessels ; WP leader: Emilien BILLAUDEAU (Naval Group)
Call Topic: MG-2.2-2016 Development and Use of High Performance and Lightweight Materials (IA)
Coordinator: CETENA (Italy) – Financial and Administrative
CMT (Germany) – Technical and Dissemination

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<table>
<thead>
<tr>
<th>WP No</th>
<th>Cluster Title / WP Title</th>
<th>Lead</th>
<th>Focus Material</th>
<th>TRL Target</th>
<th>Validation</th>
</tr>
</thead>
<tbody>
<tr>
<td>WP09</td>
<td>Modular Light System for Less Critical Internal Walls and superstructure</td>
<td>NetComp</td>
<td>BALTICO</td>
<td>6-7</td>
<td>(pre)approval</td>
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<tr>
<td>WP10</td>
<td>Lightweight Components for High Loads and Fire Class</td>
<td>PODCOMP</td>
<td>composite</td>
<td>6-7</td>
<td>(pre)approval*</td>
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<tr>
<td>WP11</td>
<td>Propeller blades by additive manufacturing</td>
<td>NG</td>
<td>metal</td>
<td>4-5</td>
<td>shore based</td>
</tr>
<tr>
<td>WP12</td>
<td>Lightweight Rudder Flap</td>
<td>BMS</td>
<td>composite</td>
<td>6-7</td>
<td>onboard</td>
</tr>
<tr>
<td>WP13</td>
<td>Ship Integration: Composite</td>
<td>DSNS</td>
<td>composite</td>
<td>7</td>
<td>onboard</td>
</tr>
<tr>
<td>WP14</td>
<td>Modular Decks for RoRo vessels</td>
<td>MEC</td>
<td>various</td>
<td>6</td>
<td>onboard</td>
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<tr>
<td>WP15</td>
<td>Lightweight aluminium and composite walls for Work Boats</td>
<td>ULU</td>
<td>composite</td>
<td>7</td>
<td>onboard</td>
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<tr>
<td>WP16</td>
<td>Composite superstructure module on steel deck for multi purpose vessels</td>
<td>DSNS</td>
<td>various</td>
<td>6</td>
<td>shore based</td>
</tr>
<tr>
<td>WP17</td>
<td>Custom Made Hull for Offshore vessel</td>
<td>DSNS</td>
<td>composite</td>
<td>6</td>
<td>shore based</td>
</tr>
<tr>
<td>WP18</td>
<td>Multi material lightweight cabin for passenger ships</td>
<td>CdA</td>
<td>various</td>
<td>6-7</td>
<td>shore based</td>
</tr>
<tr>
<td>WP19</td>
<td>Highly Loaded structural details from high tensile steel in passenger and research vessels</td>
<td>CET</td>
<td>FC</td>
<td>steel</td>
<td>6</td>
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<tr>
<td>WP20</td>
<td>Lightweight Decks using High Tensile Steel in cruise ships</td>
<td>CET</td>
<td>MT</td>
<td>steel</td>
<td>7</td>
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<tr>
<td>WP21</td>
<td>Composite Overlay to repair and improve metallic and non-metallic structures</td>
<td>CET</td>
<td>CARDA</td>
<td>various</td>
<td>7</td>
</tr>
</tbody>
</table>

*commercial approval to be done outside the project based on data elaborated in RAMSSES*
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**Objectives:** Conception, production, testing and validation of a demonstrator for composite superstructure meeting multi-criteria made up of a module on metallic deck:

- Reduce production costs
- Reduce the weight of multifunction composite structures
- Fire resistance
- Health monitoring systems
- Quick & easy (dis)assembly on steel deck
- Noise insulation
- Mechanical resistance / product lifetime
- Use of recycled/bio-based/recyclable materials

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### RAMSSES WP 16 - Schedule

|------------------------|-----------------------------------------------|--------------------------|----------------------------|-------------------------------|---------------------------|-------------------------|--------------------------|---------------------------------|

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FibreShip Workshop: June, 2019; La Ciotat

