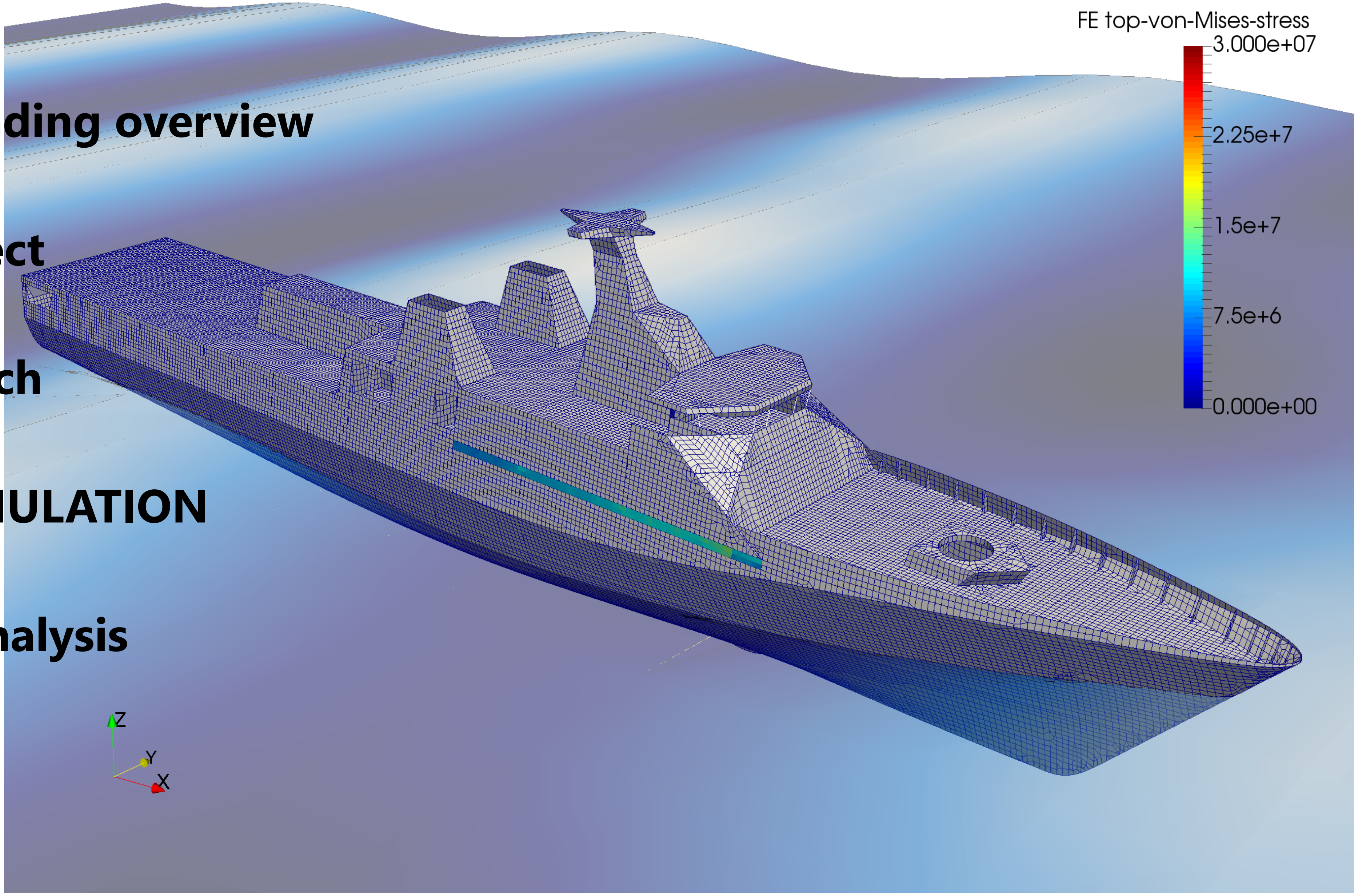
STEEL TO COMPOSITES STRUCTURAL BONDING MEASUREMENT IN LIGHTWEIGHT MARINE TRANSPORT APPLICATIONS

E LASS VIGO 2019

GREGOIRE BEAUDUIN

AGENDA

- (Hybrid) Bonding overview
- Qualify Project
- SHM approach
- Strain FE SIMULATION
- Reliability Analysis
- Com&Sens

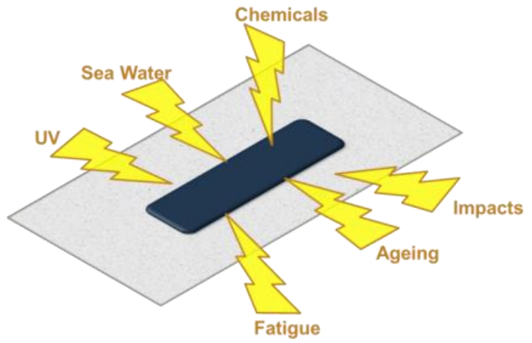


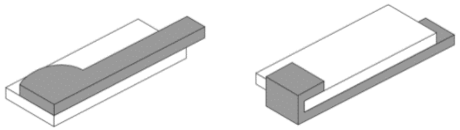
WHY BONDING?

- Assembly of **a wide variety of substrates**
    - Metal/metal, metal/composite, metal/glass…
- **Cold solution**
    - No thermal deformation, no thermal affection
    - Intervention at late construction stage
- **Cost effective** joining technic
- **Easy, simple**
    - Be careful, can be dangerous

•Surface preparation
•Environmental conditions
•External aggression
•Design

- Efficient: **Strong resistance**
- **Reduction** of weigt, noise and vibration & components

