DBI

The COMPASS Project

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E-LASS

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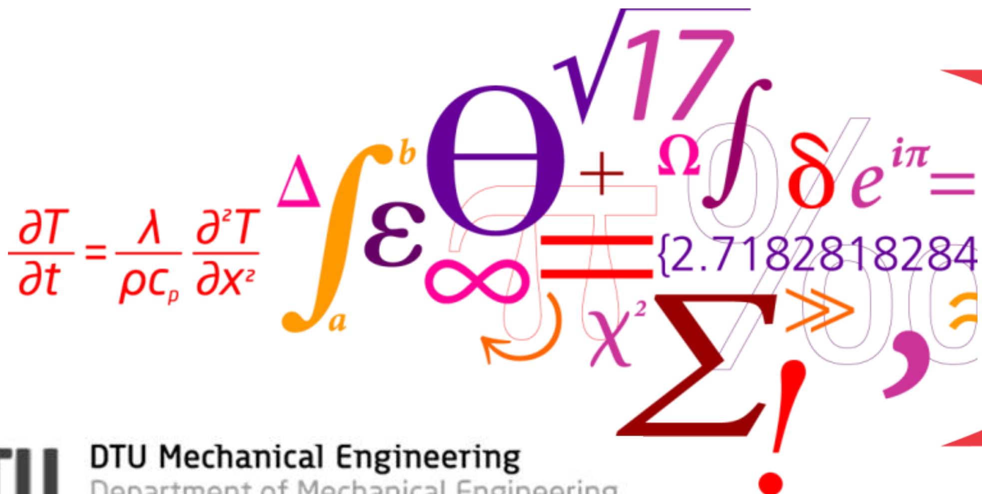

DTU Mechanical Engineering
Department of Mechanical Engineering

DTU Civil Engineering
Department of Civil Engineering

Project organisation

Partners

DTU Technical University of Denmark

DTU Mechanical Engineering
Department of Mechanical Engineering

DTU Civil Engineering
Department of Civil Engineering

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Niels Hjørnet Yacht Design

Funding

Danish Maritime Authority

Den Danske Maritime Fond

Sponsors

Diab

Morgan Advanced Materials

Scandlines

www.dbi-net.dk/compass-projekt/

COMPASS

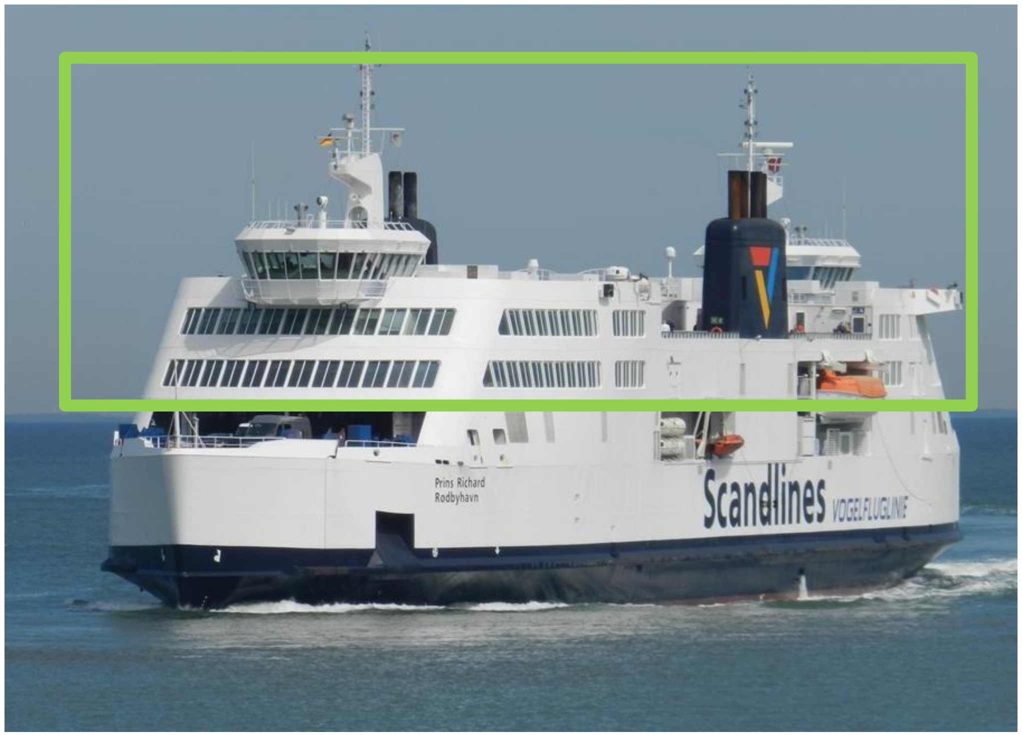
COMPASS stands for COMposite PASsenger Ships (2014-2016)

Superstructures are substantially larger in Passenger ships

-> greatly affect the stability

-> larger percentage of lightship

Large potential for retrofit and new-builds using composite materials



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Project's Main Activities

STRUCTURAL DESIGN, ANALYSIS AND TESTING

- Structural design of sandwich composites
- Modeling and FE analysis of the superstructure
- Mechanical testing at elevated temperatures
- Effects on the ship

