E-LASS Conference

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DESIGN OF CAR DECKS WITH COMPOSITE PANELS INTRODUCED ON A 7000 CARS CAR CARRIER

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Contents

- Introduction
- Background
- Design
  - Rules and regulation requirements
  - Additional assesment
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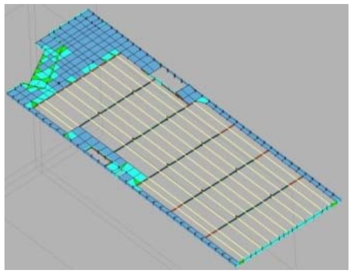
Introduction

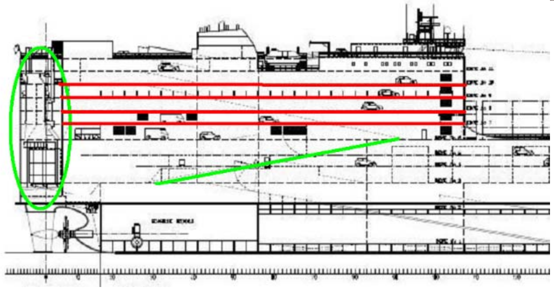
Background

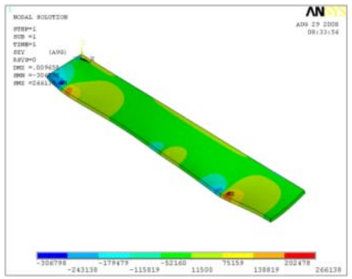
DELIGHT TRANSPORT - Cargo deck of composite materials for RO-RO vessels
(FP6-031483, 2006-2010)

DESIGN OPTIMISATION , PROTOTYPE AND TESTING

- Deck structure weight reduction up to 35%
- Fuel consumption reduction up to 2% →CO2 emission reduction
- Total Lifecycle operation cost savings
- Production process cost reduction
- Satisfactory test results

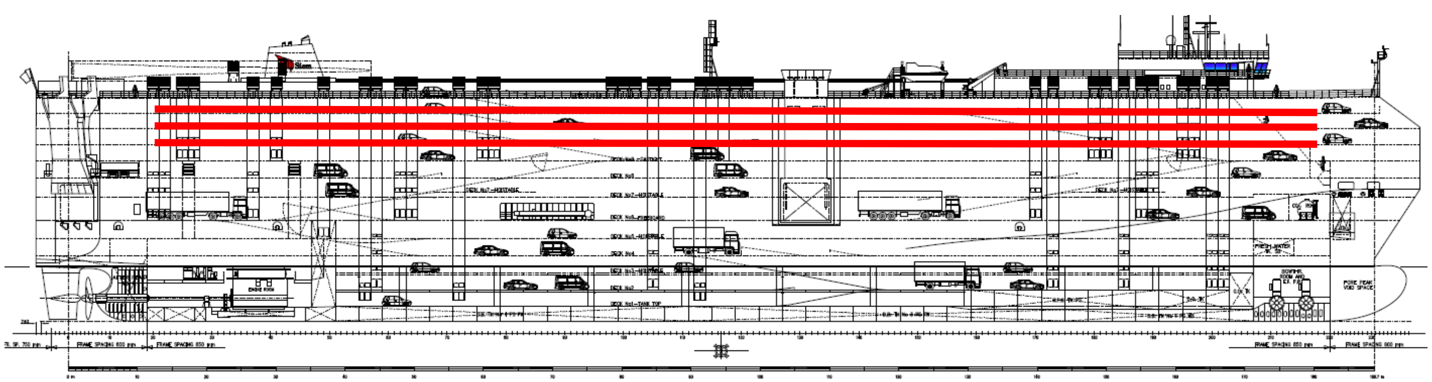


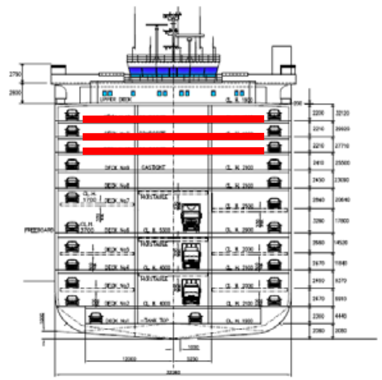




„Composite decks” on a SOLAS vessel

Car carrier - 7000 cars





MAIN PARTICULARS :

LENGTH overall	max. 200.00 m
LENGTH b.p.	188.70 m
BREADTH moulded	32.26 m
DEPTH to upper deck moulded	32.12 m
DRAUGHT design	8.00 m
DRAUGHT scantling	8.80 m
DEADWEIGHT at design draugth	13 370 t
DEADWEIGHT at scantling draugth	17 170 t
MAIN ENGINE	M.A.N. – B & W – ULJANIK 7 S 50 ME–B9.5
OUTPUT MCR	11 200 kW / 117 r.p.m.
SPEED trial (9520 kW at draught design)	19.7 knots

Classification society: Bureau Veritas

Flag: Liberia

Design prcedure

Requirements:

- Owner
- Class
- SOLAS
  - Construction
  - Fire safety

→Conventional or Alternative design procedure ?

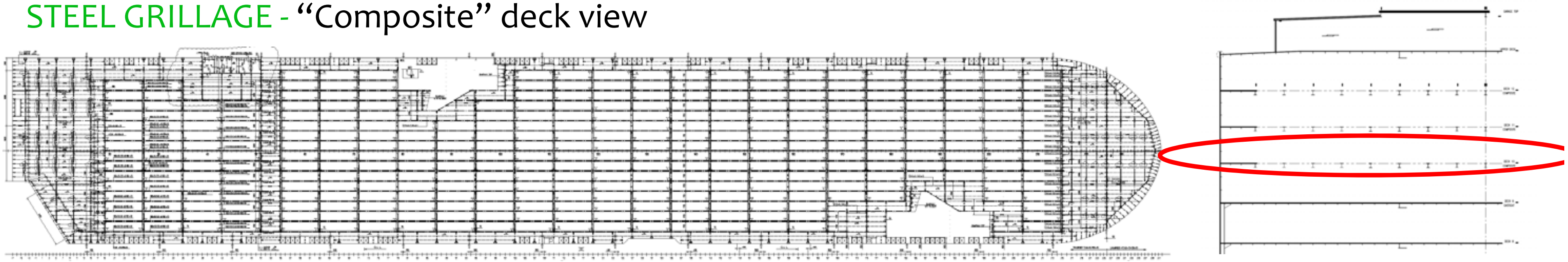
„Composite decks" on a SOLAS vessel

SOLAS - CONSTRUCTION

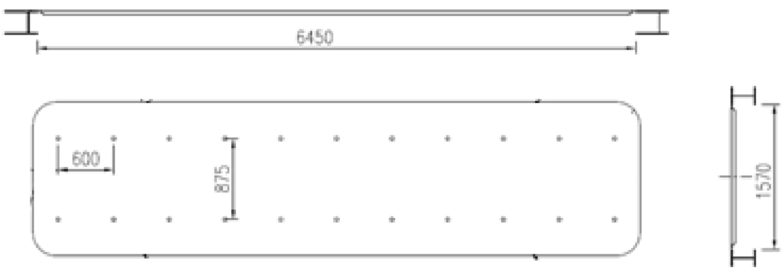
- SOLAS/Ch.II-2/Reg.11 (Structural integrity)
  - Longitudinal and ultimate strength analysis is done without participation of composite panels, only steel part considered
  - Local structural design is done to ensure that any type of car can hold their position in case of any composite panel failure