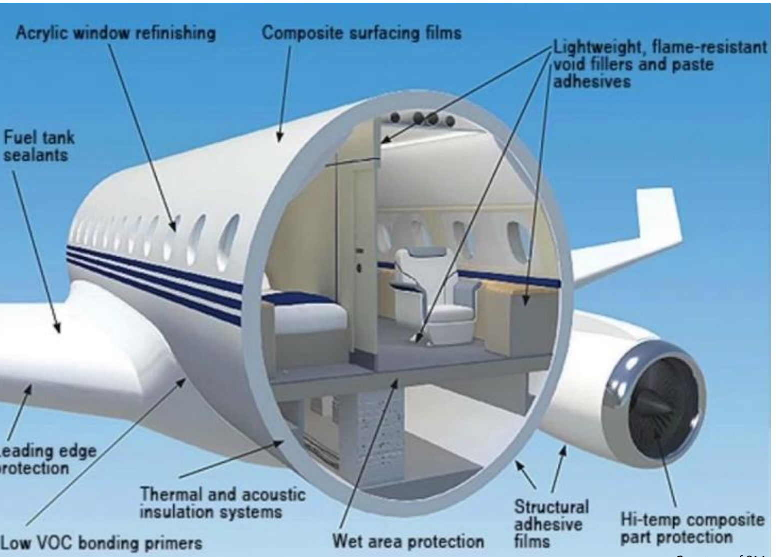




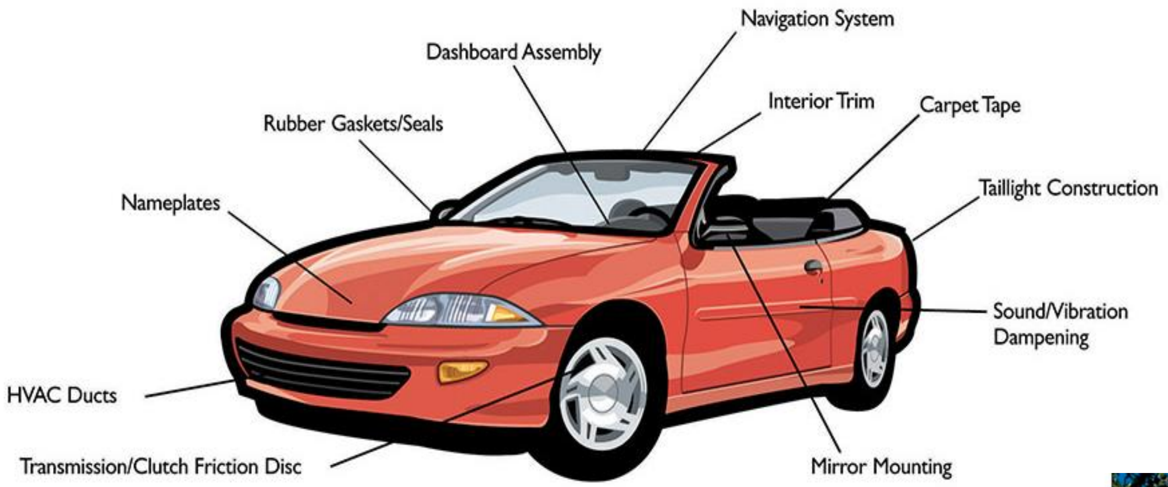
QUALIFY LIGHTWEIGHT

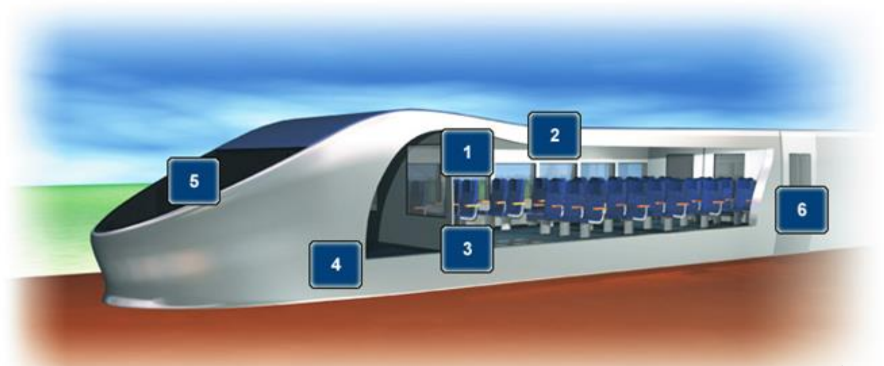
Interreg 2 Seas Mers Zeeën

ADHESIVES IN INDUSTRY



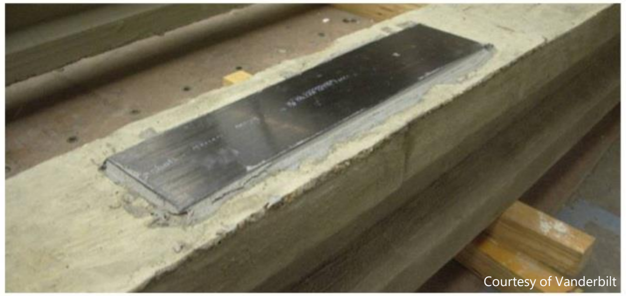
Courtesy of 3M





Courtesy of 3M

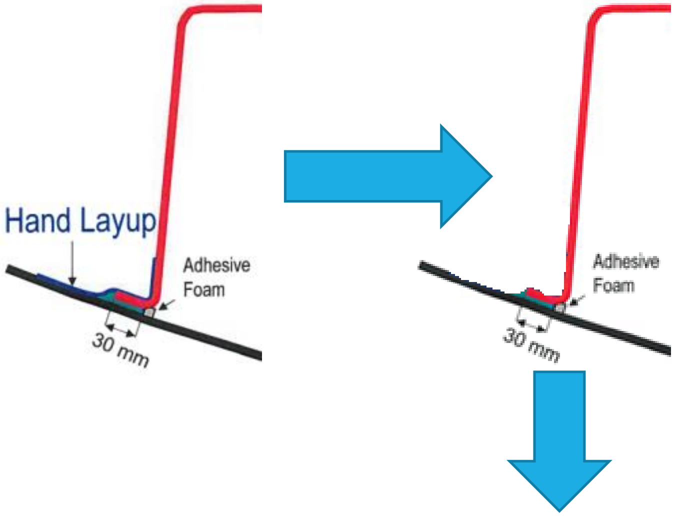
Bonded patch repair

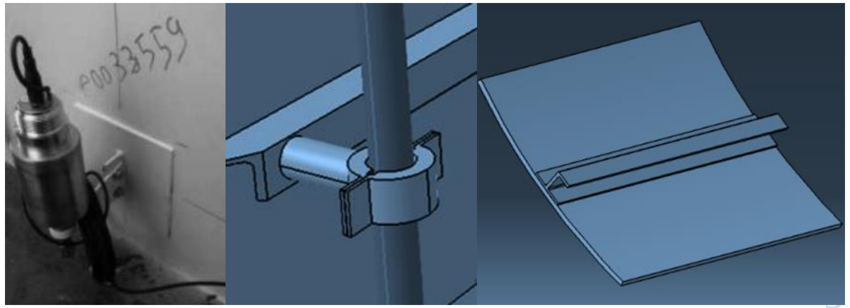


Courtesy of Vanderbilt

Courtesy of Sika

ADHESIVES IN MARINE





QUESTIONS

- Will this joint be reliable after twenty years of exposure to the harsh marine environment?

- Is it strong and tough enough?

- How can the properties of an adhesive joint be optimized?

- What types of adhesive joint designs are best to withstand specific loading and service conditions?

- Can we accurately model the response of an adhesive joint?

QUALIFY PROJECT

ENABLING QUALIFICATION OF HYBRID STRUCTURES FOR
LIGHTWEIGHT AND SAFE
MARITIME TRANSPORT

Project partners:

M2i materials innovation institute
DAMEN
COM&SENS adding value by sensing
BAE SYSTEMS
TU Delft
GHENT UNIVERSITY
BUREAU VERITAS 1828
PARKWIND
Lloyd's Register
UNIVERSITY OF CAMBRIDGE
Knowledge Centre WMC

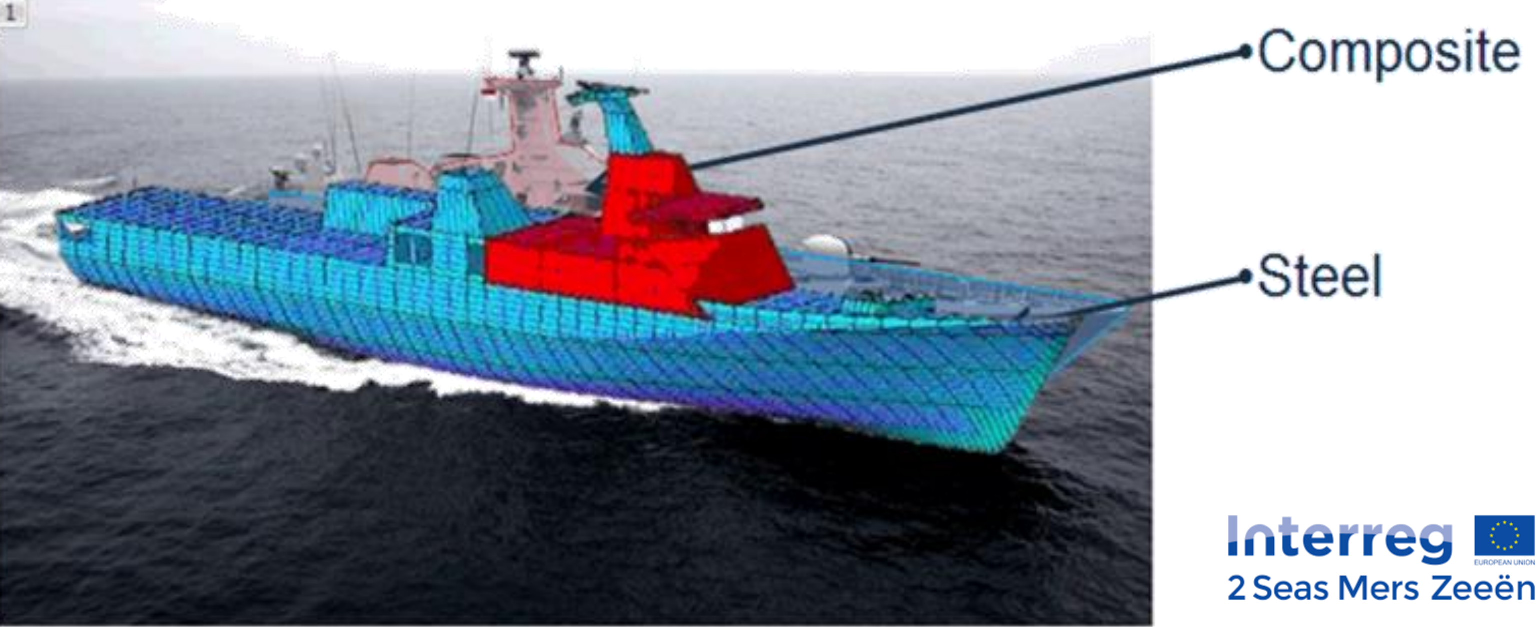
Interreg
EUROPEAN UNION
2 Seas Mers Zeeën
European Regional Development Fund

Enabling Qualification of Hybrid Structures for Lightweight and Safe Maritime Transport.

QUALIFY will deliver the knowhow and guidelines for the uptake of hybrid marine structures (metal/composite).

OBJECTIVES

- Evaluate the **long term** structural **performance** of the adhesively bonded joint under representative environmental conditions
- Develop a **certification procedure** for adhesively bonded hybrid joints representative for marine structures
- Develop a **reliable inspection** and **maintenance protocol** for adhesively bonded hybrid joints



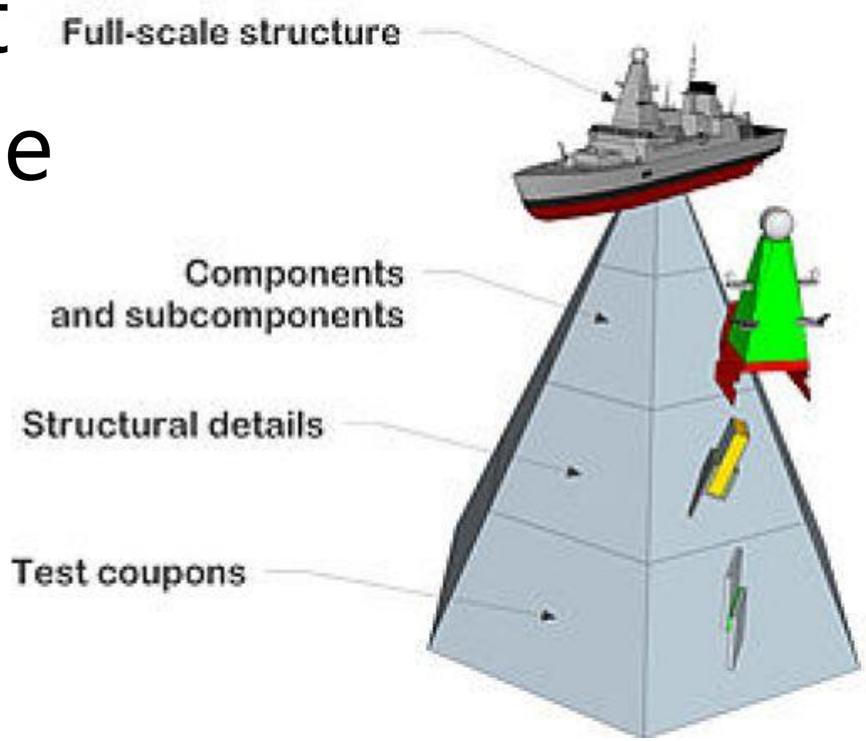
QUALIFY LIGHTWEIGHT

Interreg 2 Seas Mers Zeeën

WP 2 MONITORTING : SHM OBJECTIVE

Establishing a **structural health management** methodology for **in-situ monitoring** of adhesively bonded bi-material joints to enable decision making protocols aiming to shift the current schedule based maintenance scheme to a

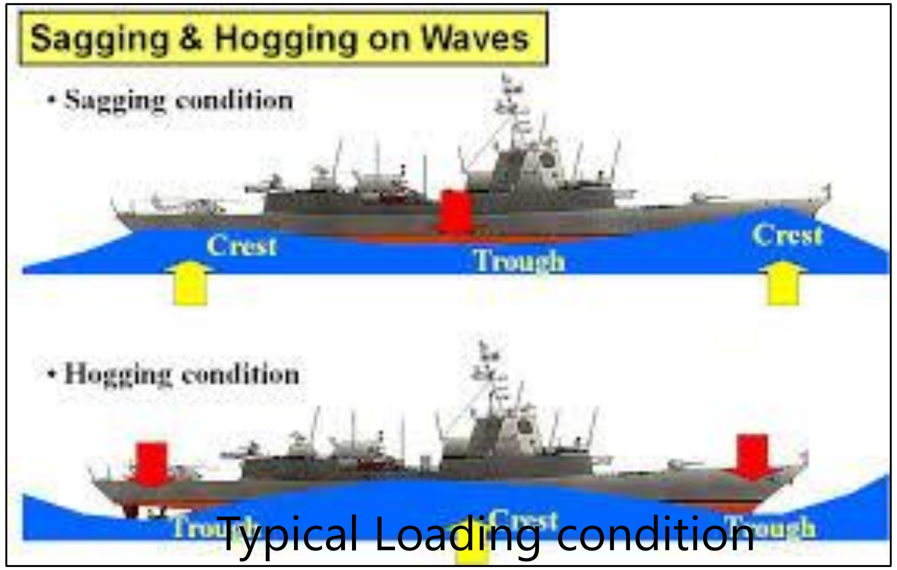
condition based maintenance paradigm.