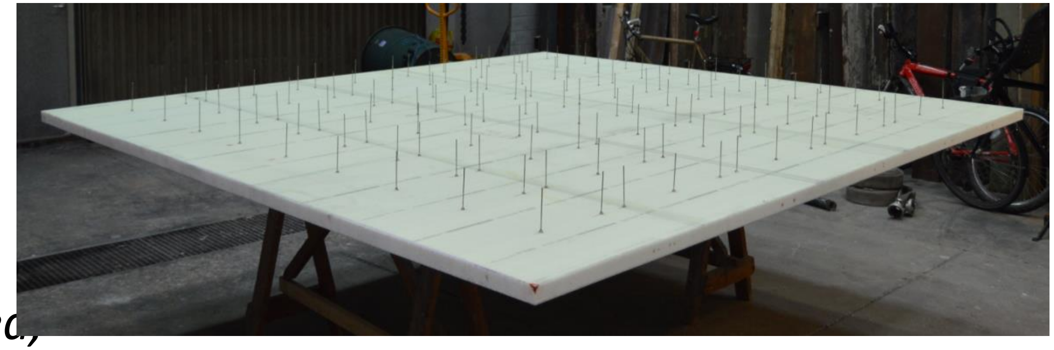
FIRE SAFETY TESTING AND ANALYSIS

- Reaction to fire properties of composites
- Development of numerical tools

INVESTIGATION UNDER COMBINED THERMOMECHANICAL LOADING

- Joint design (FRP superstructure to steel deck)
- Development of a medium-scale test method with combined thermal and mechanical loading
- Fire resistance and ultimate performance of metallic and composite bulkheads

Composite Structural Design

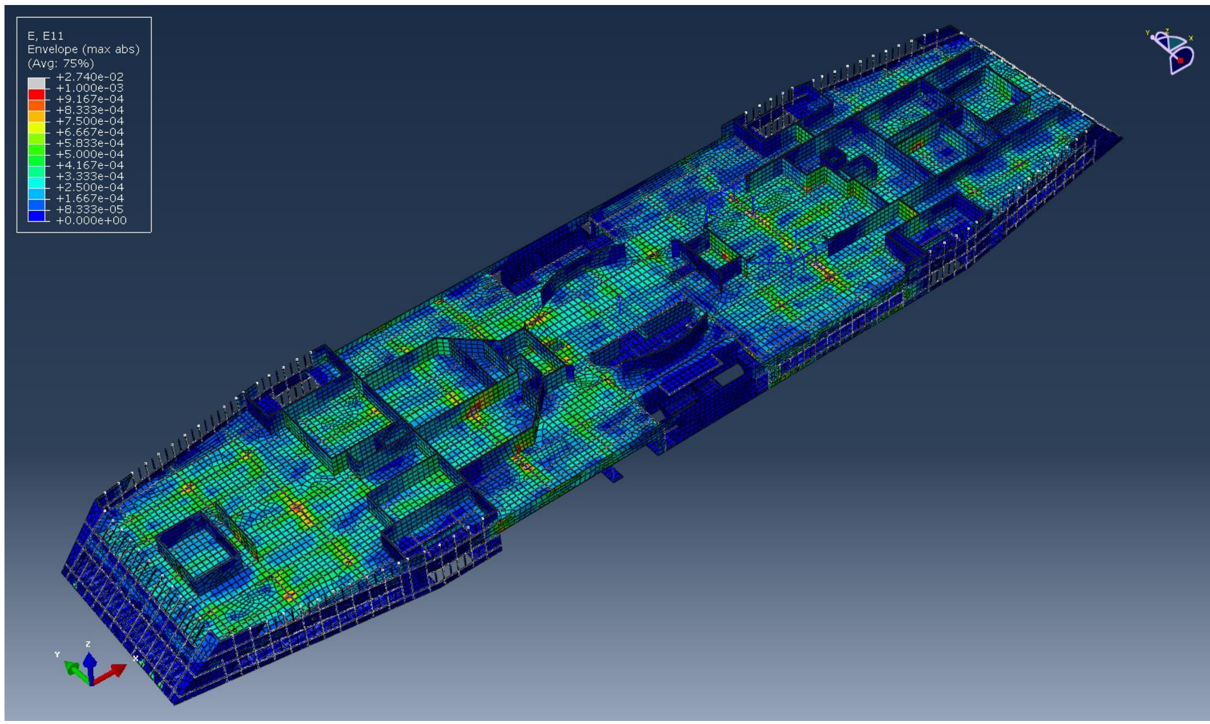


•Design loads:

DNV-GL Rules for Classification of Ships

•Scantling requirements:

DNV-GL's Rules for Classification of High Speed, Light Craft and Naval Surface



•Materials:

- Glass/epoxy laminate
- PET core P100 (DIAB)

•Structural Analysis (FEM)