RAMSSES WP 16 – Composite superstructure module on a steel deck for multi purpose vessels; WP leader: Emilien BILLAUME (Naval Group)
Design assessment of the WP16 demonstrator case
Analysis based on BV rules:
- NR 467
- NR 546

Task 16.3 – Requirements
Task 16.4 – Product design
Task 16.5 – Product engineering
Task 16.7 – Site testing
• Offshore Patrol Vessel

Ship particulars:
- Full Load Displacement at delivery: ≈ 3000 tons
- Draught: ≈ 3.9 m
- Length between Perpendiculars: 105 m
- Length Overall: 110 m
- Breadth at the waterline: 14 m

• Classification requirements
  - NR467 Part D chapter 16 of BV rules gives applicable requirements for ship classed with OPV service notation.
  - Loadings from NR467
  - Calculation methodology, testing, surveys from NR546
  - Safety coefficients from NR600
Structural analysis approach

- Serial approach:
  Global analysis first then transfer of boundary conditions to assemblies models

  - Experimental results (tests on coupons)
  - Mechanical properties
  - Assumptions note related to the application case

  Global Finite Element Analysis (FEA)
  Global model of the selected module in order to comply overall requirements

  - Experimental tests on Structural Assemblies
  - Experimental tests on adhesive lab Specimens

Task 16.4 – Product design
FEA of the superstructure block

Global model of the selected module in order to comply overall requirements:

- Eigen values
- Deflection
- Buckling stability
- Tsai-Wu failure criterion (GFRP)
- Core analysis

<table>
<thead>
<tr>
<th>Composite superstructure block (WP16 design)</th>
<th>Metallic superstructure block (Original design)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural calculation made by Naval Group</td>
<td>Up to 60% of weight reduction</td>
</tr>
<tr>
<td>Internal referential</td>
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Task 16.4 – Product design
• Overall design of the demonstrator case and its junctions
Selection of materials

- Material selection for the sandwiches panels
  - Skins: Glass/Vinylester for external bulkheads (evaluation of Carbon/Epoxy) Glass/Polyester or Glass/Vinylester for internal bulkheads
  - Core: 3D reinforced foams or balsa wood
  - Protection against fire: LEO Coated and/or intumescent paint

Sandwich lay-up (GFRP + reinforced foam) before vacuum infusion

Sandwich lay-up (CFRP + Balsa) before vacuum infusion

Sandwich pannel with intumescent paint
• Adhesive bonding with the disassembly function
  – Multi-material assembly
  – Flexible resin (damping, tolerance, thermal expansion)
  – Disassembly function by heating the metallic part

  **Evaluation:** Heating by a hot air device
  **Industrial potential:** Joule effect heater with addings in the adhesive or induction heating
• Experimental approach

General Campaign

- Experimental approach

**Demonstrator scale tests**
- Fire behaviour tests (WP07)
- Mechanical tests on assemblies

**Intermediate level tests**
- Joints and composite panels
  - Mechanical tests on joints (static and cyclic)
  - Fire behaviour (WP07 - RISE)
  - Resistance to marine environment evaluation

**Material coupons tests**
- Mechanical tests (WP16 and WP07 - Fraunhofer)
- Physico-chemical tests (WP16 and WP07 - Fraunhofer)
- Fire reaction tests (WP07 - RISE)

- Task 16.7 – Site testing

- Load bearing Bulkhead – FRD Test according to FTP code part 11
- Non-load bearing Bulkhead - Fire Resisting Division Test (FRD) according to FTP code part 11
- Assembly on the steel deck
- T Assembly between nonload bearing and load bearing bulkhead
- L Assembly of load-bearing bulkhead
• Experimental approach – Tests on coupons

**Mechanical**
- **Monolithic and skins**
  - 3-point bending
    - ISO 14125
  - Interlaminar shear test
    - ISO 14130
  - Tensile test
    - ISO 527
- **Sandwich**
  - 3-point bending
    - NF T54-606
  - 4-point bending
    - NF T54-606
  - Interlaminar shear test
    - NF T54-606