→ Structural integrity is fully ensured by steel members → SOLAS compliant

STEEL GRILLAGE - "Composite" deck view

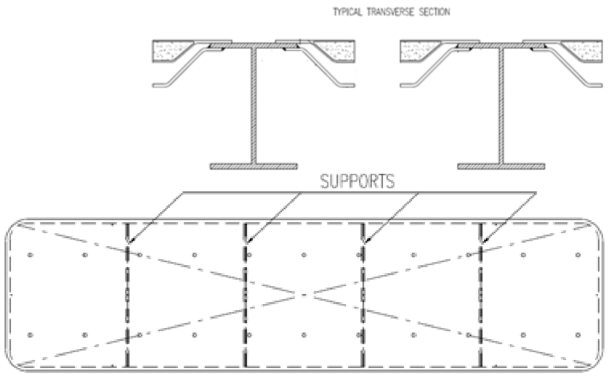


COMPOSITE PANEL – covering the openings in the steel grillage



Conventional design procedure

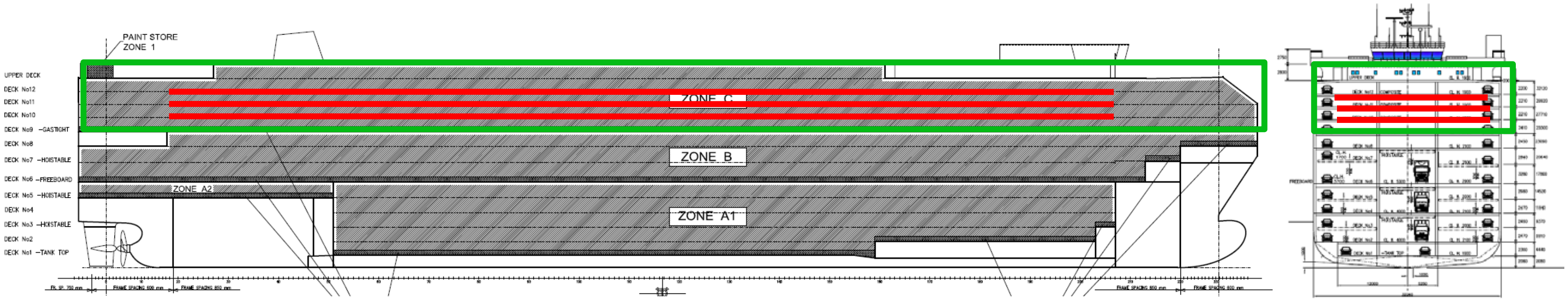
→Additional supports



„Composite decks" on a SOLAS vessel

SOLAS - FIRE SAFETY

- SOLAS/Ch.II-2/Reg.9(Containment of fire)
  - Composite decks are within same fire zone bounded by steel gastight structure → no fire protection requirements by SOLAS → SOLAS compliant
- CLASS: no requirement additional to SOLAS



Design procedure

WORK DONE ACCORDING TO RULES&REGULATIONS REQUIREMENTS

- Structure design
  - Steel grillage
  - Composite panels
- Firefighting and fire detection system
- Outfit design
  - Cargo Lashing – on the composite panel

ADDITIONAL ASSESMENT – owner requirement, was not requred by rules&regulations

- Fire safety assesment done by independent company (RISE)
  - Two HAZID workshops
  - preliminary analysis in qualitative terms
  - Large scale fire tests (steel and composite deck structure)
  - quantitative analysis – 12 FDS simulations performed (6 steel & 6 composite)
- Improvements of the deck design according to fire safety assesment results

SOLAS compliant vessel with respect to Fire safety according to SOLAS „Alternative design procedure”

Composite sandwich panel design

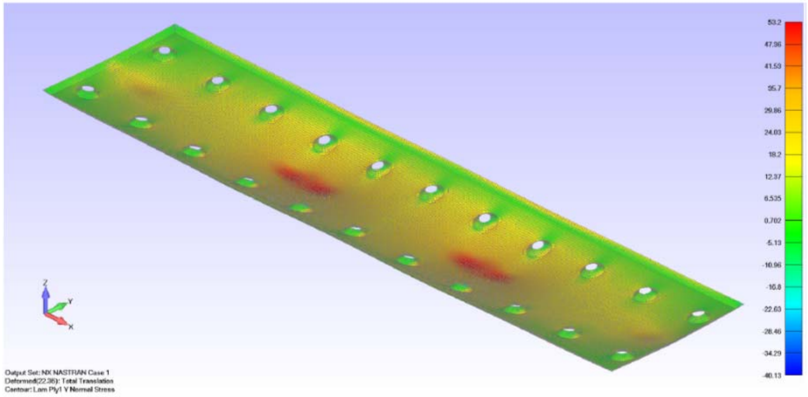
Composite sandwich panel optimisation :

- Number of glass fiber layers and fiber direction optimisation
- Core type analisys (PVC, PET, PUR)
- after selection of the core type

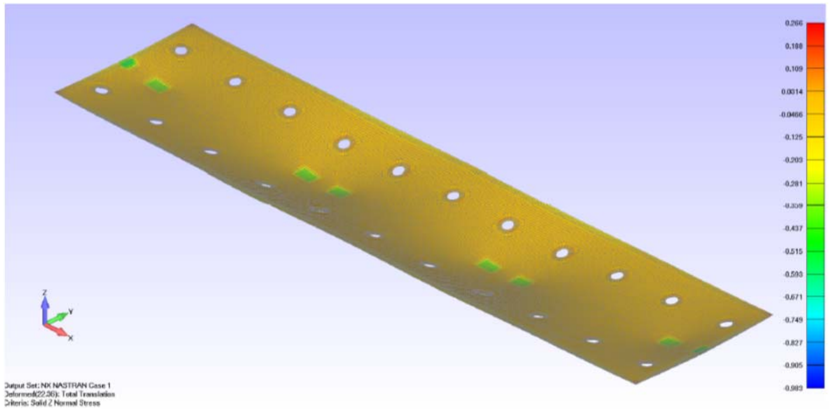
→Core layout optimisation

→ different properies at specific locations (PVC80 and PVC100 used)

FEA according to BV Rules



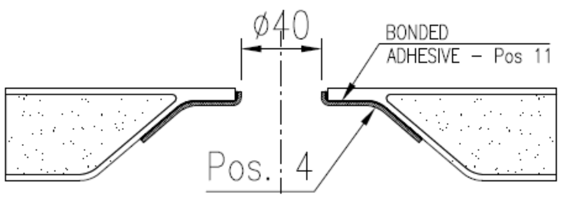
NAME	LOAD AT	AXLE LOAD (t)	TYRE PRINT (mm)	HOMMOGENOUS LOADING (t/m2)
PRIVATE CAR	SEA	L=4.8 m B=1.9 m 2500 1.5 0.7	140 140 1630 177 177	0.20



Composite sandwich panel design

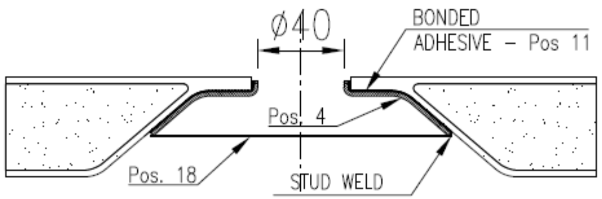
PANEL OUTFITTING: CARGO LASHING

INITIAL VERSION



FINAL VERSION

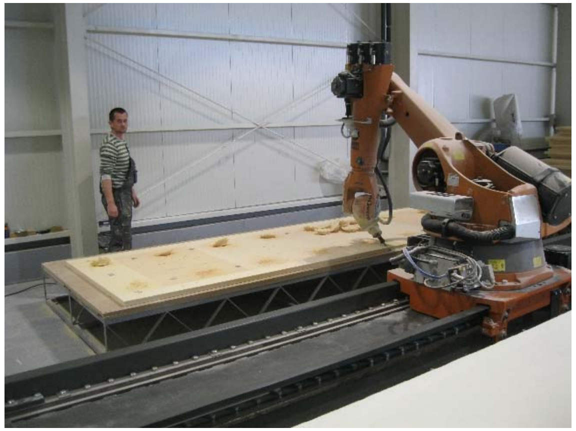
- improved according to fire test results
- lashing opening closed with steel plate

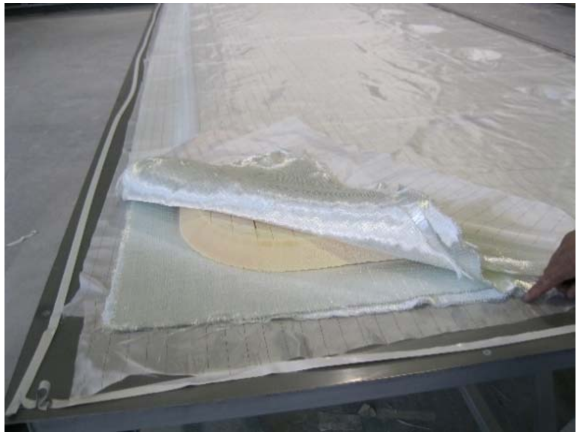


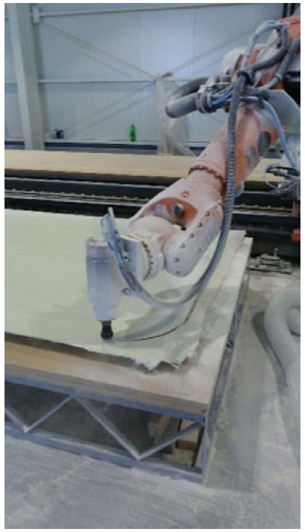
Composite sandwich panel production

IMPLEMETATION ON CAR CARRIER / 7000 cars

1043 composite panels installed on three upper decks (glass fibers, PVC Core, vacuum infusion,…)