- Steel
- Composite

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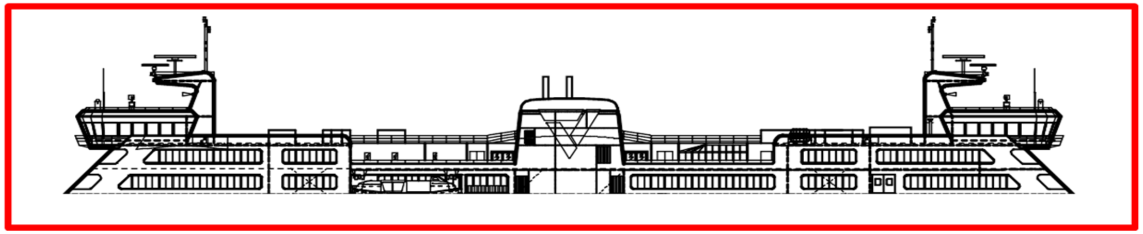
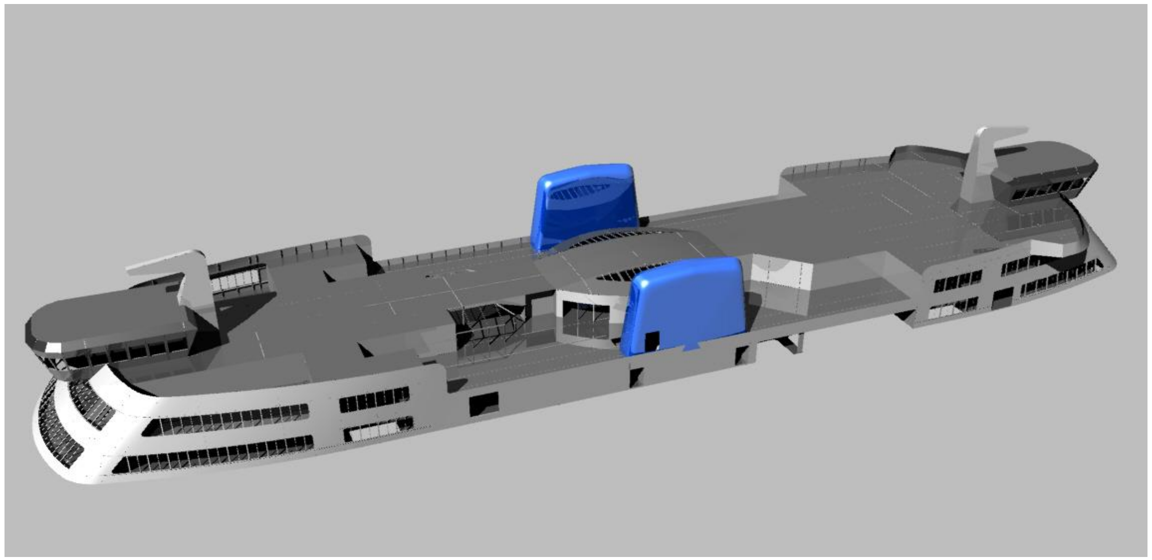
Effects on the ship



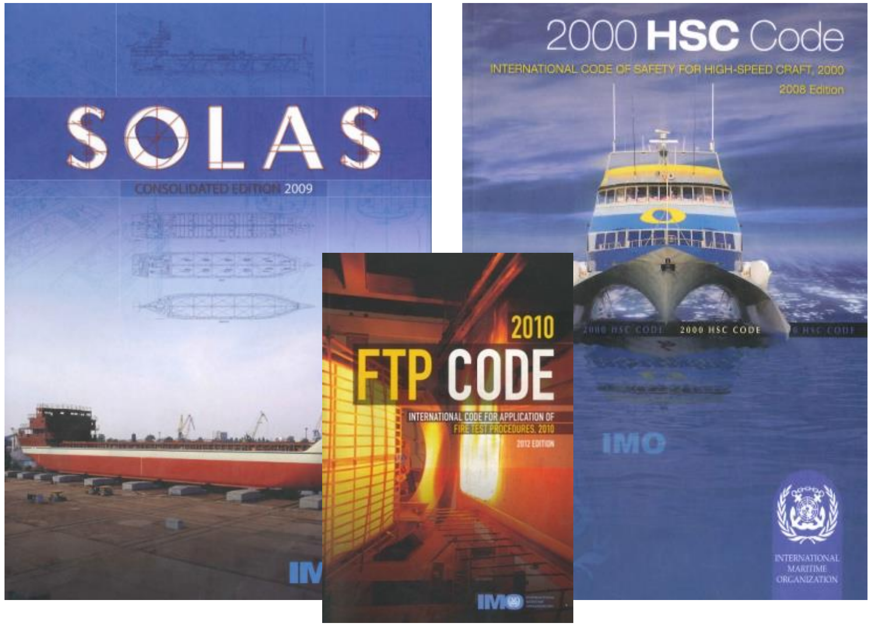


Lightship = Wst + Wot +Wm

		Steel	Composite
Weight of the superstructure to be retrofitted	[t]	475.4	142.5
Lightship	[t]	6346	6013

- Reduction of the Lightship and of its KG ≈ **5%**
- Increased overall stability
- Simplified estimation of annual fuel consumption ≈ **1.5% reduction**

Implicit Robustness



The combination of SOLAS/HSC and the FTP-code result in "an acceptable" level of safety.

Class A-60 (steel) - Performance

- Temperature exposure (ISO834)
- Loadbearing capacity – not evaluated

Class FRD-60 - Performance

- As Class A-60 (steel) plus,
- Loadbearing capacity (7.0kN/m)

"Implicit robustness" arise from using regulations beyond the intentions for which the regulations was written.