**Physico-chemical**
- **Monolithic, skins and core materials**
  - Density
    - ISO 1183
  - Fiber content
    - ISO 1172
  - DSC
    - Differential Scanning Calorimetry
      - ISO 11357
  - TGA
    - ThermoGravimetric Analysis
      - ISO 11358

**Fire**
- **Sandwich samples**
  - Cone calorimeter
    - ISO 5660

• NI546 based approach:
  - A first campaign has been performed by Naval Group to select the materials
  - Then 2 materials will be tested at Fraunhofer within WP07 framework
Experimental Campaign

Task 16.7 – Site testing

- Experimental approach – Tests on coupons
  - Experimental campaign on monolithic coupons to feed a decision matrix based on mechanical and physicochemical tests
    - Reinforcements: Glass, Carbon, Basalt, flax
    - Resins: Vinylester, polyester, epoxy
    - Fire retardant: FR infusion resin, coated fabric, intumescent gelcoat
  - 3-point bending on sandwich samples

- Sandwich lay-up (vinylester GFRP + reinforced foam)
  Shear strength: 1.9 MPa

- Sandwich lay-up (polyester GFRP + balsa wood)
  Shear strength: 4.0 MPa

- Sandwich lay-up (epoxy GFRP + PET foam)
  Shear strength: 0.9 MPa

Tensile test on woven flax/baslat monolithic coupons
• Experimental approach – Intermediate level tests – Tests on adhesives

**Modified Arcan test**

**Test on coupons**

**Objectives of this campaign:**
- Adhesive multiaxial characterization (static and fatigue)
- Definition of the linear elastic material constants
- Definition of a failure stress based criterion

**Objectives of this campaign:**
- Evaluation of the intrusivity of the fibre bragg grating sensors
- Behaviour of the assembly with and without primary
- **Durability** (unaged and aged samples)
Experimental Campaign

Task 16.7 – Site testing

- Experimental approach – Intermediate level tests – Tests on adhesives
- **Experimental approach – Demonstrator scale tests – Test on junctions**

**Mechanical tests on assemblies**
Monotonous and cyclic loadings with SHM (sQRS and Bragg gratings)

<table>
<thead>
<tr>
<th>Configuration 1</th>
<th>Configuration 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bonding principle of 2 external bulkheads</td>
<td>Assembly detail of steel deck and internal composite bulkhead</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Configuration 3</th>
<th>Configuration 4</th>
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</thead>
<tbody>
<tr>
<td>Assembly detail of steel deck and external composite bulkhead</td>
<td>FAUSST System</td>
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<td>Assembly detail of steel deck and external composite bulkhead</td>
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</tbody>
</table>
Multiaxial fatigue platform (ENSTA Bretagne):

**hydraulic actuators (400 kN): bending**

Design of specific clamping device
Experimental Campaign

Task 16.7 – Site testing

• Characterization of structural specimens of bulkhead junctions
  – Structural specimen test campaign:
    • Design of a clamping device
    • 1 loading case: Bending
    • Monotonic and Fatigue tests
  – Numerical approach:
    • FEA linear elastic model from Composite (Naval Group) and Adhesive (ENSTA B.) material parameters
    • Based on a coupled approach: Definition of the process zone for each loading case to evaluate the stress criterion

![Diagram of clamping device and load cases]
Production of extra sandwich panels

- Fire and mechanical tests within WP07 framework

Analysis and production of junction specimens

- Composite and multi-material junctions (rivets, adhesive and FAUSST)
- Integration of Structural Health Monitoring (SHM)

Test on junction specimens

- Monotonous loading
- Fatigue evaluation

Production of large panels for demonstrator case and fire tests

- Single Burning Intems (SBI)
- Fire Resisting division Tests (FRD)

June 2019

- Demonstrator scale tests
- Intermediate level tests
- Material coupons tests

June 2020

- Demonstrator case finalized
- Single Burning Intems (SBI)
- Fire Resisting division Tests (FRD)
Thank you for your attention

Any question?

Contact: emilien.billaudeau@naval-group.com
RAMSSES receives funding from the European Research Council (ERC) under the European Union’s Horizon 2020 research and innovation programme under grant agreement n° 723246.

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