provincie Oost-Vlaanderen

COM&SENS
adding value by sensing

QUALIFY LIGHTWEIGHT

Technological innovation

Interreg 2 Seas Mers Zeeën
European Regional Development Fund

ON-LINE MONITORING TECHNIQUE FOR BONDED JOINTS USING FIBER BRAGG GRATING SENSORS IN A MARINE ENVIRONMENT

Partner: Com&Sens
Speaker: Dr. Ir. Geert Luyckx
21/10/2021

CONTENT

- Com&Sens at a glance
- Requirements for a monitoring system of bonded joints in a marine environment
- Monitoring of bonded hybrid joints laboratory and field testing
- Conclusions/future work

CONTENT

- **Com&Sens at a glance**
- Requirements for a monitoring system of bonded joints in a marine environment
- Monitoring of bonded hybrid joints laboratory and field testing
- Conclusions/future work

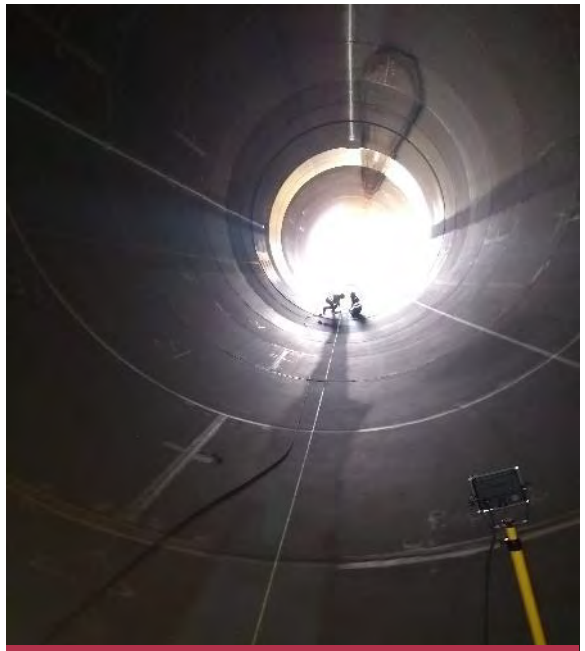
COM&SENS
adding value by sensing

SENSORS DESIGNED FOR HARSH ENVIRONMENTS

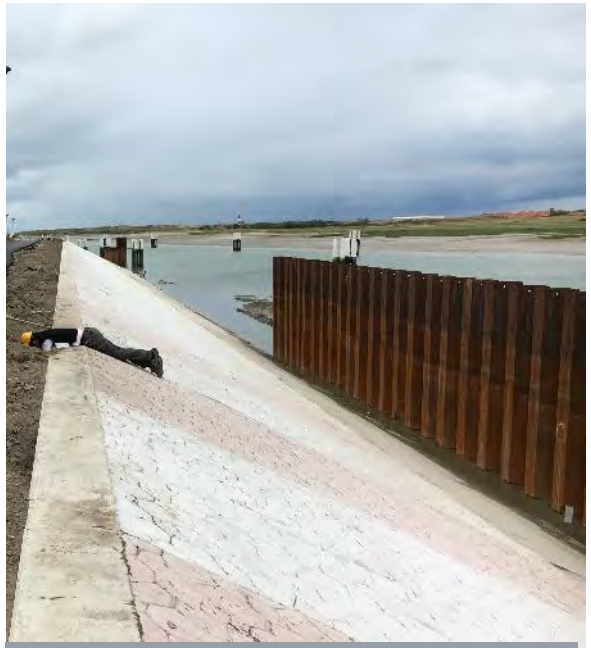
Technological innovation

WE ENGINEER, PRODUCE AND IMPLEMENT CUSTOMIZED COMPOSITES SENSING TAPES FOR HARSH ENVIRONMENTS.