Composite sandwich panel production

FIBER CONTENT M=74.2 %
200 tests (1000 specimens)

PANEL WEIGHT =155 kg
TOTAL 162 t (1043 pcs)

„Composite decks" –Steel grillage production

„Composite decks” on a SOLAS vessel

Flexible bolt connection

Total building tolerance at each connection

+-5 mm

„Composite decks” on a SOLAS vessel

- Total area covered by composite structure: **12600 m2**
  →2.5 football field
- Total Weight reduction of **230 t**
- Steel weight reduction of **390 t** →equal to the weight of one conventional steel deck
- Improved stability performance
  → Reduced balasst weight in double bottom tanks
  2.5x weight reduction or **575 t**

Summary:

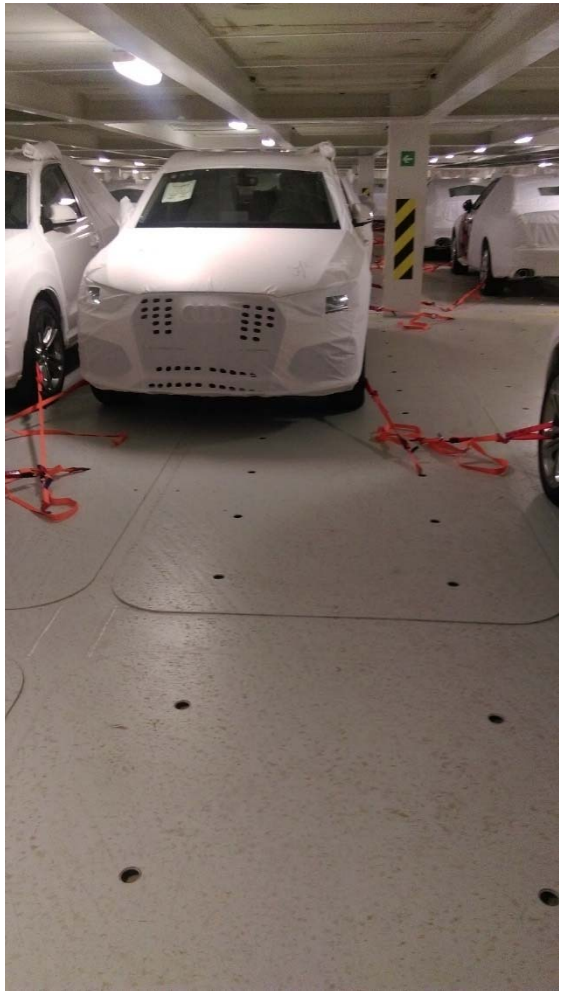
- Increased cargo intake for 230 t +575 t = 805 t
- Or reduced fuel consumption for 4.5% (2.1 t/day) and CO2 emmisions for same cargo intake

”lowest fuel consumption per CEU of any PCTC in its class”

Life cycle

Life cycle


SAFETY FIRST
NO SMOKING
SIEM CICERO
© Hartema Heyken
MarineTraffic.com

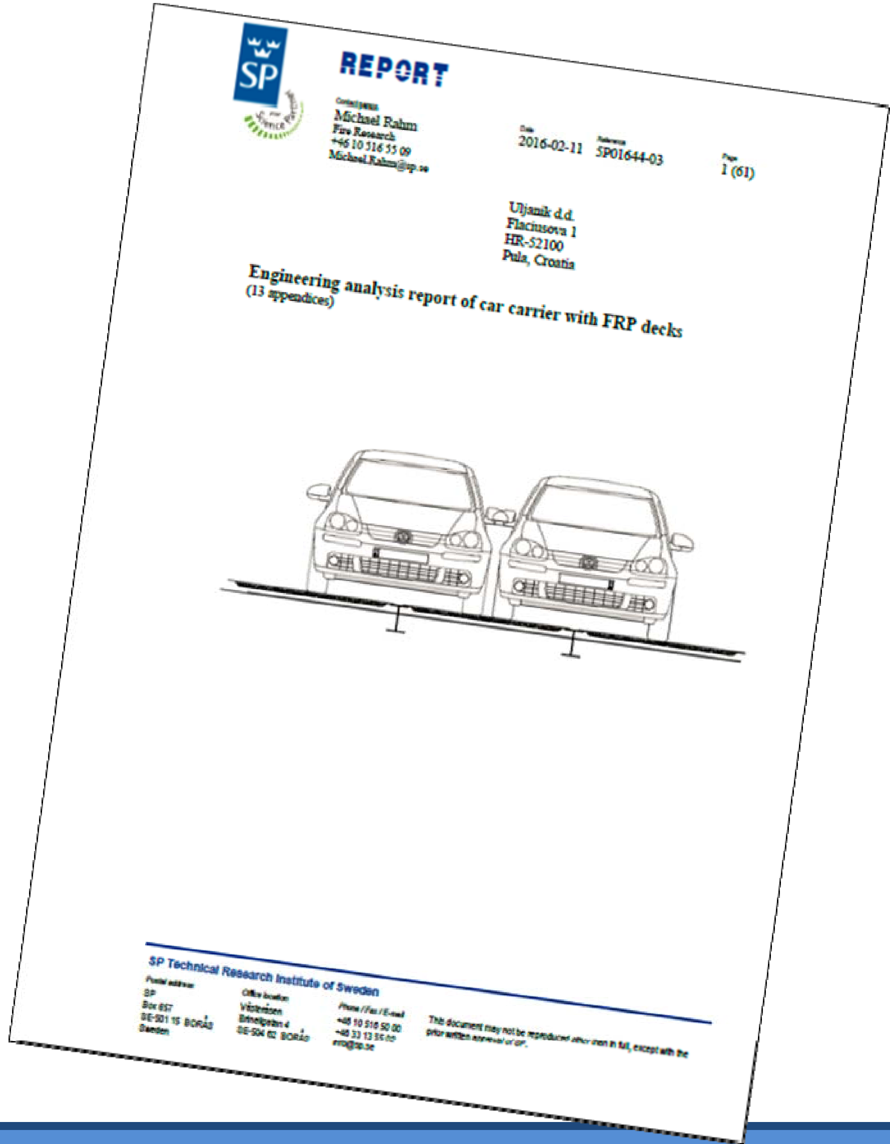


Fire safety assesment

Fire safety assesment

Fire safety assessment

- Background
- Advantages/disadvantages of the design
- Performance criteria
- Fire tests
- FDS-simulations
- Evacuation analysis
- Results



REPORT

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Engineering analysis report of car carrier with FRP decks
(13 appendices)

SP Technical Research Institute of Sweden

Fire safety assesment

Background

- Flag considered the design compliant to prescriptive requirements
- Fire safety assessment performed for further demonstration of sufficient safety
- Assessment performed according to MSC/Circ.1002

Fire safety assesment

Advantages/disadvantages of the design in case of fire

Advantages

- Delayed fire spread through decks
    - Insulating material
    - Closed lashing holes delays vertical fire spread
- Escape routs can be over the panels in case of fire below deck
- Global structural integrity depends on the steel part of structure
- Cargo safety
    - Cargo Lashing functionality

Disadvantages

- Increased fire growth rate
- increased fire load
- structural integrity of the panel
- Toxicity; burning PVC creates hydrochloride.

Fire safety assesment

Performance criteria

- Safe evacuation (at dock)
    - Fire risk is measured in expected fatalities due to a superstructure fire
    - One fatality = a person exposed to untenable conditions
    - Average risk presented as Expected Fatalities per Fire in gastight zone C (EFF).