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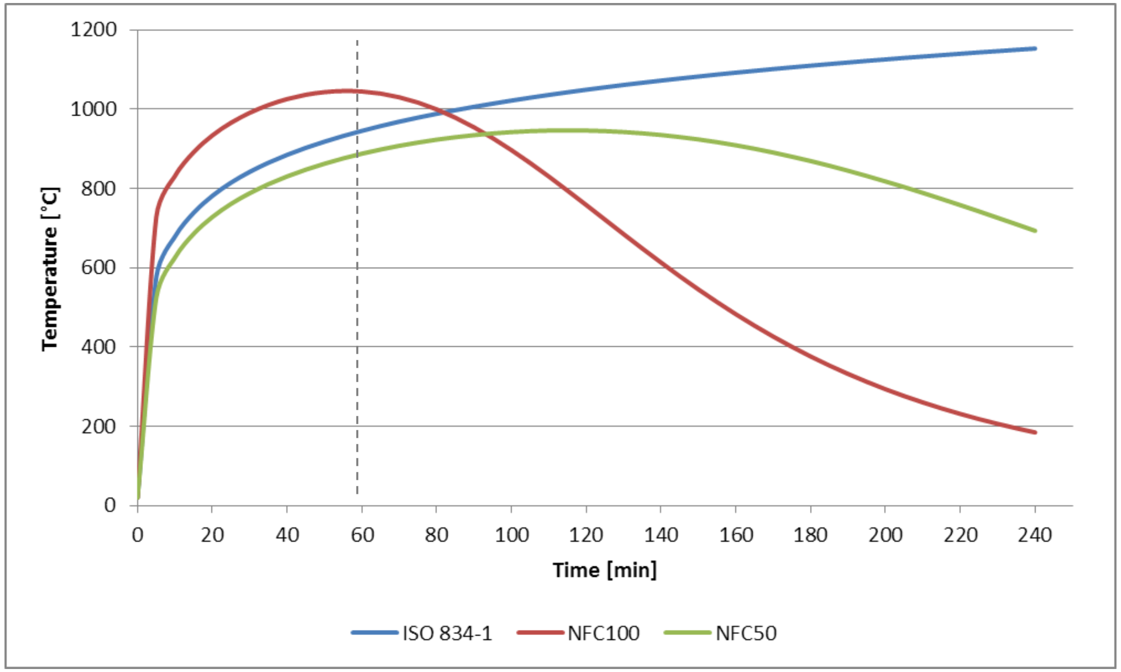
Full Scale tests

Bulkhead type	Fire curve	Mechanical loading
Steel	ISO834	7.0 N/m
	NFC50	510 kN/m Utilization: 26 %
	NFC100	
Aluminium	ISO834	7.0 N/m
	NFC50	123 kN/m Utilization: 50 %
	NFC100	
FRP	ISO834	7.0 N/m
	NFC50	36 kN/m Utilization: 50 %

All bulkheads insulated to 60 minute fire resistance according to the FTP Code



ISO curve vs considered Natural fire curves (NFC)

Full Scale tests

Steel, Aluminum, Sandwich dimensions: 3.14 x 2.93 m

- Steel Bulkhead according to existing drawings
- Aluminum and Composite Bulkheads designed based on DNV-GL's regulations

6.5 mm Thick plate
3 x 100x7 mm bulb flats

Steel

6.0 mm Thick plate
3 x 80x40x6 angle bars

Aluminum

1 x XE905 Biaxial E-glass +/-45
1 x XE905 Biaxial E-glass +/-45
40 mm Divinycell P100
1 x XE905 Biaxial E-glass -/+45
1 x XE905 Biaxial E-glass -/+ 45

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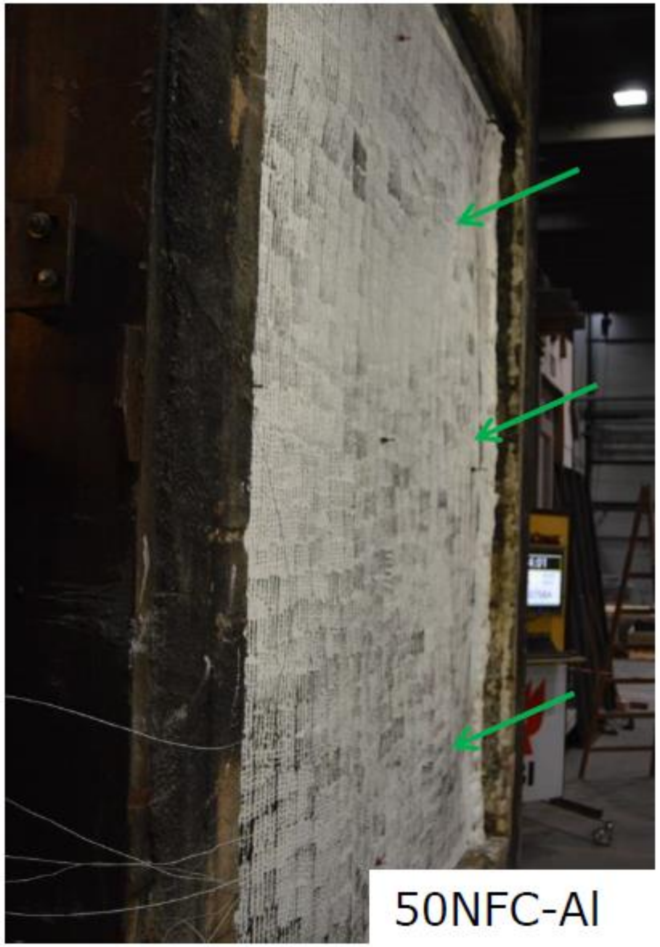
Full Scale tests