SHM APPROACH

- Test approach via FEM simulation
  - Effect of debonding on different levels (glue/steel, composite/steel interface or within the glue)

  → Use strain transfer from boat to superstructure and vice versa
  - Minimum Size of detectable debond/crack



Typical Loading condition

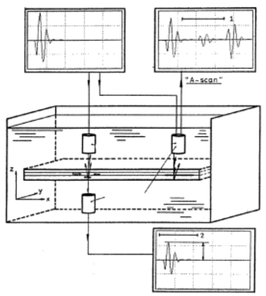
SHM approach 2 steps (2 different techniques)

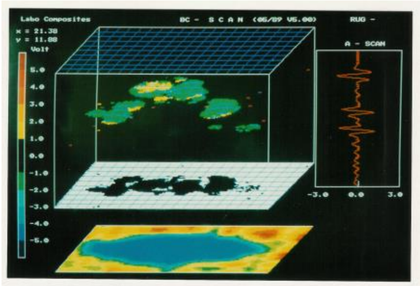
- Integrity monitoring on sea→ detecting hot spots and size of defect
- Harbour inspection → detailed size of deffect

MONITORING TECHNIQUES

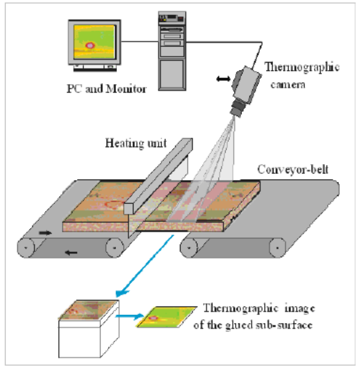
OFFLINE TECHNIQUES

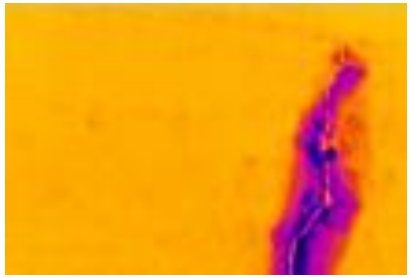
Ultrasonic





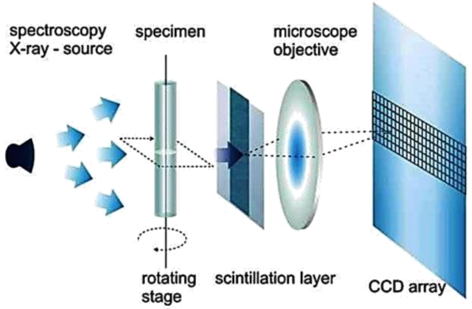
Thermography

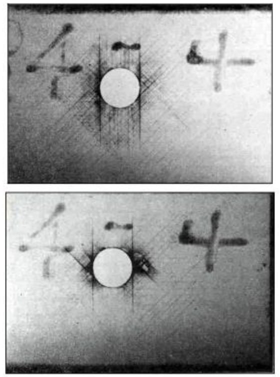




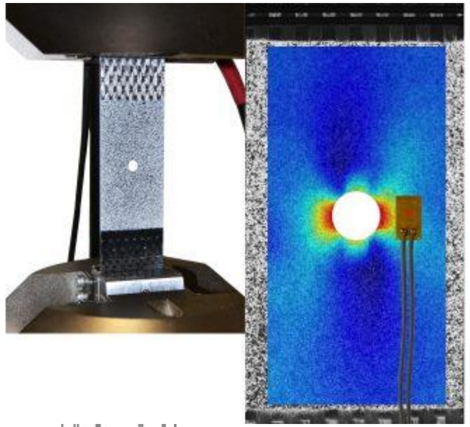
Crack damage in a composite

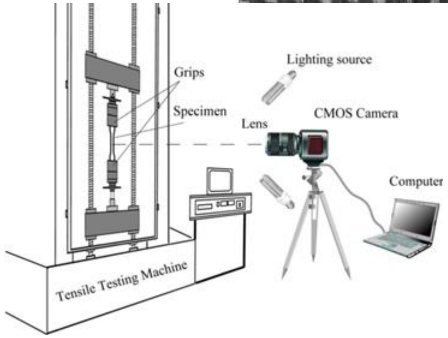
CT scan





DIC

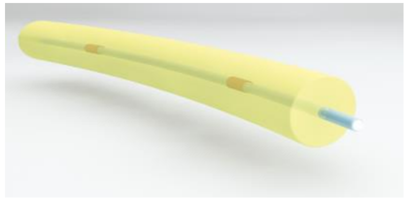




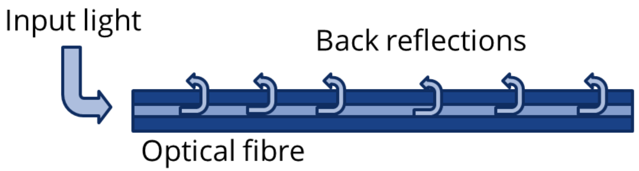
MONITORING TECHNIQUES

ONLINE TECHNIQUES

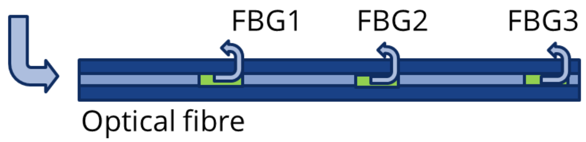
Fibre Optics



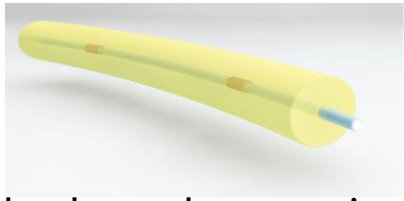
Distributed



Grating-based

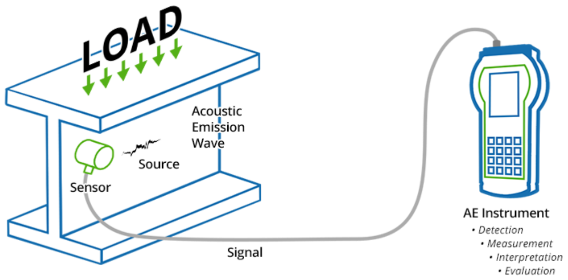


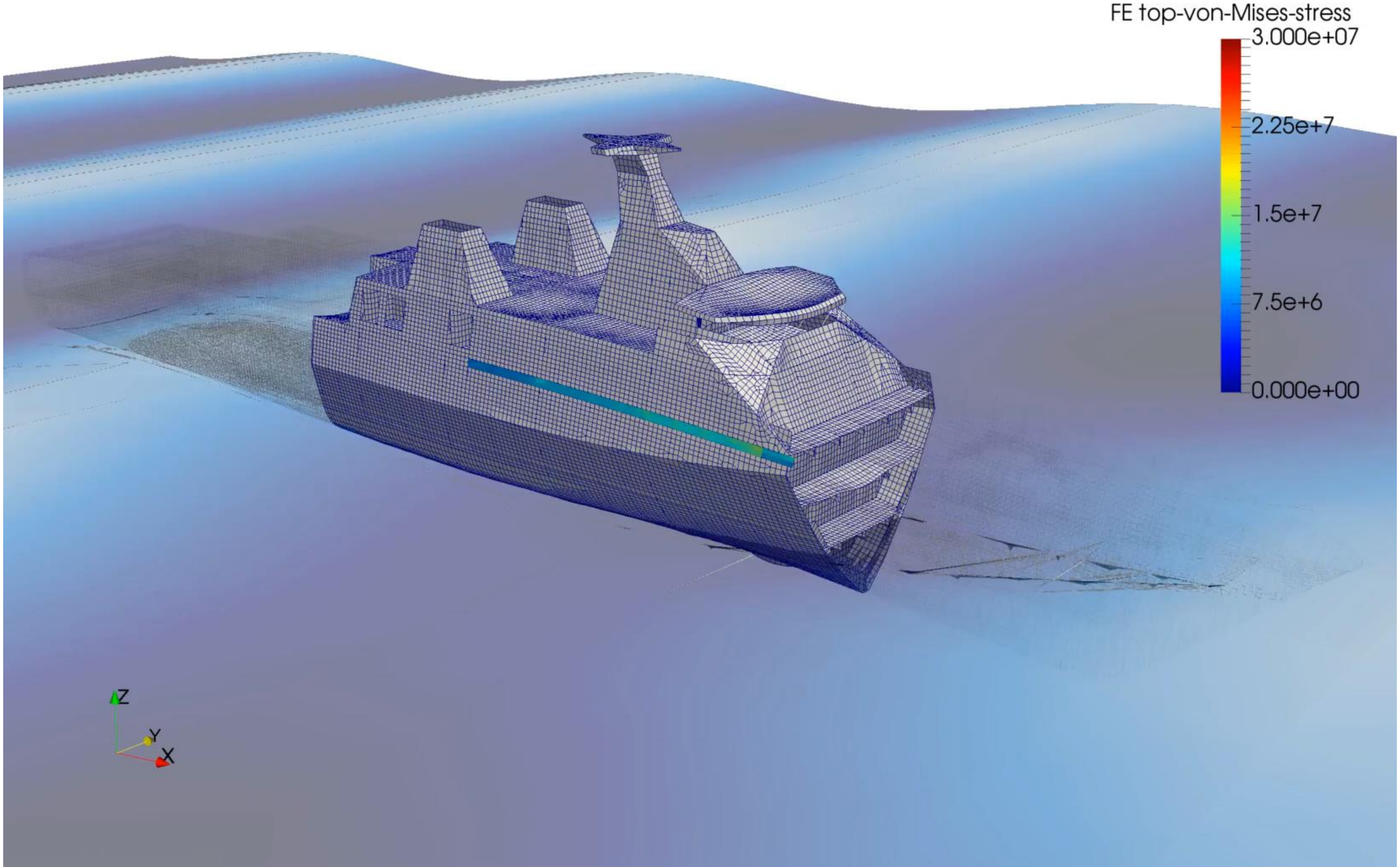
Accelerometer



Can be based on optical fibres

AE

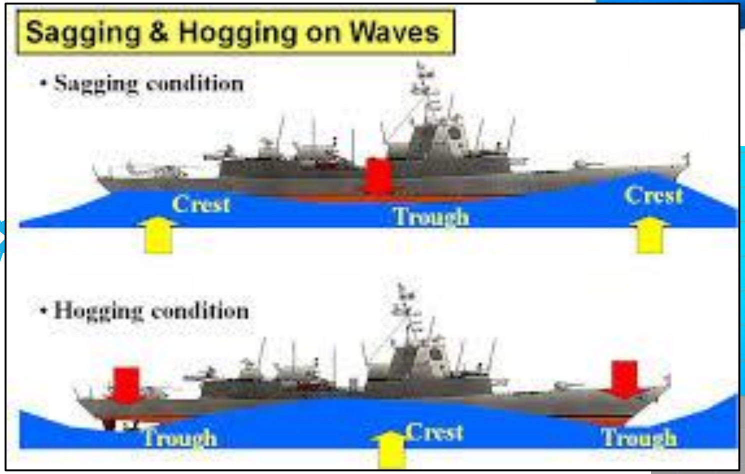



FE top-von-Mises-stress
3.000e+07
2.25e+7
1.5e+7
7.5e+6
0.000e+00
Z
Y
X

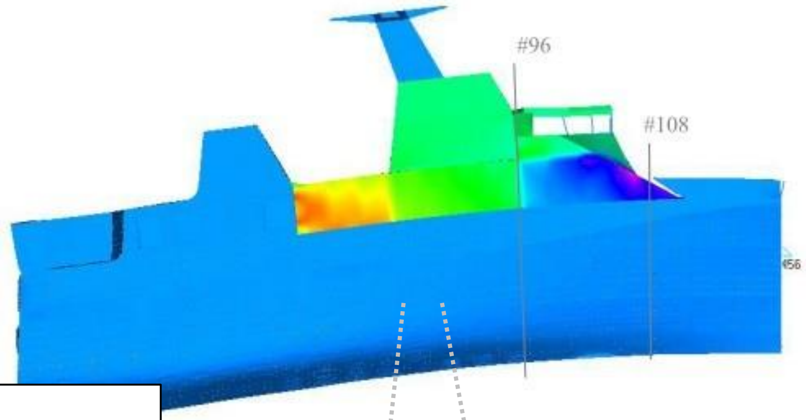
PRELIMINARY ANALYSIS

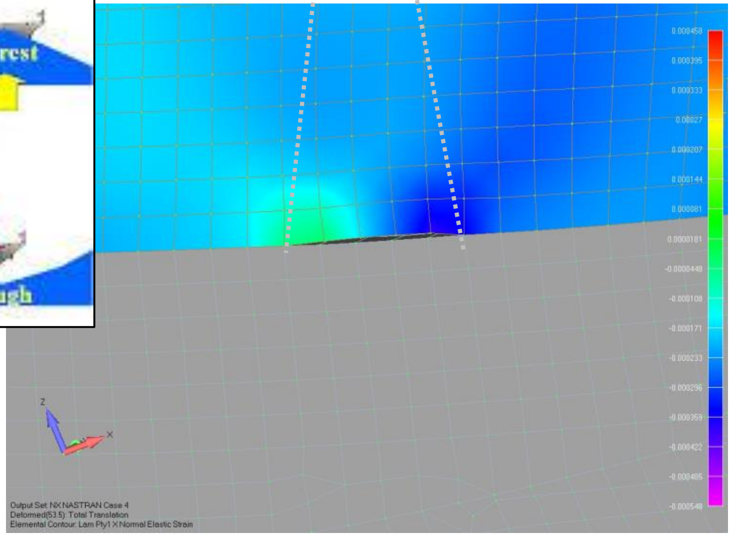
- 2 load cases analyzed at fore end of superstructure
- Length of disconnection :
  - 0 mm
  - 600 mm
  - 900 mm
  - 1200 mm
  - 1500 mm

Load cases	Frame 90	Frame 108
	VBM (kN.m)	VBM (kN.m)
Case "Acrest" (moment)	Design VBM #90 hogging	Design VBM #108 hogging
Case "Acrest" (shear aft)	73.7 % of Design VBM hogging	90.1 % of Design VBM hogging
Case "Acrest" (shear fore)	71.2 % of Design VBM hogging	72 % of Design VBM hogging
Case "Atrough" (moment)	Design VBM #90 sagging	Design VBM #108 sagging