- Structural integrity (at sea)
    - Probability of integrity loss and expected time is analyzed for all relevant end events.
    - The risk measure is presented as a weighted expected time to integrity loss.
    - $\dfrac{1}{\sum \frac{Probability\ of\ integrity\ loss}{Time\ to\ integrity\ loss}}$

- Containment of fire (at sea)
    - Probability of containment failure and expected time is analyzed for all relevant end events.
    - The risk measure is presented as a weighted expected time to containment failure.
    - $\dfrac{1}{\sum \frac{Probability\ of\ containment\ loss}{Time\ to\ containment\ loss}}$

Fire safety assesment

Fire tests

Performed to evaluate differences regarding:

- Fire growth rate
- Vertical fire spread

Steel deck:

Fire safety assesment

Fire tests

Performed to evaluate differences regarding:

- Fire growth rate
- Vertical fire spread

FRP deck:




Fire safety assesment

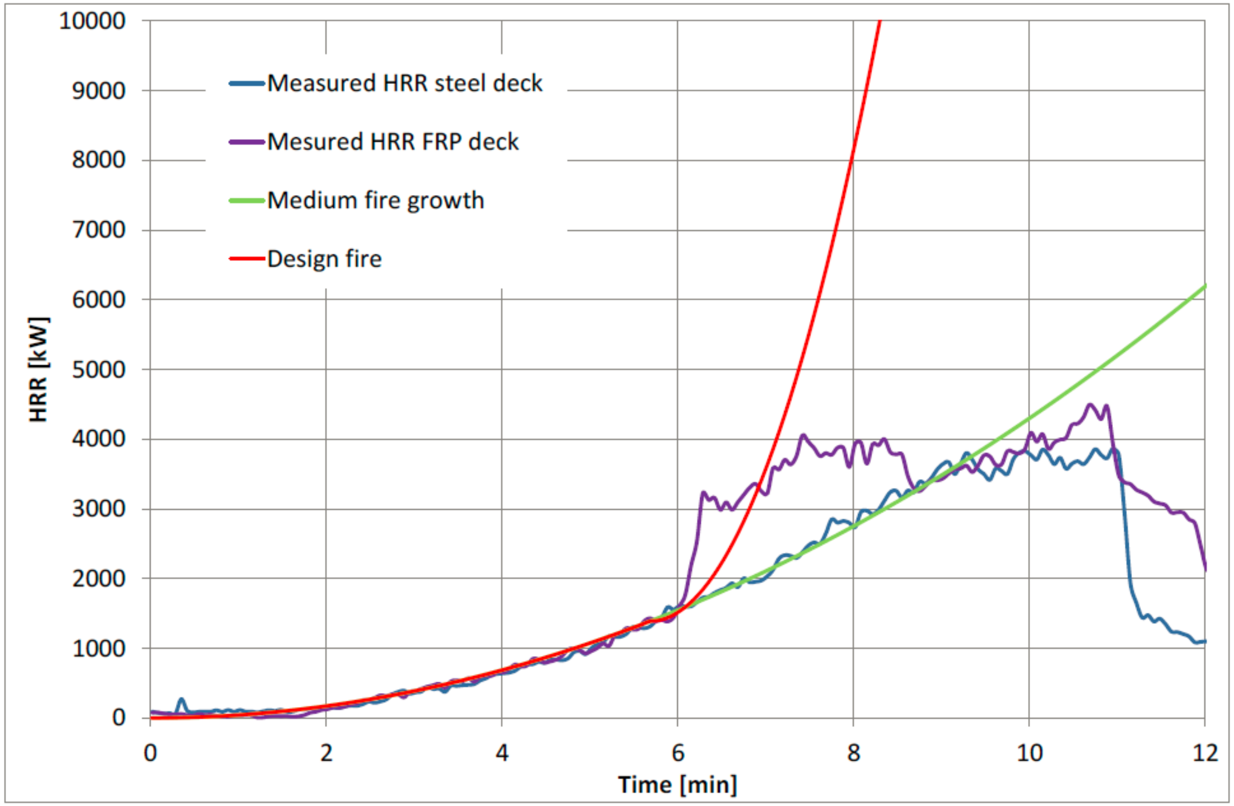
Fire tests - Observations

Observation	Time for observation		
	Test 1, Steel	Test 2, FRP FR-coated	Test 3, FRP
Smoke from the tyres on the deck	04:54	03:54	03:26
Flames through lashing holes	08:45	04:12	05:30
Ignition of first tyre	09:41	05:22	06:06
All tyres are burning	10:21	06:26	06:09
Lashing ropes ignites	10:51	Not established	N.A.

Fire safety assesment

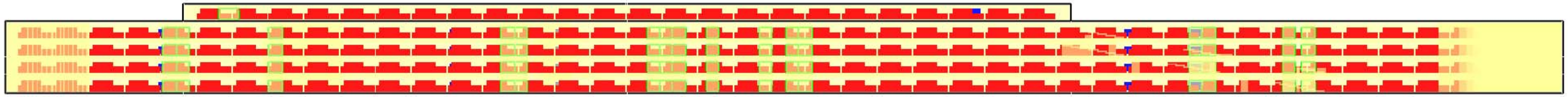
Fire tests - HRR

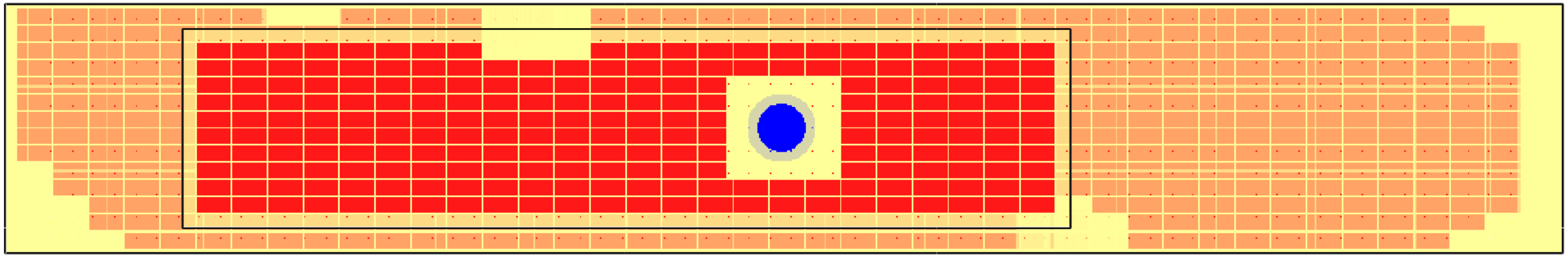
- HRR Steel deck:
  Measured HRR (oxygen consumption calorimetry) from the test with the steel deck
- HRR FRP deck:
  Measured HRR from the test with the uncoated FRP
- Medium:
  Medium fire growth, representing car fire on steel deck. Will be used as design fire in steel case in the simulations.
- Design fire:
  Based on measured HRR in these tests and earlier experience with vertical fire spread. Will be used as design fire in FRP case in the simulations.



Fire safety assesment

FDS Simulations – The model





Fire safety assesment

FDS Simulations

18 simulations were performed, varying:

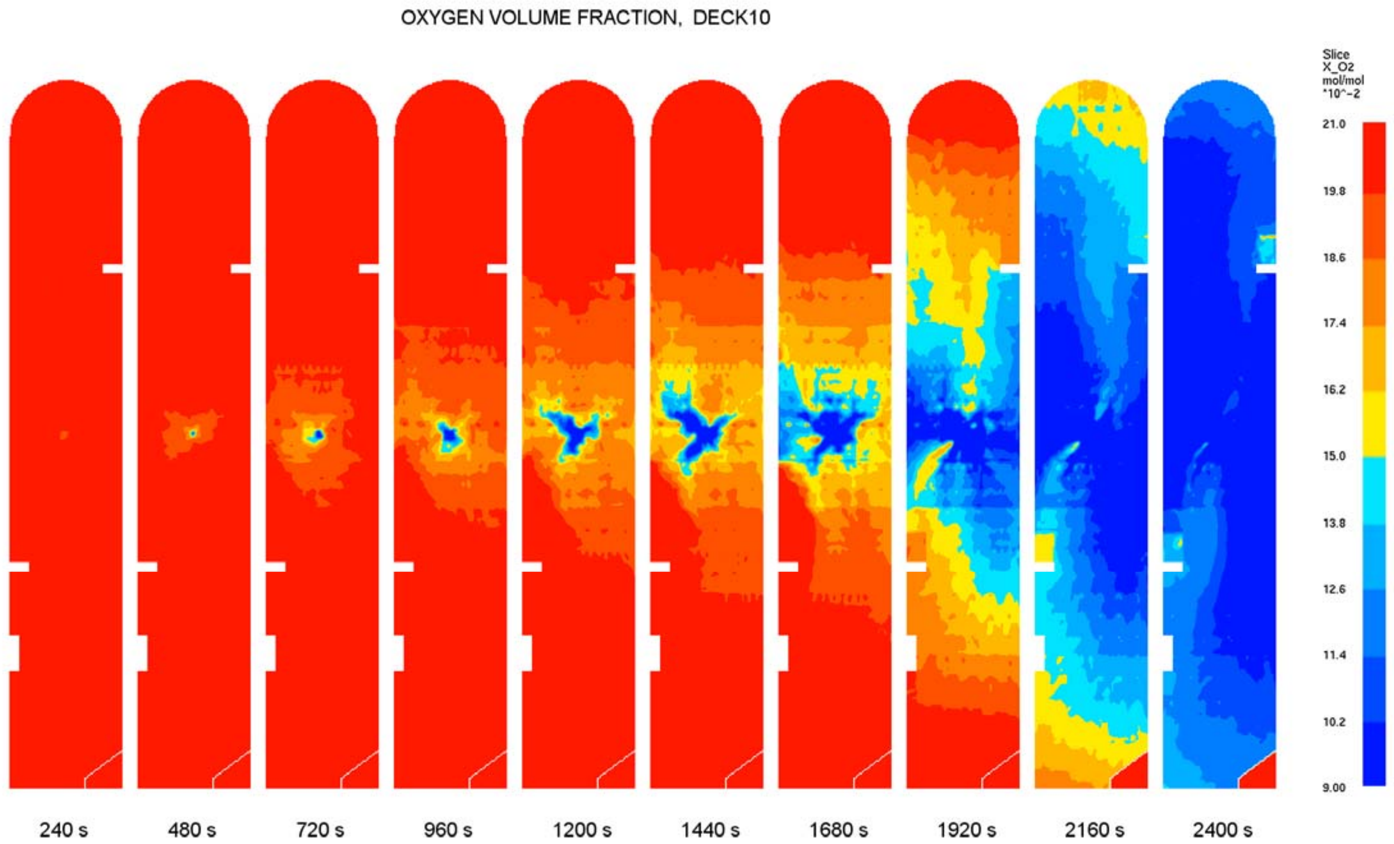
- Fire growth rate (steel/FRP)
- Ventilation conditions
  - Land/sea scenario
  - Time to close vents
- Fire origin deck
- Time to vertical fire spread (steel/FRP)