No critical structural failure at the metallic specimens

FTP Temperature criteria violated @ 50 – 70 minutes based on the scenario



50NFC-Al

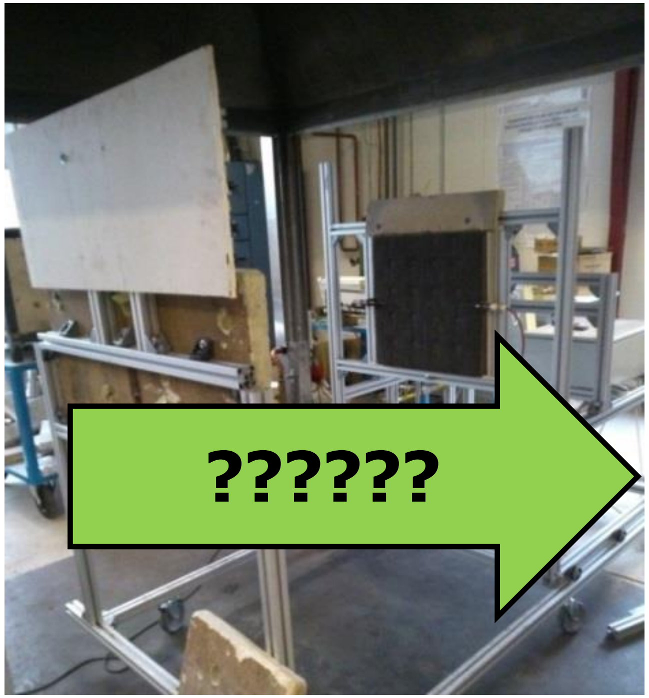
50NFC-Steel

Full Scale tests

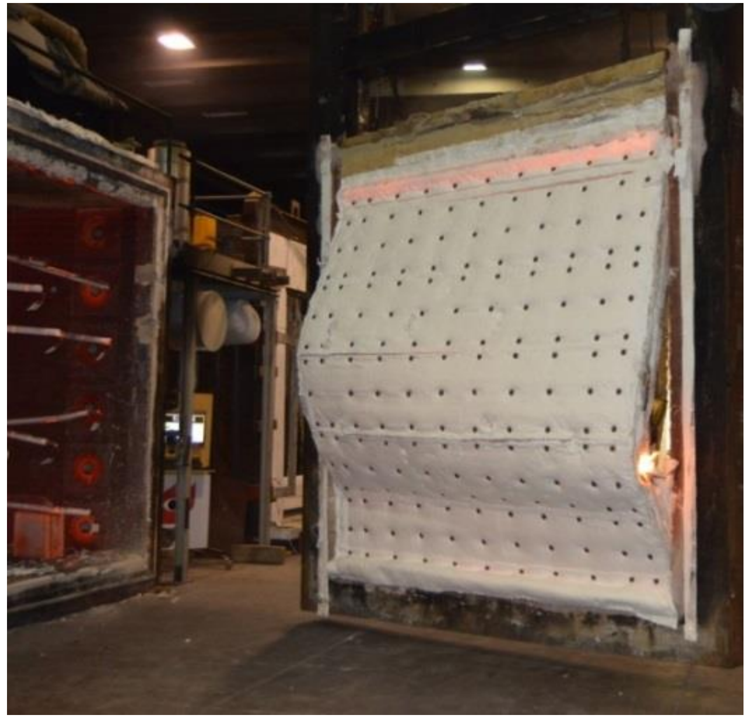
Loss of Load bearing capacity @ 82 minutes (ISO834) and @ 66 minutes (NFC)

Testing Scales

- **Small scale tests**
- **Cone Calorimeter**
- **Material Characterisation tests**
- Not Fire resistance tests



- **Intermediate scale tests**
- **H-TRIS**
- ***Can replicate the ISO834 curve + application of mechanical loading***