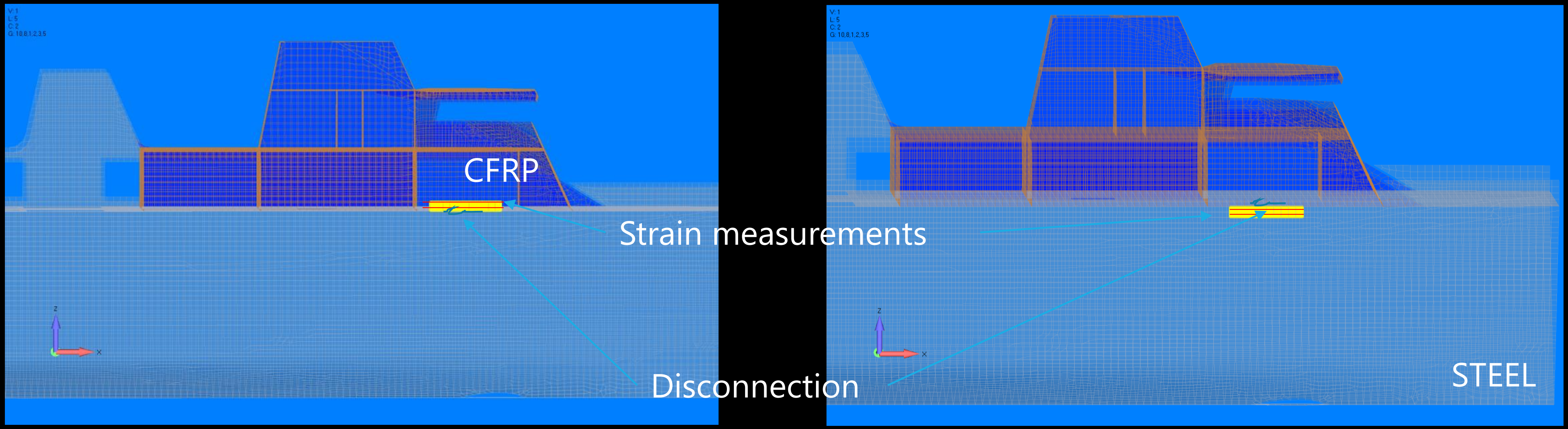


Continuous mesh
No full joint geometry included





SIMULATIONS DONE ON CFRP AND STEEL



ANALYSIS ON STEEL

About 100 mm

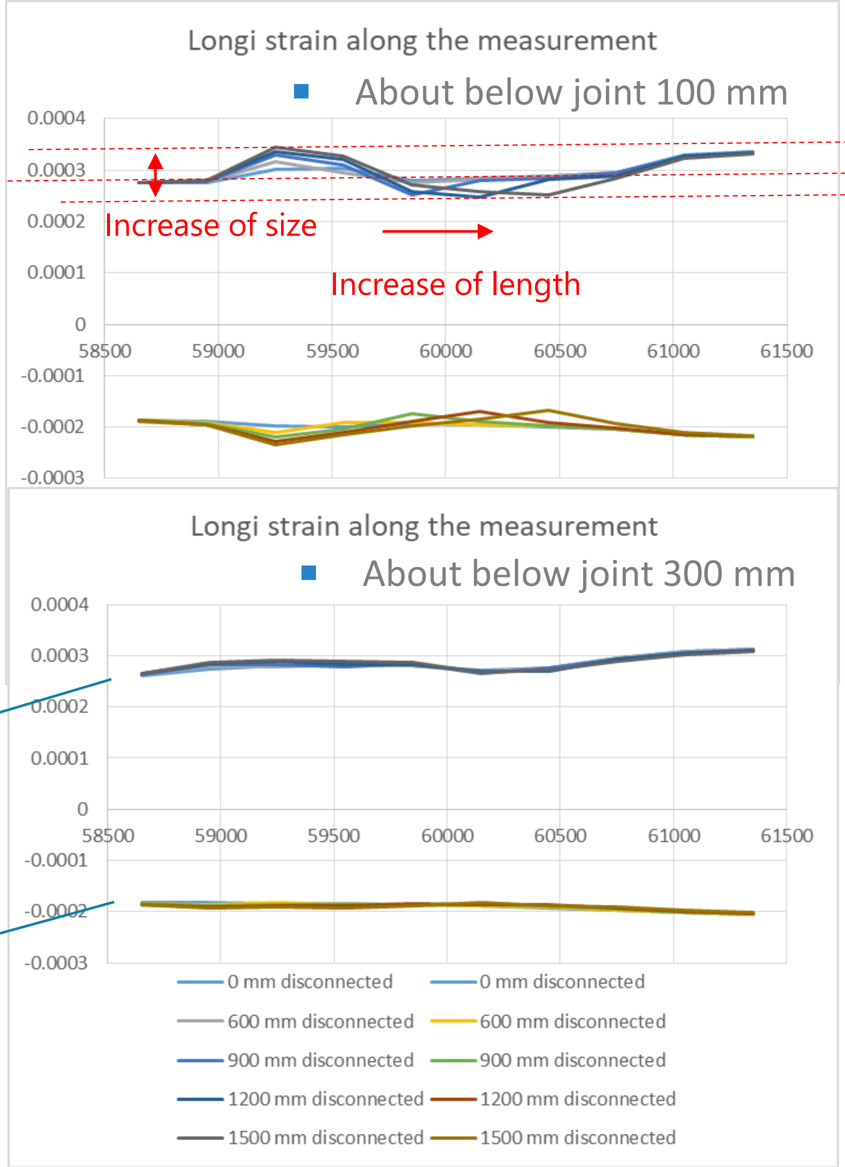
- Clear change in strain values

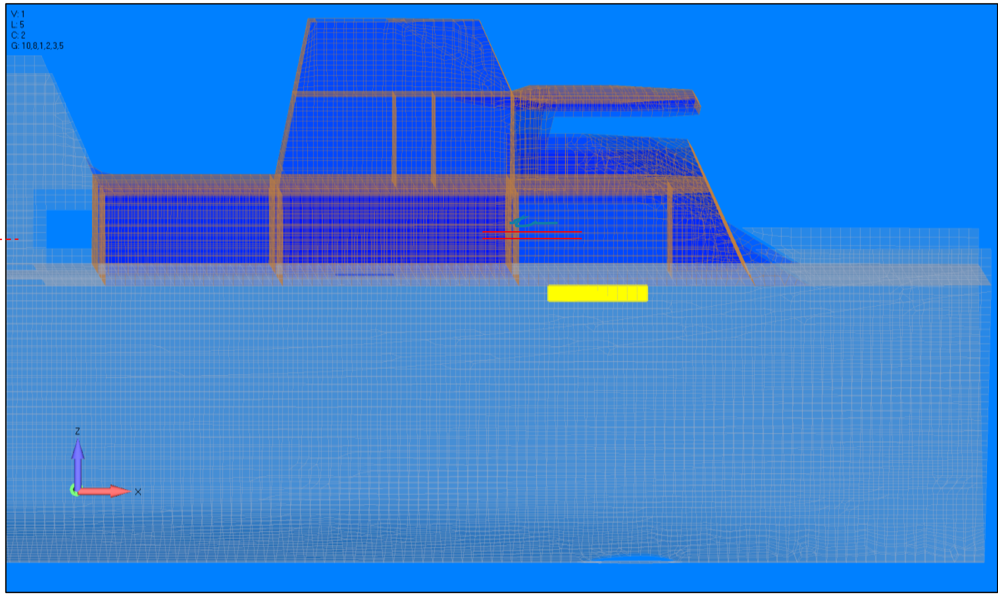
About 300 mm

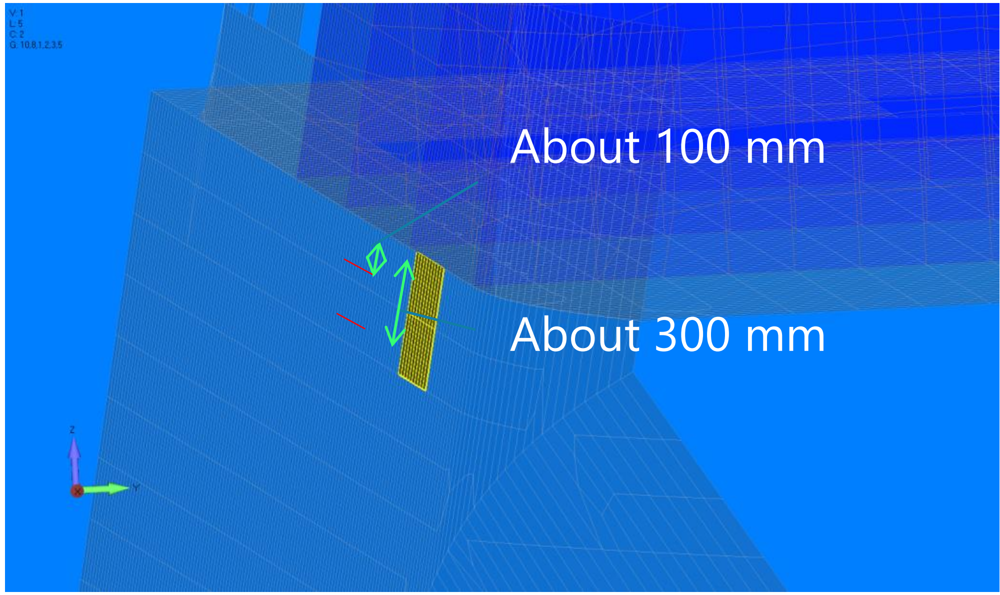