Fire safety assesment

FDS Simulations

Example

- Steel design
- Land scenario
- Fire start on deck 10

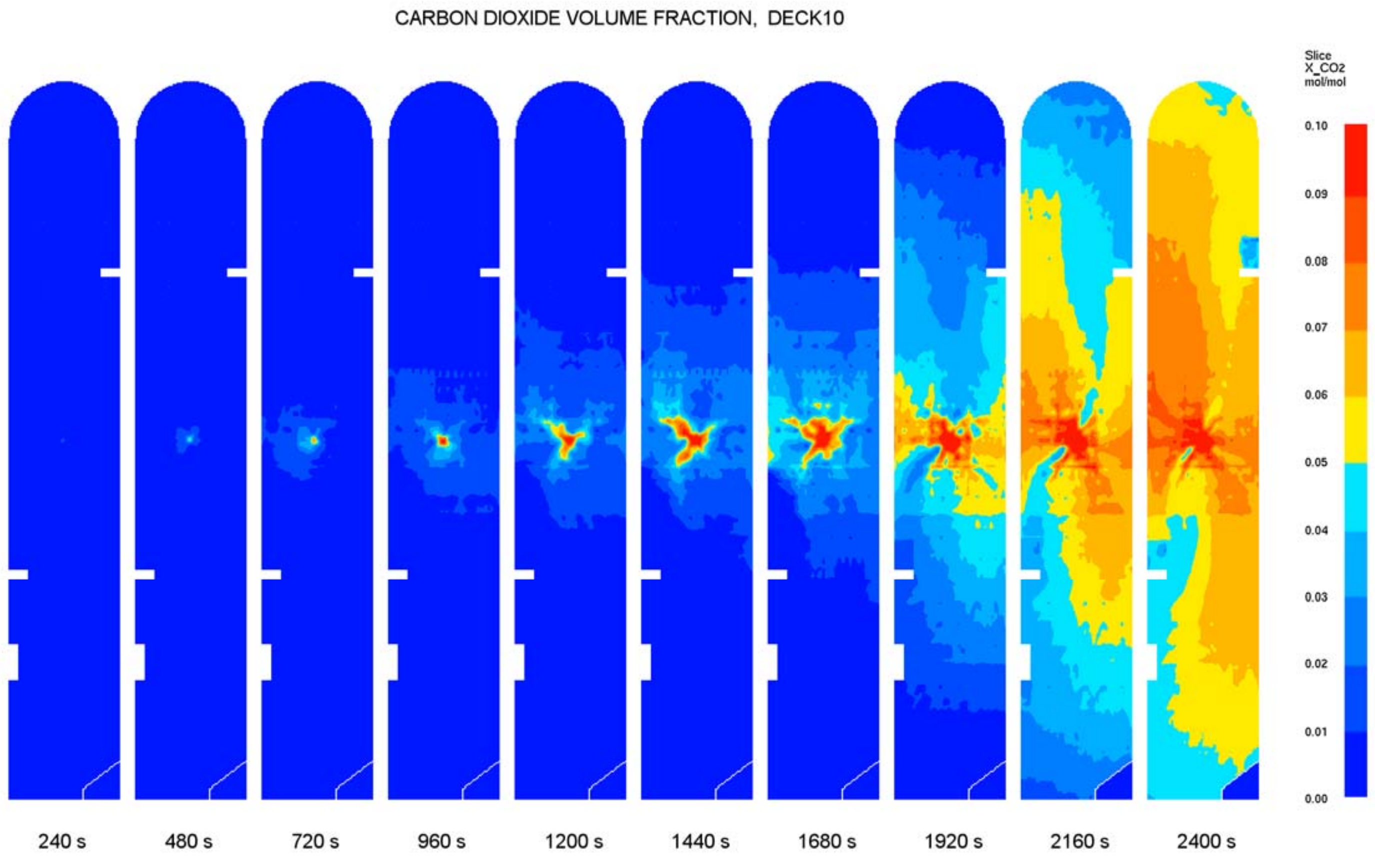


Fire safety assesment

FDS Simulations

Example

- Steel design
- Land scenario
- Fire start on deck 10

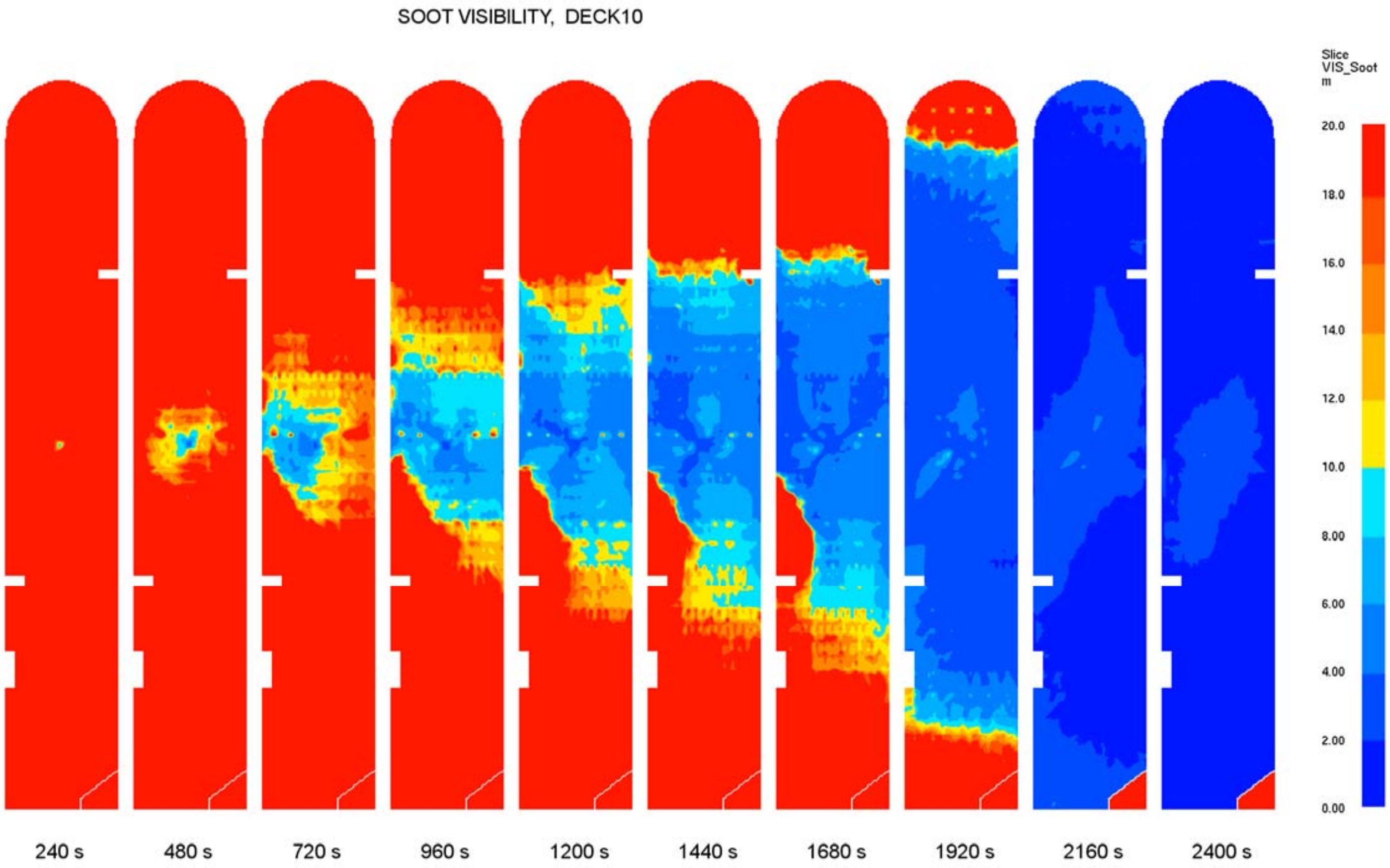


Fire safety assesment

FDS Simulations

Example

- Steel design
- Land scenario