- **Full scale tests**
- **FTP Code**
- Costly, Pass or fail tests

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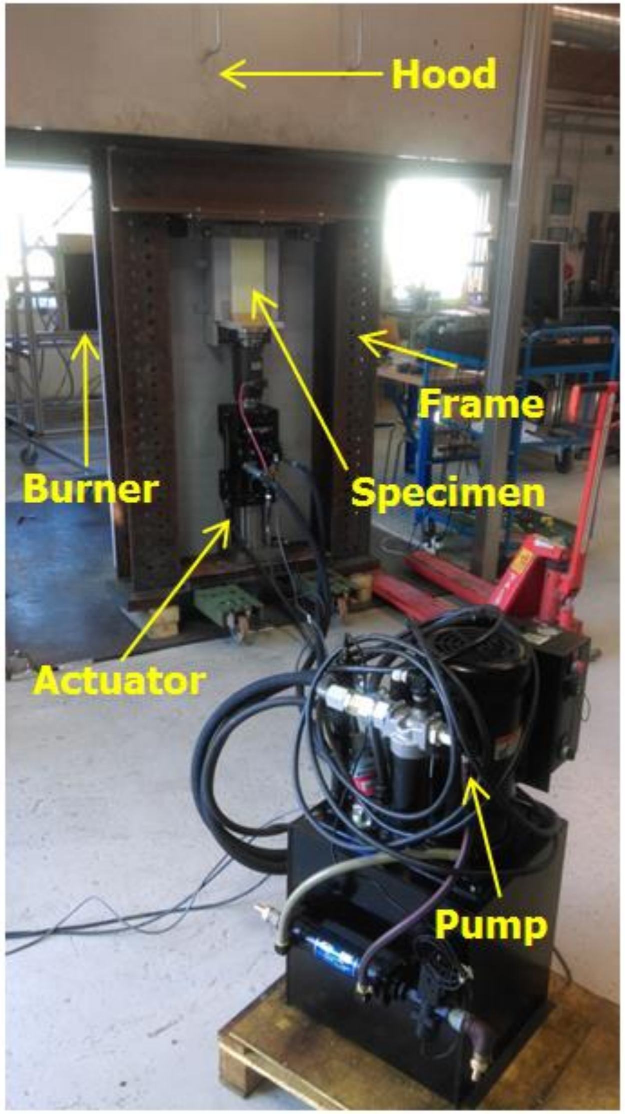
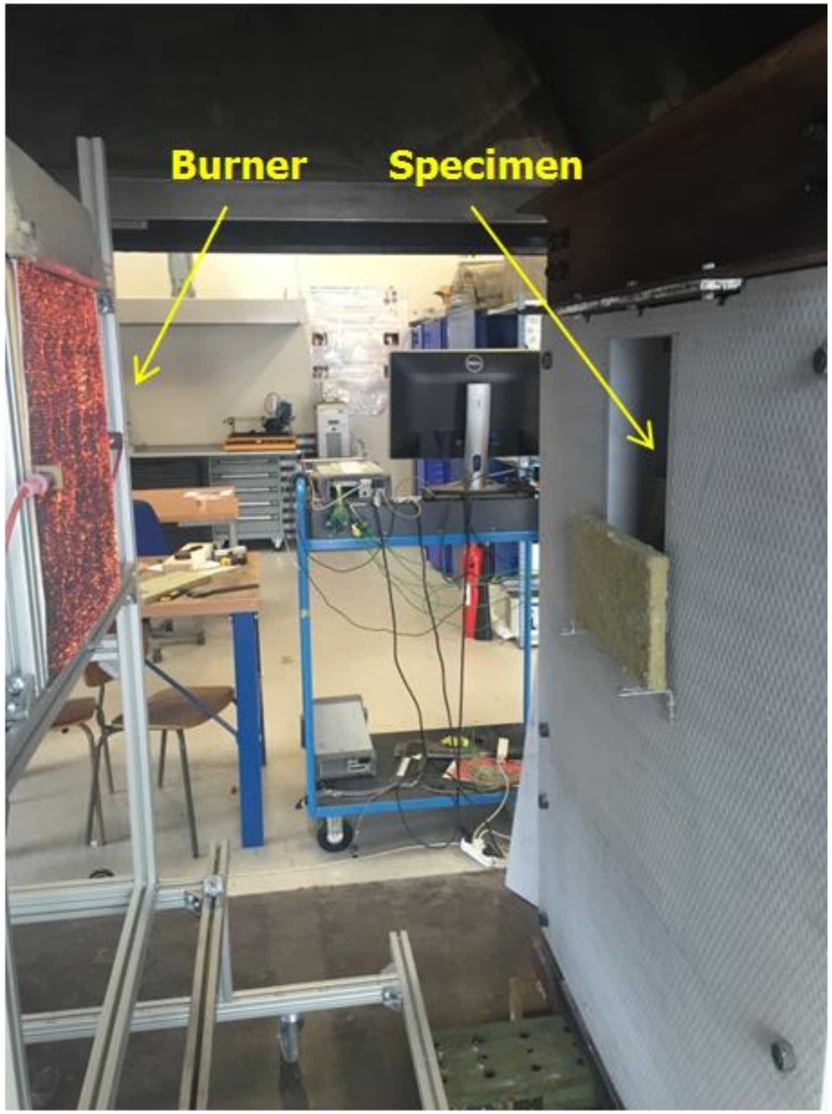
Developed Test Setup (H-TRIS)