- No change in strain values

Case A+

Case A-





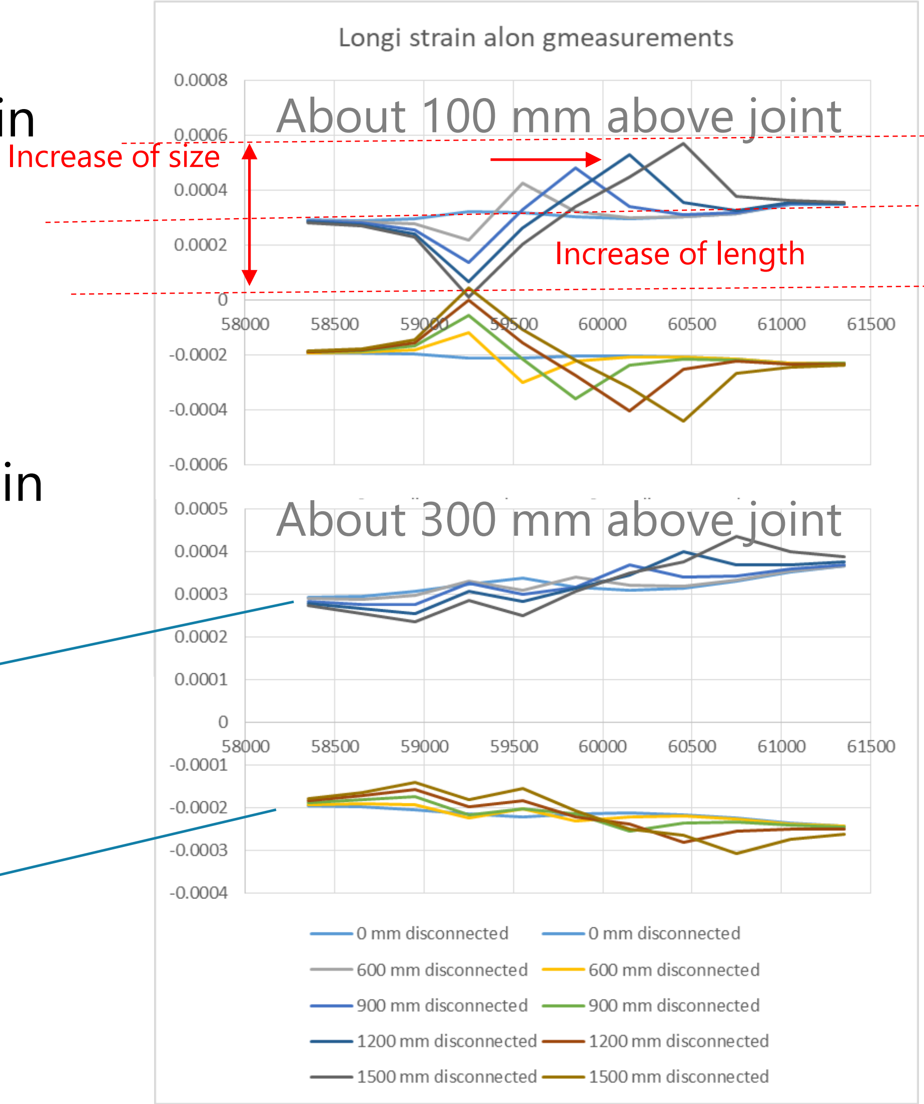


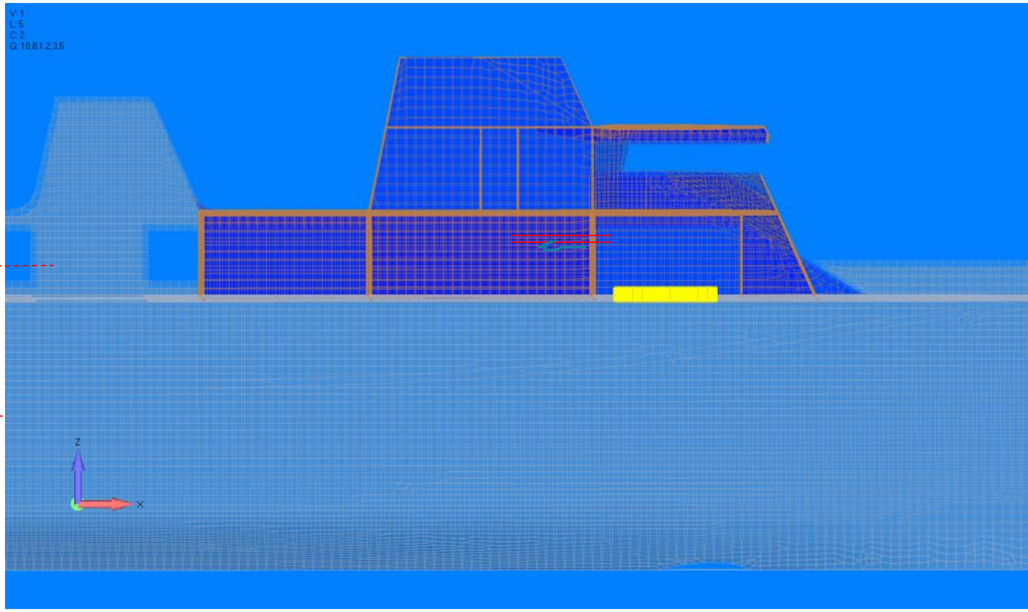
ANALYSIS ON COMPOSITES

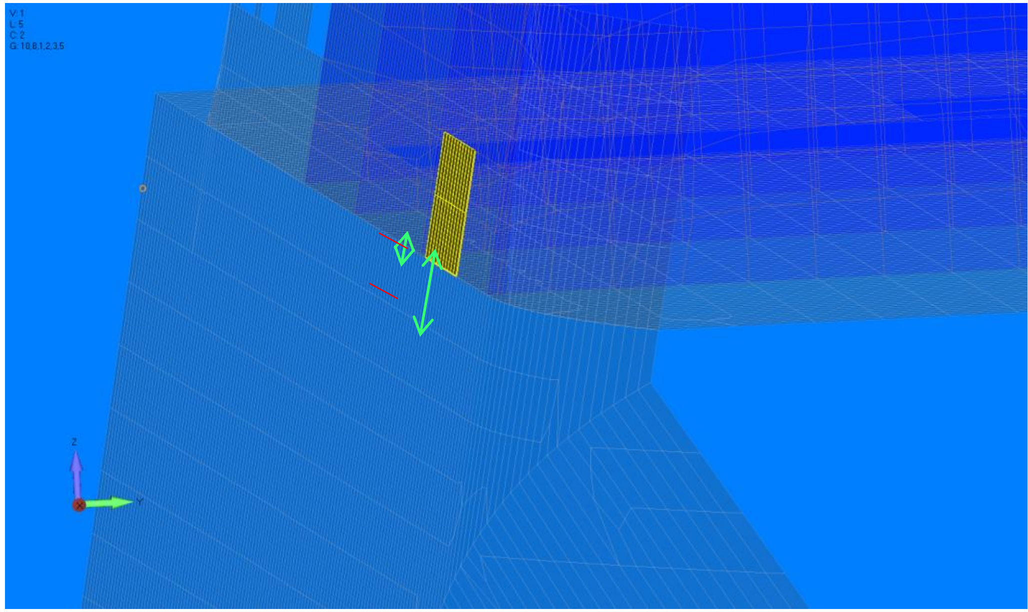
- At two heights:
  - About 100 mm
    - Clear change in strain values
    - + and -300με
  - About 300 mm
    - Small change in strain values
    - + and -100με