- Fire start on deck 10

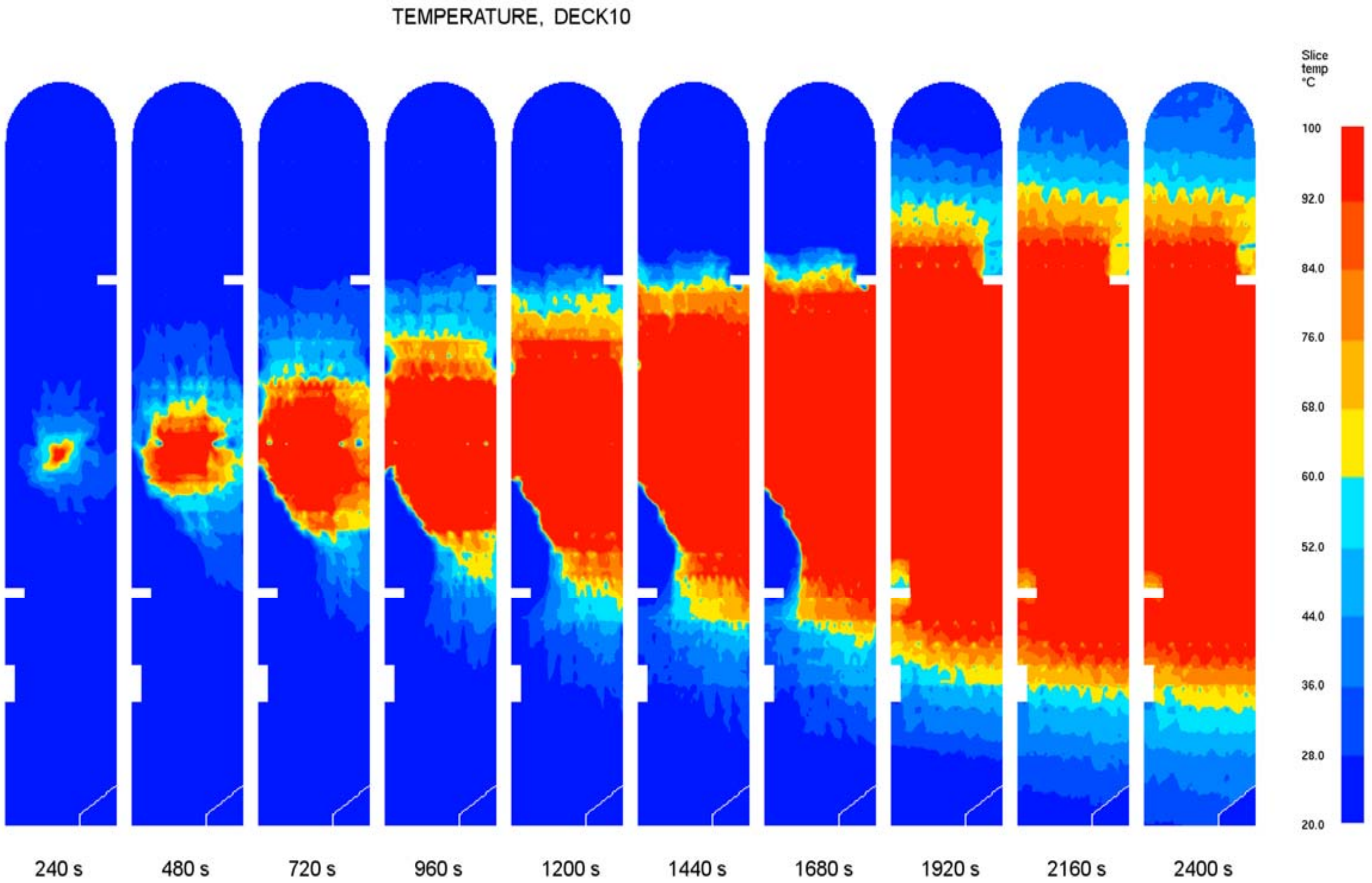


Fire safety assesment

FDS Simulations

Example

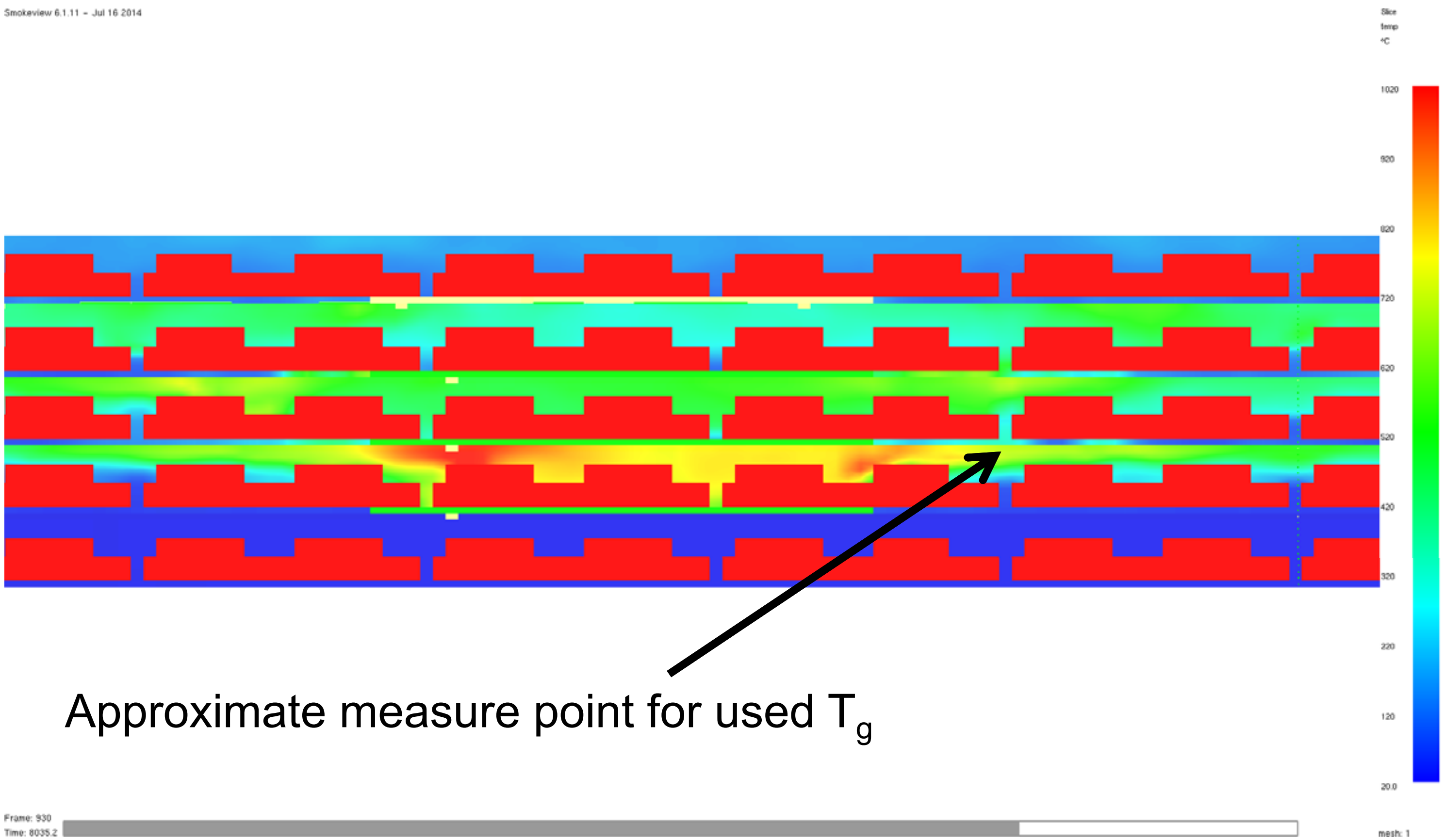
- Steel design
- Land scenario
- Fire start on deck 10



Fire safety assesment

Steel beam temperatures

- Gas temperatures taken from CFD simulations 40 cm above and below the deck closest to the fire.
- Homogene steel temperature.