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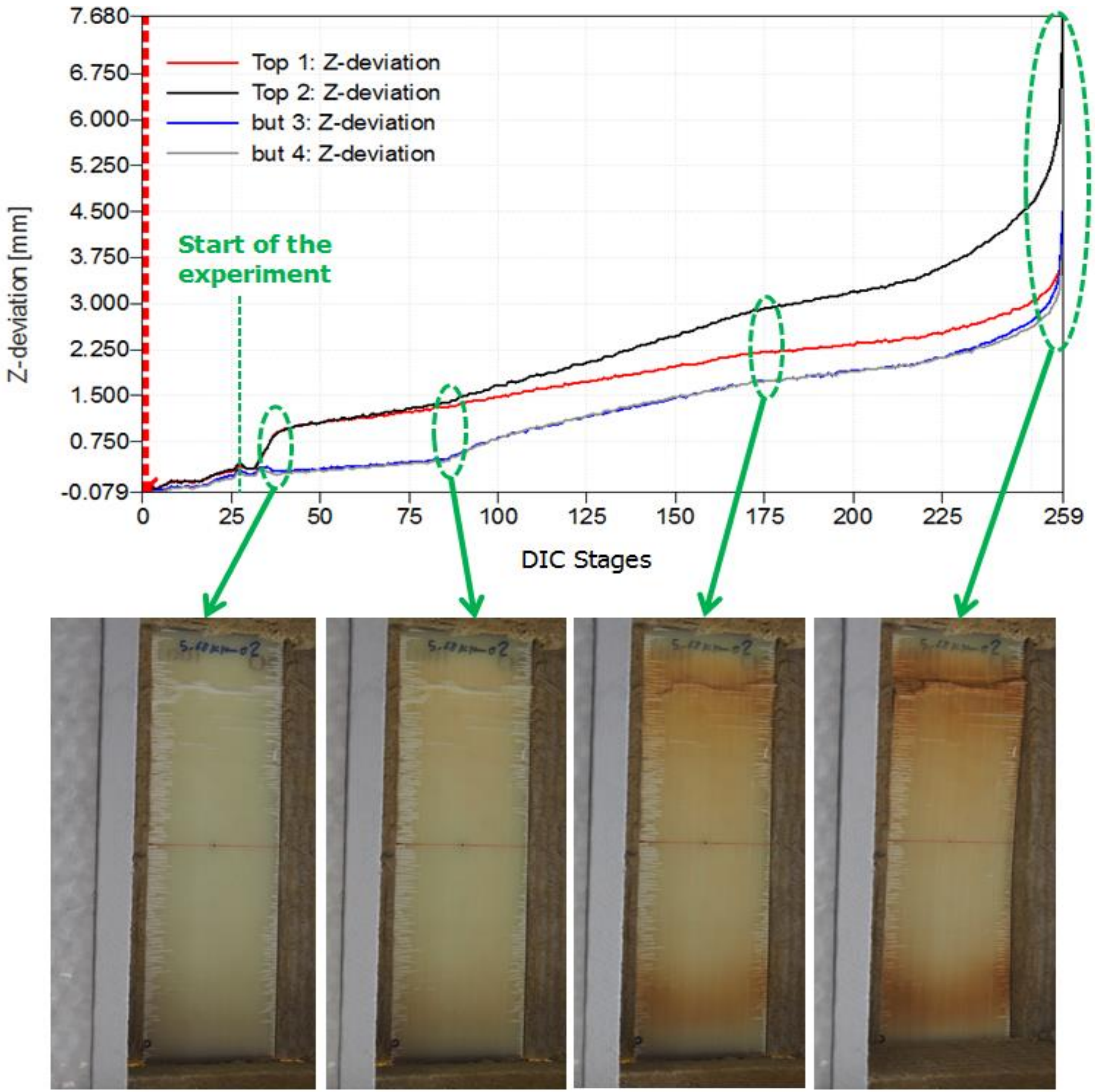
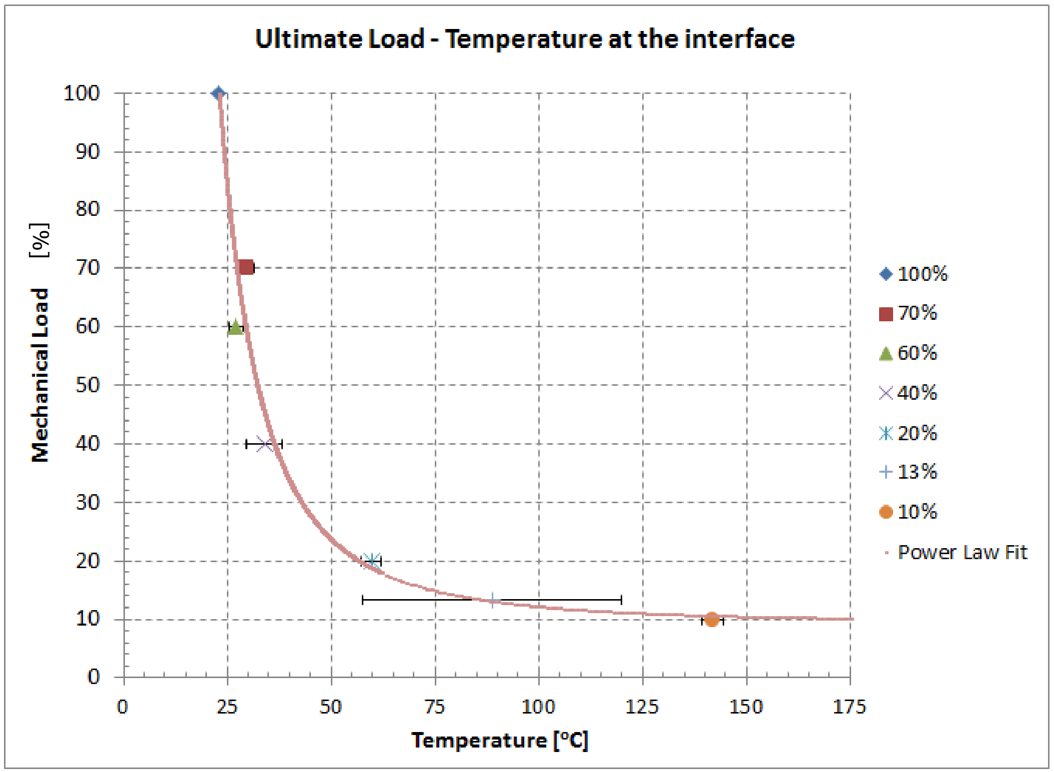
Indicative Results