Case A+

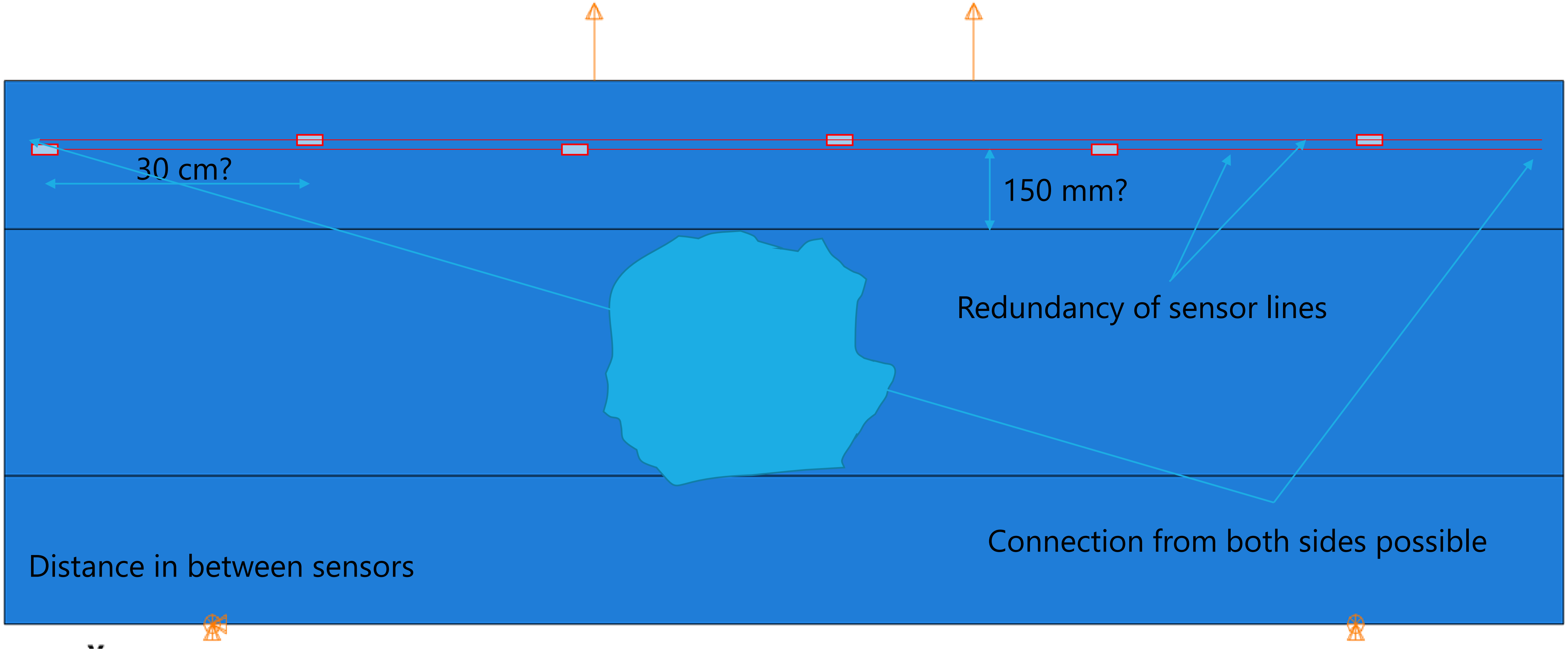
Case A-







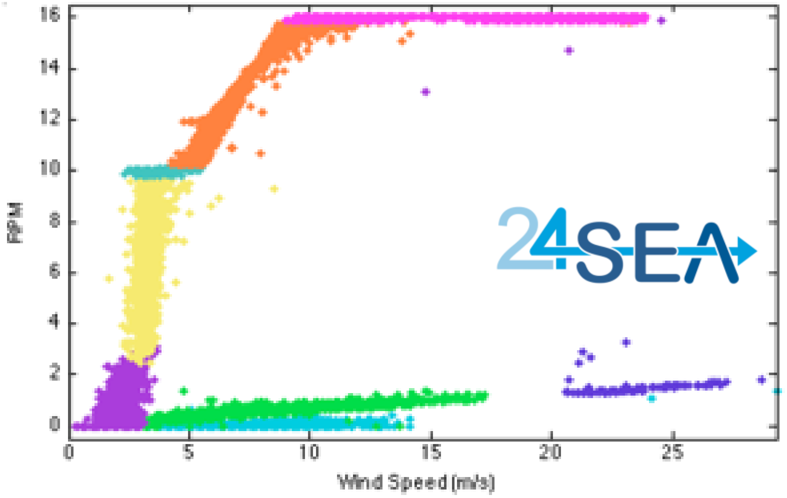
FBG SENSING POINTS POSITION



CONCLUSIONS

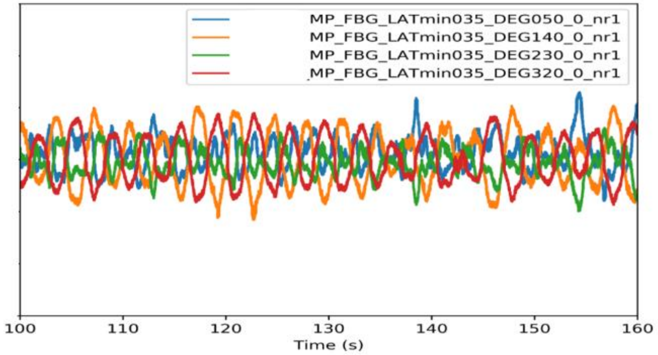
- Further Finite element simulations are needed
- Possibility to detect defects/disbonds by looking at the strains on the composite side
- If we have every 30 cm a sensor a potential defect of 15 cm can be detected
- Necessity to know the loading condition, wave direction to do **active classification of loading conditions**

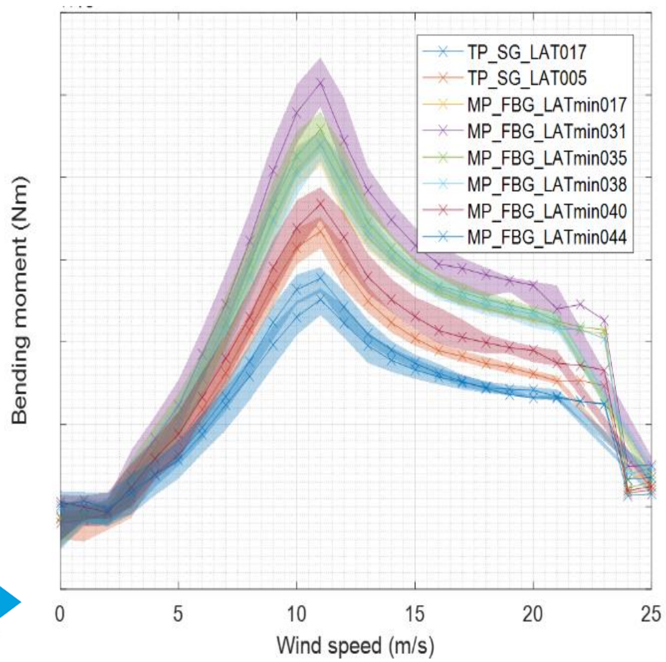
	Wind speed (m/s)		rpm		Pitch angle (deg)	
	Min.	Max.	Min.	Max.	Min.	Max.
1:Pitch : >80	n/A	n/A	n/A	n/A	80	100
2:Pitch : ±80	0	20	n/A	n/A	70	80
3:Pitch : ±20	n/A	n/A	n/A	n/A	19.5	20.5
4:RPM : <10	n/A	n/A	2.5	9.8	n/A	n/A
5:RPM : ±10	n/A	n/A	9.8	10.2	n/A	n/A
6:RPM : <16	n/A	n/A	10.2	15.9	n/A	n/A
7:RPM: ±16	n/A	n/A	15.9	17	n/A	n/A
8:Cut-Out	20	n/A	n/A	n/A	70	80

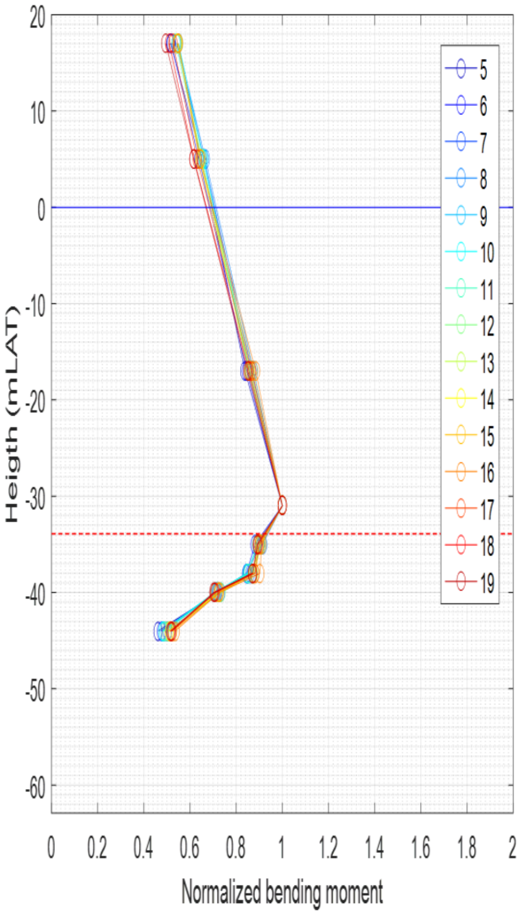


Example Different loading conditions for a wind turbine (Courtesy 24Sea)

LOAD MONITORING CONCEPT







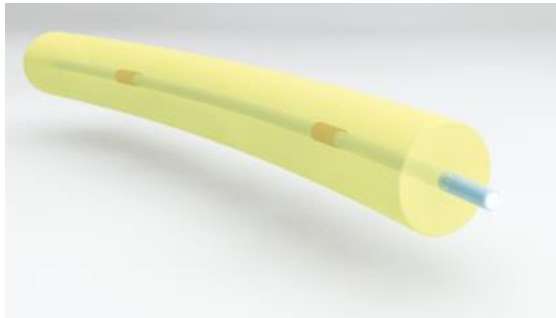
FBG SENSORS IMPLEMENTATION

- ONLINE~~/OFFLINE~~
- APPLICABILITY:
  - Glue fibres on boat-hull, superstructure (accessibility to structure needed, from outside)
  - Multiple fibres can be used with multiple sensors,
  - Measurement frequency high enough to detect dynamic effects
- REPAIRABILITY:
  - Only when not embedded in the bonded joint
  - Renew/repair sensor is possible