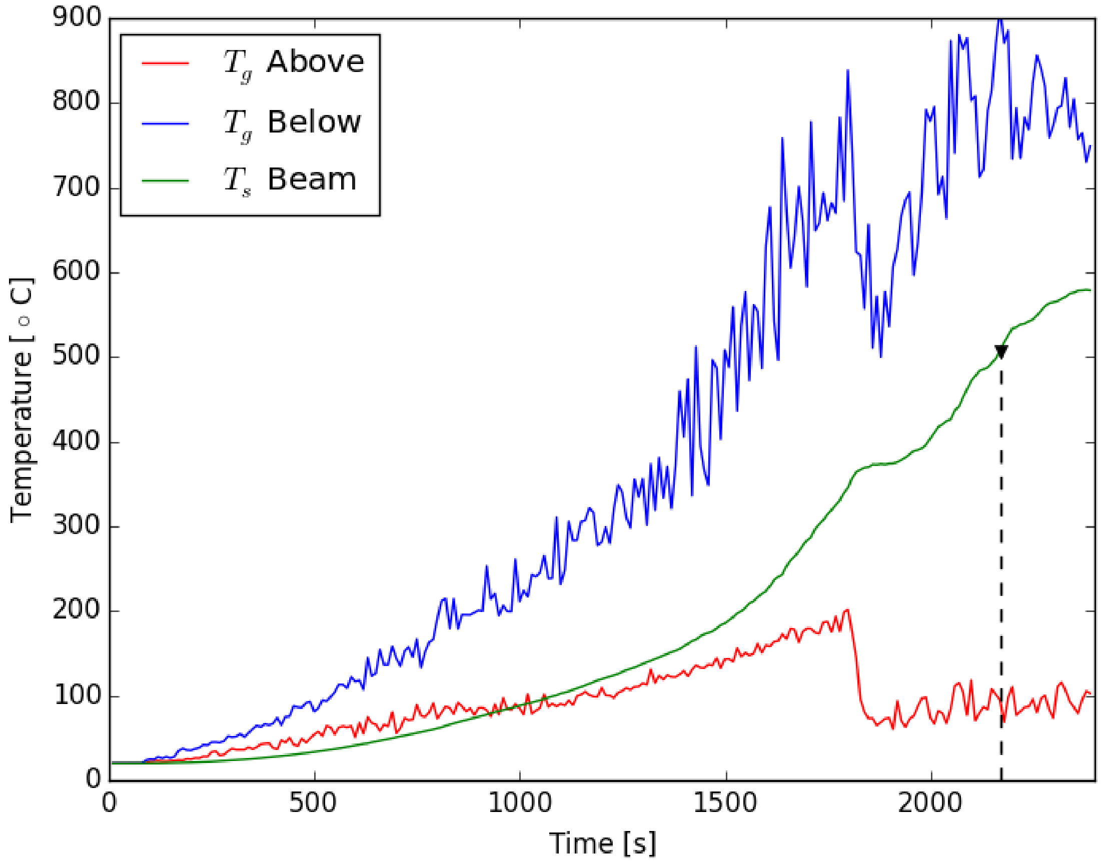


Fire safety assesment

Steel beam temperatures

Example

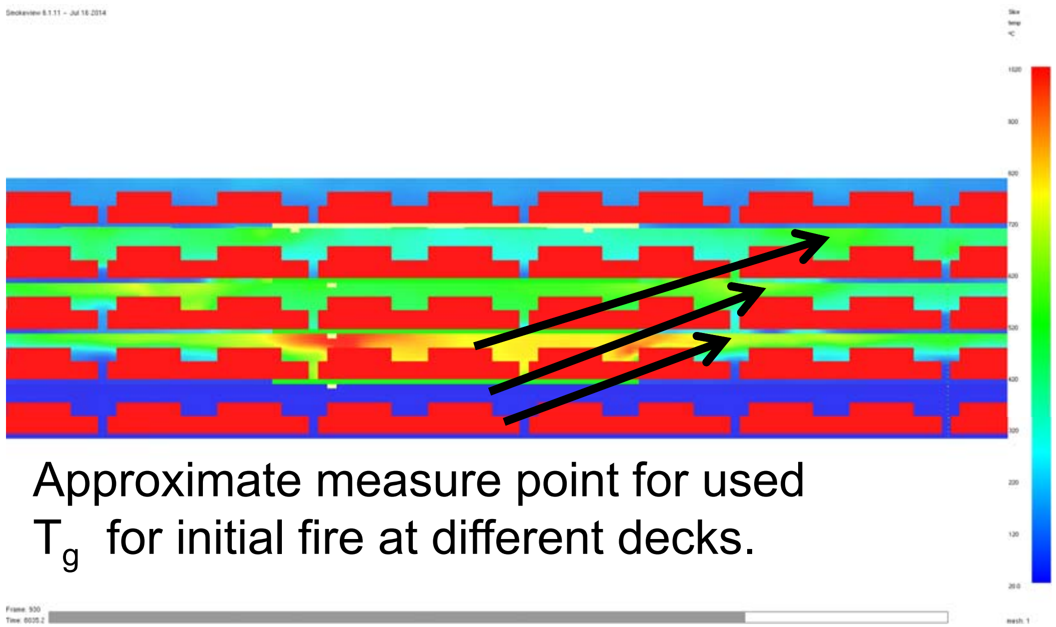
- Steel design
- Land scenario
- Fire start on deck 10



Fire safety assesment

Fire spread to accomodation

- Gas temperatures taken from CFD simulations 40 cm below the deck right above, 2 decks above, and 3 decks above the initial fire.
- Fire spread is assumed to happen when $\Delta T = 140°\mathrm{C}$ which means T=160°C.
- Material properties for worst possible A30 deck used.
- No cooling on top of deck.