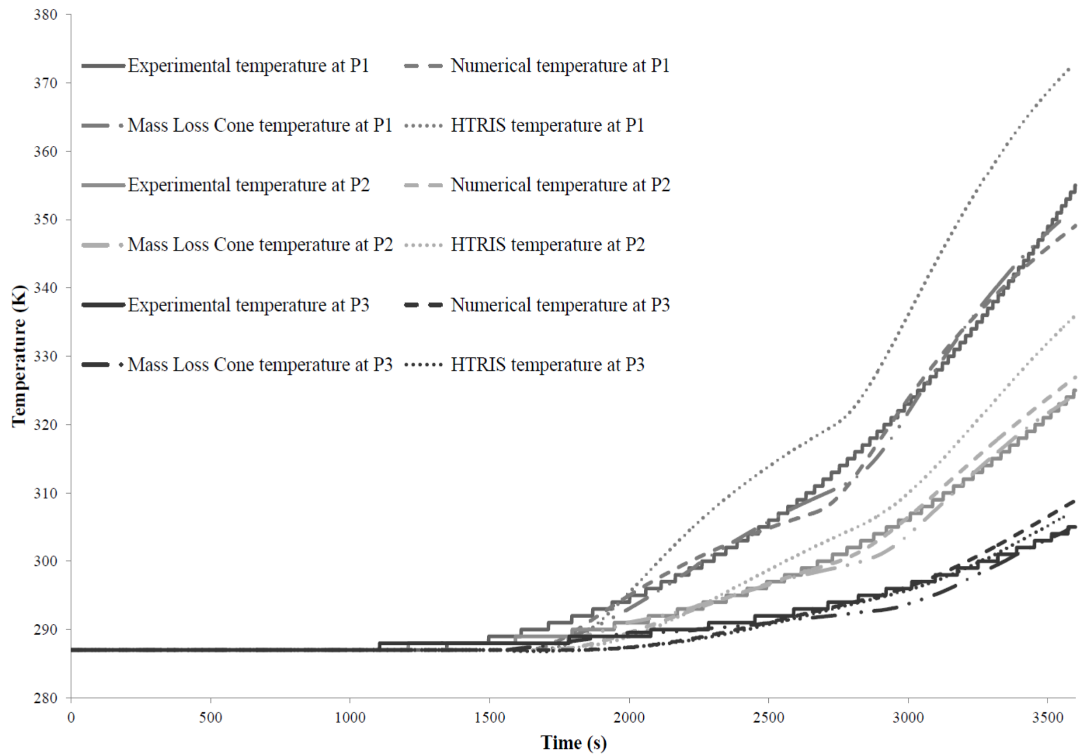


Association of out of plane deflections measured at the unexposed side of the specimen using DIC (top) to the initiation and evolution of damage at the exposed side (bottom)

Indicative Results

- Ultimate load bearing Capacity as a function of temperature at the interface
- Constant Heat Flux and different loading (10%, 20%, 40%, 60%, 70% of the reference ultimate load)
- Variable Heat flux to simulate the ISO834 curve at 13% of the reference ultimate failure load
- Satisfactory replication of the ISO834 curve through suitably chosen heat flux scenarios





Discussion (I)

Composite design and effects on the ship

- Structurally feasible
- Reduction of Lightship
- Significant increase in stability
- Resistance reduction around 1%
- Insignificant savings on fuel for the selected case (1.5%)

Remarks

- Selected study case does not need to be retrofitted
- General arrangement was kept the same as the steel one
- Non optimized design with respect to the ship's Life Cycle
- Increase efficiency by increasing the payload to displacement ratio and not reducing fuel consumption

Discussion (II)

Findings regarding the fire resistance/performance

- Resistance to fire failure mode steel and aluminum bulkheads are similar.
- Considering load bearing failure

– No failure for the tested metallic specimens

– FRP loss of loadbearing capacity, no such thing as implicit robustness

Remarks

- The conclusions are linked to the types of constructions tested
- New material systems emerging
- Better definition of the operational criteria that FRP should meet
- Flexible design could potentially meet the (well) defined criteria

Discussion (III)

Intermediate Experimental Campaign

- Good repeatability for the majority of the conducted experiments
- Ultimate failure and type of failure dependent to the thermomechanical combination
- Better understanding of the damage mechanisms
- A simple phenomenological approach for the selected material which looks promising
- The ISO834 temperature curve could be successfully reproduced by the H-TRIS
- Significantly lower operational cost and reduced testing time compared to furnace tests

Remarks

- Complicated failure mechanisms which are interdependent and competing
- Further research is needed for the extrapolation of the intermediate scale approach to the full scale tests

Thank you for your attention!