FEASIBILITY OF INSTALLATION

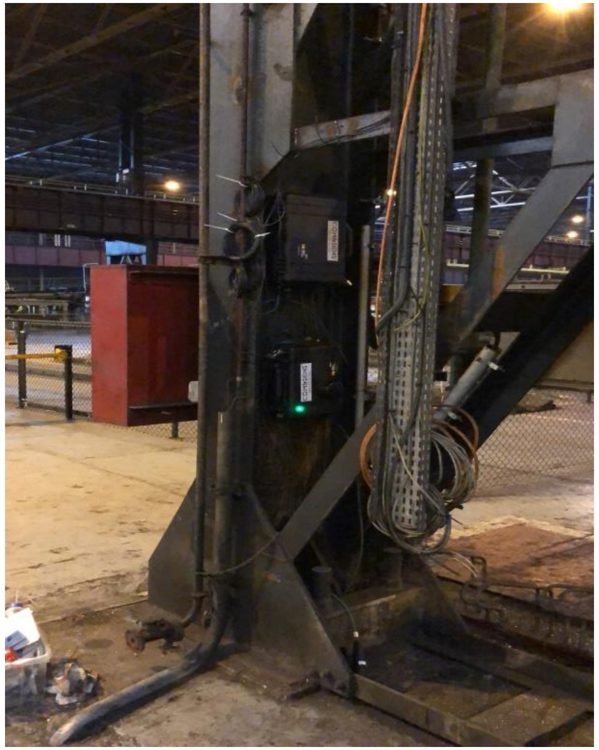
Flat sensor strip

Protection of environment



Switch to round GFRP rod

Stand alone read-out unit
- Measurement
- 4G



RELIABILITY ANALYSIS

- Unprotected steel samples with optical & electrical strain gages
- Optical sensors and glue have survived the salt spray
  - Spectrum can still be read completely
- Corrosion got between strain sensor and steel, so most likely no longer measuring strain (As expected, to be verified)
- Corrosion prevention required for sensors glued steel

- CFRP samples with same sensors now in salt spray chamber at TUD
  - Much better results expected since no corrosion under adhesive

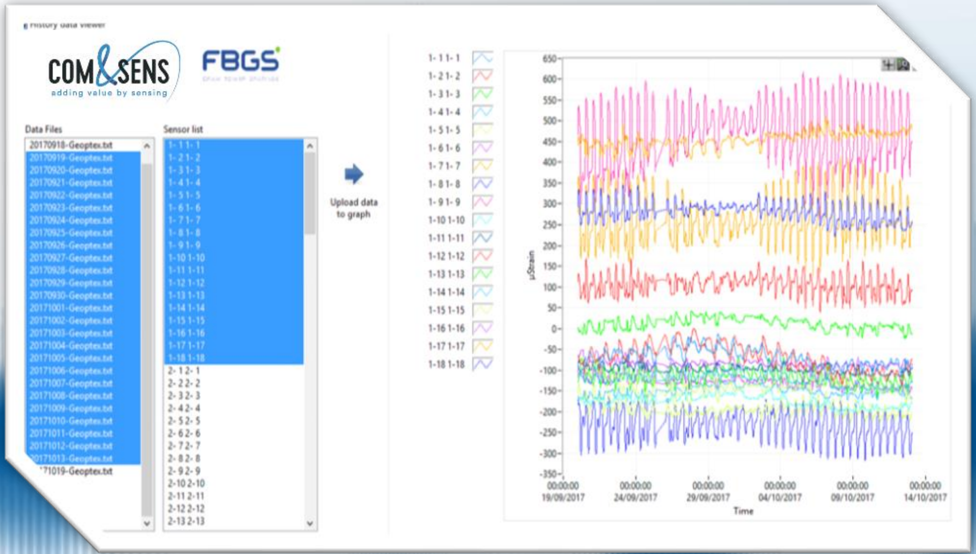
COM&SENS
adding value by sensing

FRONT RUNNER IN FIBER OPTIC SENSING

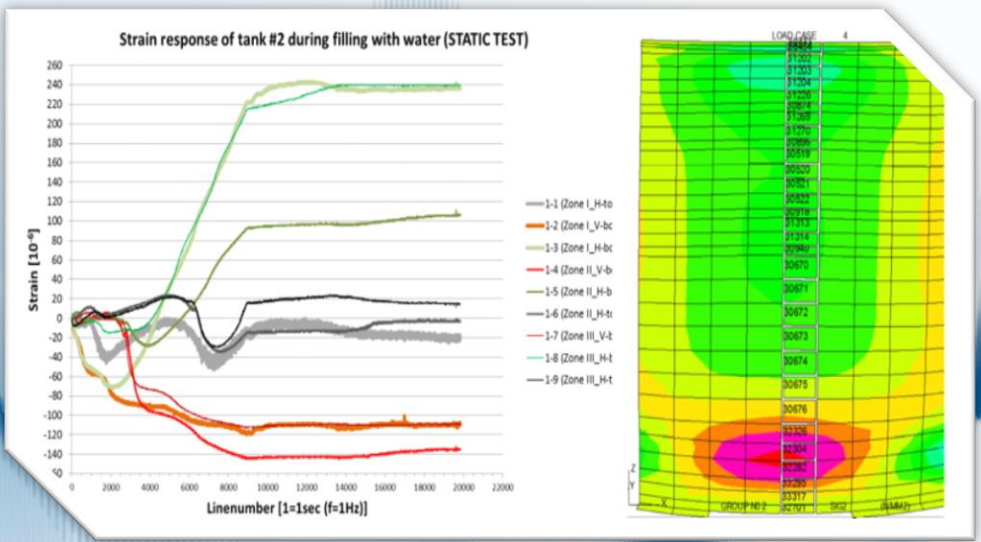
JUNE 2019

SERVICES | ADDING VALUE BY SENSING

STRUCTURAL MONITORING



DEVELOPMENT PARTNER



ENGINEERING > PRODUCTION > INSTALLATION > COMMISSIONING > DATA MANAGEMENT

SENSING FLOW

TECHNOLOGY IMPLEMENTATION

SENSOR SYSTEM INSTALLATION

ENGINEERIN
G

PRODUCTION &
INSTALLATION

OPERATION &
COMMISSIONING

DATA OUTPUT

DATA ACQUISITION &
MANAGEMENT

DATA ANALYSIS &
INTERPRETATION

DATA
REPORTS

WE DELIVER SMART STRUCTURES DATA

ASSET MANAGEMENT

Increase production uptime

Collect real data of structural integrity

Shift to predictive maintenance

Avoid blind spots between periodic inspections

Reduce TCO

Use data for diagnostics and statistics

Predict LIFETIME

Automate alerts of critical faults

DESIGN VALIDATION

In Situ loads measurements
Get real insight of loading conditions

Real load monitoring
Reliable & accurate

Avoid trial & errors
Design fit for purpose

Validate your Finite Elements
System wide stress, strain & temperature

PROCES CONTROL

Non Intrusive

In-situ embedded strain, temperature sensing

Sensor Network

Multiplexing of sensing points

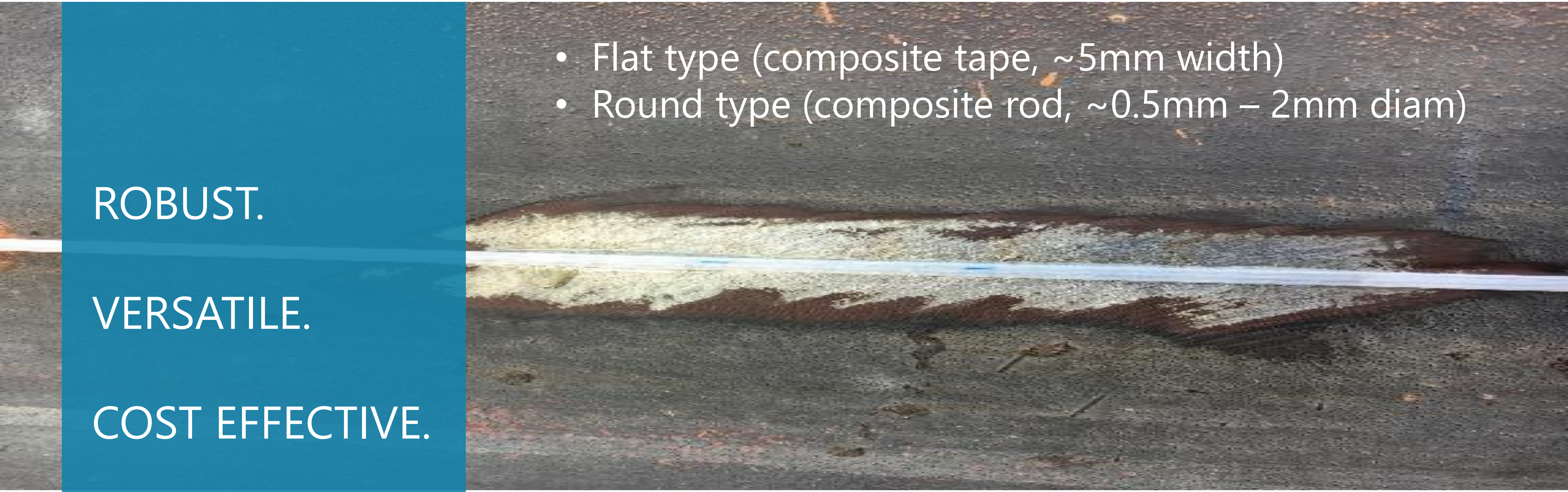
Strainmapping

Reliable & Accurate measurements

Cure & flow analysis

Composites process control

STRIP | COMPOSITES REINFORCED FIBER OPTIC SENSORS



- Flat type (composite tape, ~5mm width)
- Round type (composite rod, ~0.5mm – 2mm diam)

ROBUST.

VERSATILE.

COST EFFECTIVE.