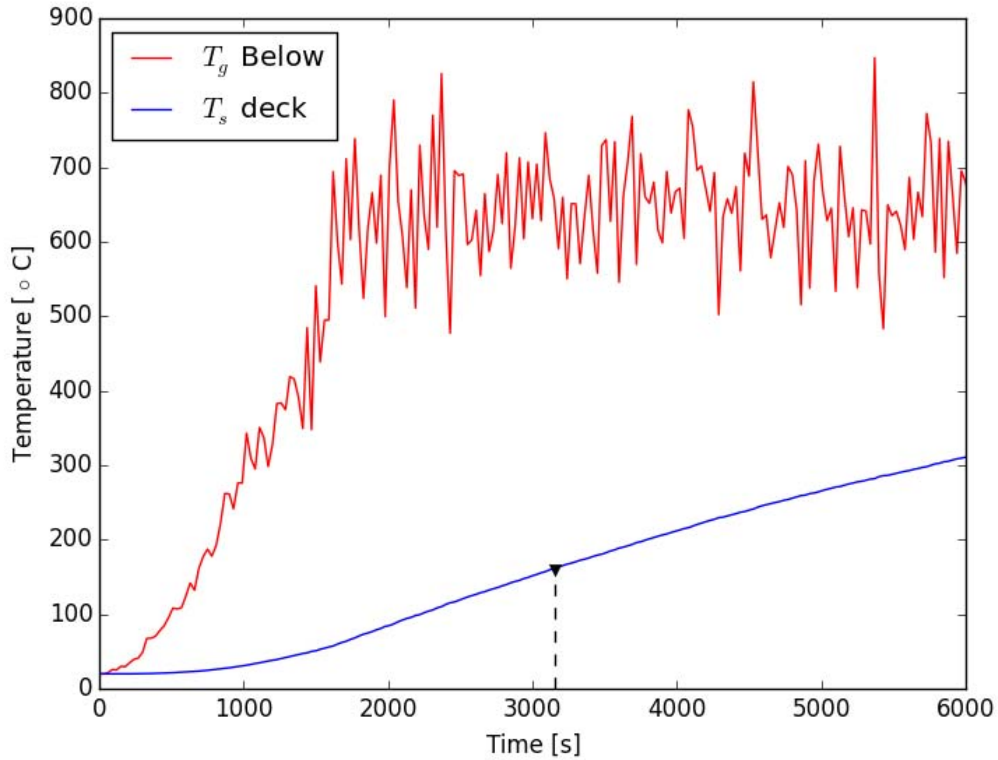


Fire safety assesment

Fire spread to accomodation

Example

- Steel design
- Vents not closed
- Fire start on deck 12



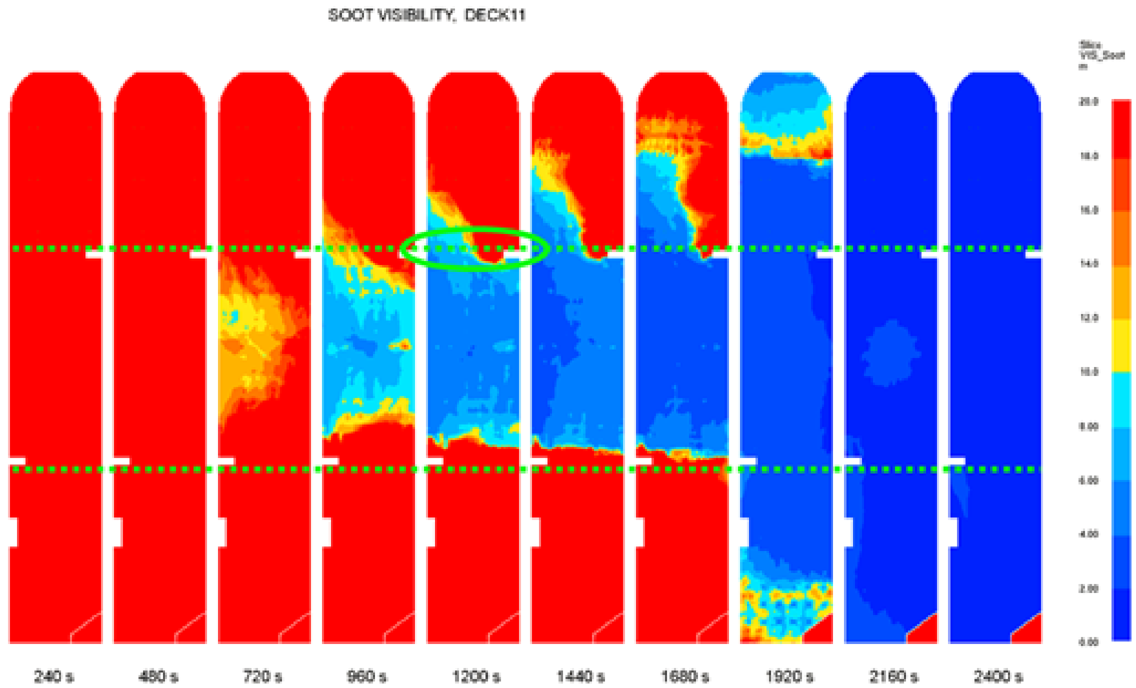
Fire safety assesment

Evacuation analysis

ASET – RSET > 0

ASET = Available Safe Egress Time:

- Time to untenable conditions in a compartment:
  - Visibility: 1,8 m above floor level the visibility must be more than 10 m.
  - Temperature: max 60°C
  - Toxicity: 1,8 m above floor level:
  - CO > 1400 ppm
  - CO_2 > 5 %
  - O_2 < 15 %
  - HCL > 1000



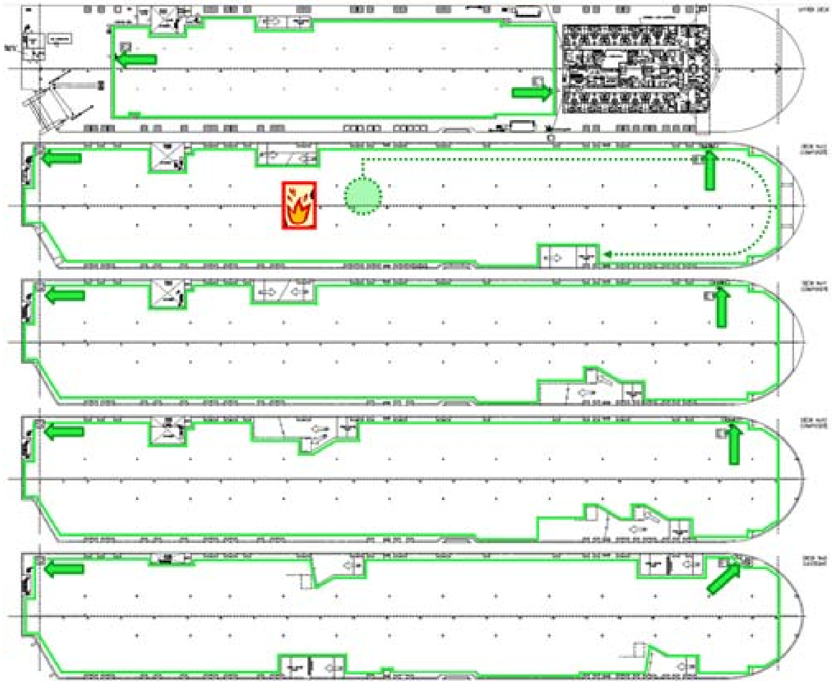
Fire safety assesment

Evacuation analysis

ASET – RSET > 0

RSET = Required Safe Egress Time:

- RSET (evacuation time)=recognition time + response time + movement time
  - Recognition time: 1-10 min depending on detection, position (what deck) and alertness
  - Response time: 1-5 min depending on detection, alertness, and if actual fire signatures are observed.
  - Moving time: 0.6 m walkways along ship side. 150 m distance (see fig). 1.2 m/s (corridors according to MSC/Circ.1033). ->2 minutes walking time



Fire safety assesment

Results

Criteria	Prescriptive design	Base design
PLL	0	0
Expected safety margin	20.5 min	13.5 min
Probability of structural integrity failure	12 %	51 %
Probability of loss of containment	10 %	10 %
Weighted average time to structural integrity failure	418 min	31 min
Weighted average time to containment failure	706 min	597 min

Fire safety assesment

Trial alternative design 2

- New lashing hole design
  - Prolonged vertical fire spread
  - Fire spread to deck below (burning droplets) eliminated
  - Cargo lashing functional for longer time in fire scenario
- Automatic/remote controlled dampers
  - Fast closing (immediately after alarm); fire is ventilation controlled before structural damage and containment loss.
  - Reduced probability of failure (automatic functionality + manual effort in case of failure)
  - Faster CO_2-activation
- Position feedback on doors and dampers
  - Allows crew to focus on failing doors and dampers
  - Reduces risk of CO_2 activation despite failing doors and dampers
- A30 insulation below lifeboat embarkation station
  - Allows safe lifeboat embarkation in case of uncontrolled fire in Gastight zone C

Fire safety assesment

Results

Criteria	Prescriptive design	Base design	TAD2*
PLL	0	0	0
Expected safety margin	20.5	13.5	13.5
Probability of structural integrity failure	12 %	51 %	3 %
Probability of loss of containment	10 %	10 %	1 %
Weighted average time to structural integrity failure	418 min	31 min	552 min
Weighted average time to containment failure	706 min	597 min	5973 min

***In addition: safer embarkation, earlier CO_2-activation (less damaged cargo)**

Conclusion

SOLAS compliant vessel with composite structure:

- Deck structure weight reduction of 25% (230 t)
- Increased cargo intake for 805 t or fuel consumption reduction of 4.5% (2.1 t/day HFO) for same cargo intake
- Production cost and lead time
- Improved safety of cargo in case of fire
- Improved safety of crew in case of fire below deck with respect to Escape routs

SOLAS compliant vessel with respect to Fire safety according to SOLAS „Alternative design procedure”

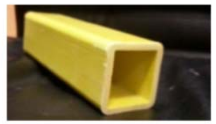
Further development at RAMSSES (WP14)

Project full title:**Realisation and Demonstration of Advanced Material Solutions for Sustainable and Efficient Ships (**Grant agreement No.:**723246)**

ULJANIK YARD 513 (Car Carrier 7000 cars) - to be used as base design where :

- -FRP structure design using the technology of Pultrusion
  - as a replacement of the sandwich composite panel
  - as a replacement of the sandwich composite panel and steel supporting structure
  - Combination of profiles and sandwich panel

Expected improvements: Improved flexibility in the design process, Production cost and lead time reduction, Joints development, Modular assembly of Composite components on board the ship



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