Customized sensor configuration

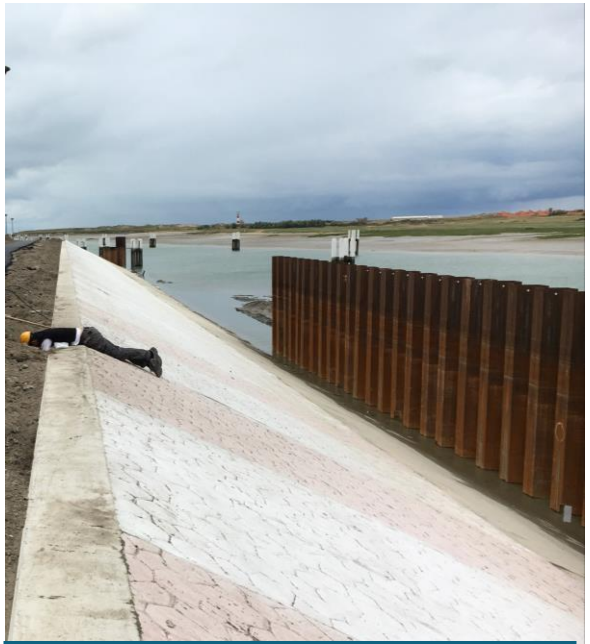
- Variable lengths (~1m – 100m or more)
- Variable amount of sensing points (~max 20/line)
- Custom predefined sensor locations (min 1cm spacing)

ROBUST

DESIGNED FOR HARSH ENVIRONMENTS

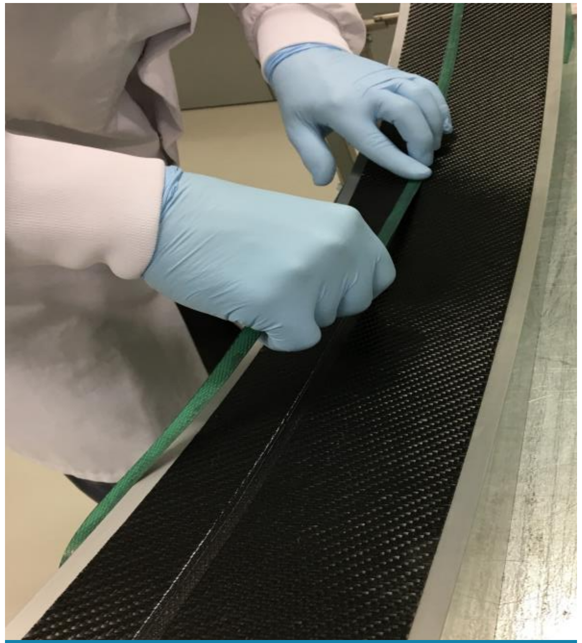
EMBEDDED OR SURFACE MOUNTED COMPOSITES BASED SENSORS

STEEL STRUCTURES



CONCRETE

ASPHALT

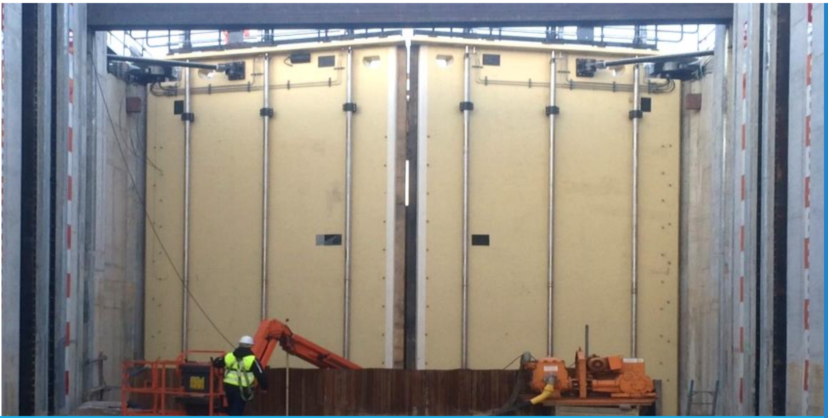


COMPOSITES

- **Fast installation time**
- **Variable & unlimited in length**
- **Geometric freedom (round, square, L-shape)**
- **Extensive multiplexed sensor network**
- **Chemical resistant (sea water, oil,...)**
- **Reproducible UV glueing**

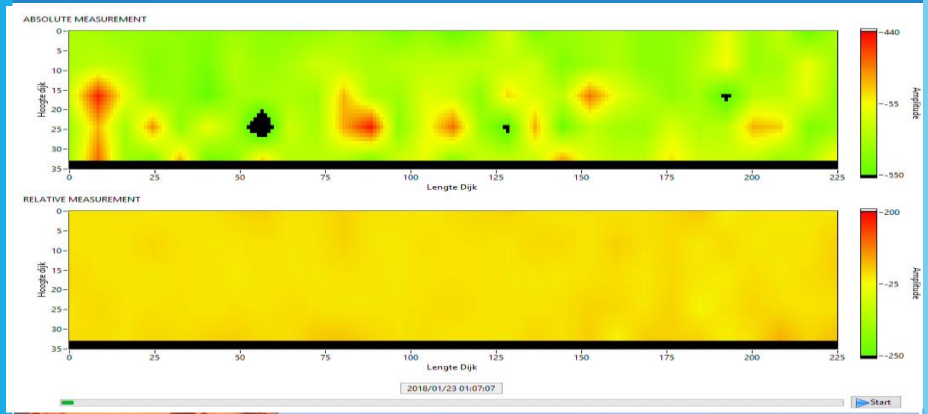
&REFERENCES

FIBRE OPTIC SENSING MONITORING

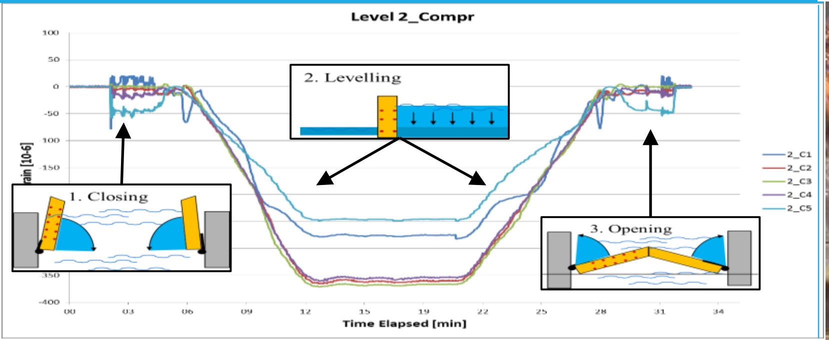


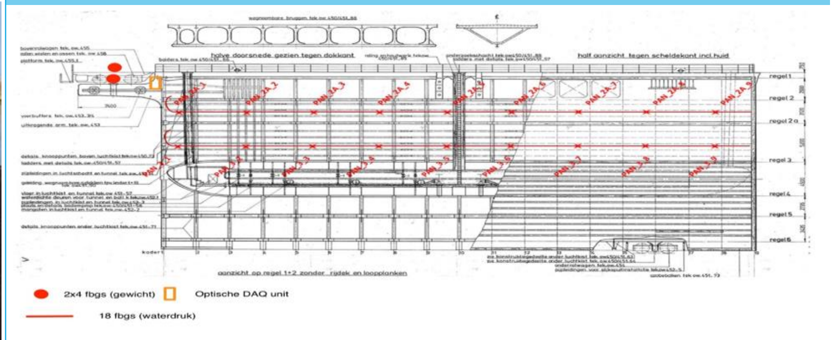
GEOTEXTILE SLOPE MONITORING

COMPOSITES WATERLOCK MONITORING



SURFACE MOUNTED HARSH ENVIRONMENTS MONITORING

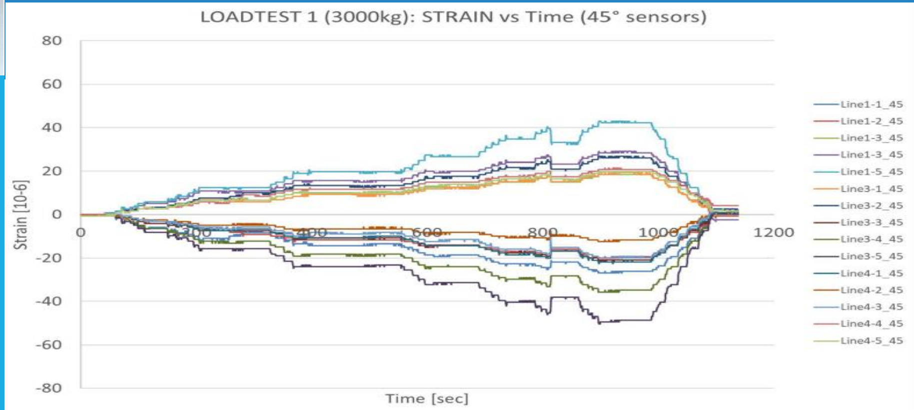




REFERENCES

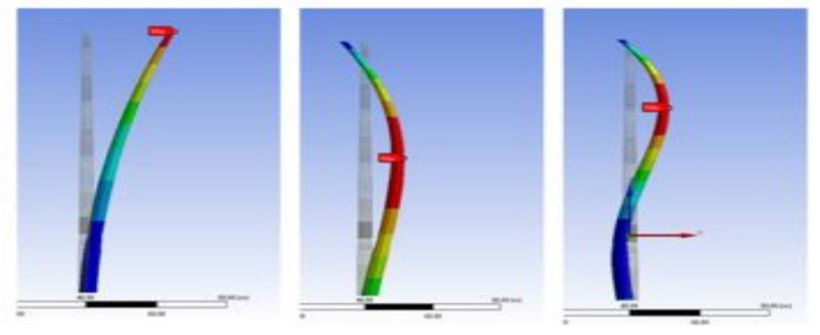
FIBRE OPTIC SENSING MONITORING

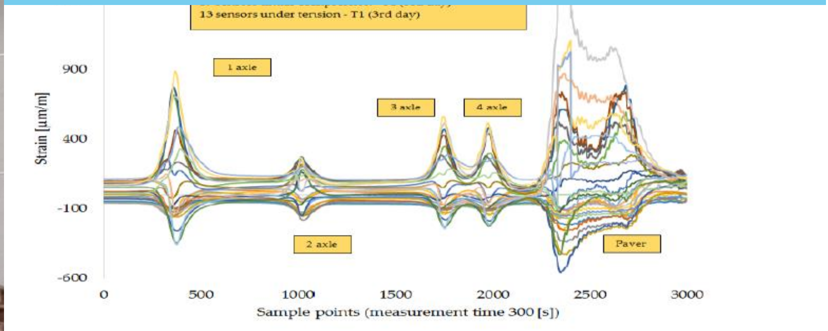
SUPER YACHT CARBON RUDDER



OFFSHORE FOUNDATIONS

ASPHALT STRAIN MONITORING





EDGE CONNECTION

SMART COMPOSITES

c&s

Repairability & **Connection** of embedded optical fibre in machined composites structures

Fiber optic edge connection solution for embedded optical fibres in composite materials
non-intrusive connection featuring low optical-loss and fiber strain relief with standard FO pigtail.

Patent EP16180924.9

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