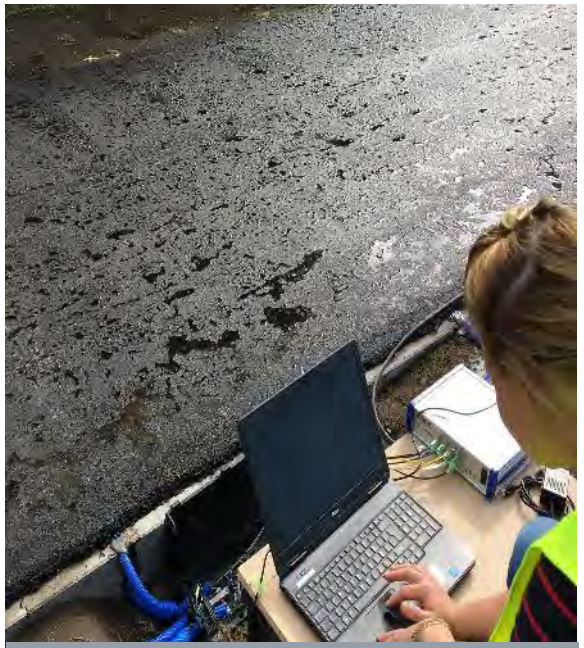
EMBEDDED OR SURFACE MOUNTED COMPOSITES BASED FBG OPTICAL FIBER SENSORS



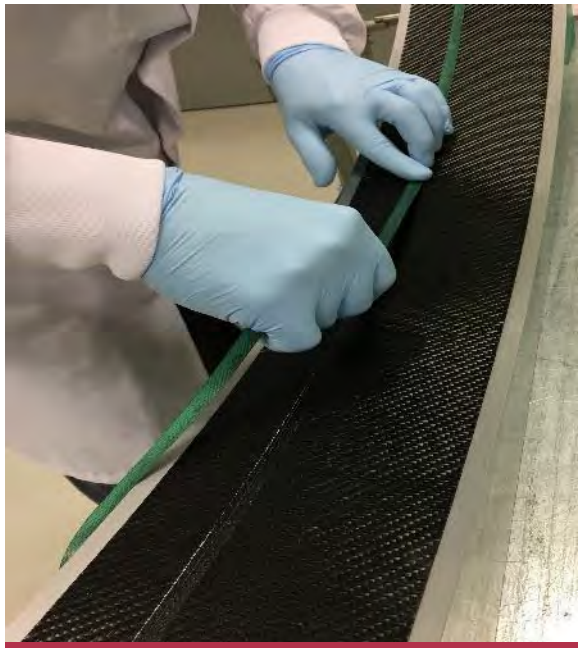
STEEL STRUCTURES



CONCRETE



ASPHALT

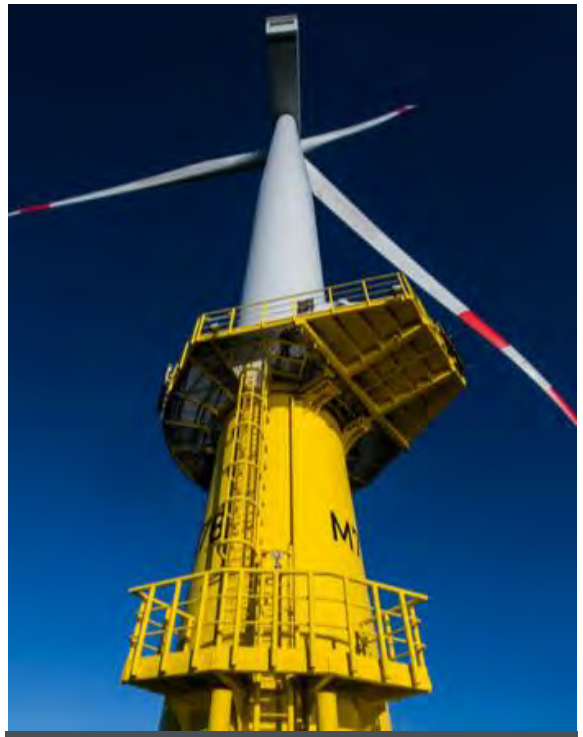


COMPOSITES

FORERUNNERS IN FIBER OPTIC SENSING

Technological innovation

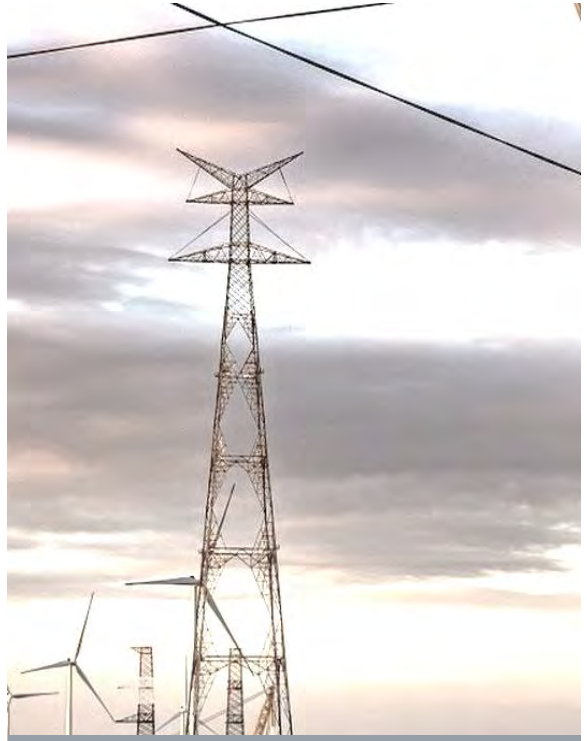
WE ENGINEER, PRODUCE AND IMPLEMENT FIBER OPTIC SENSING TECHNOLOGIES FOR STRUCTURAL HEALTH MONITORING OF STRUCTURES



RENEWABLES

MARINE

CIVIL ENGINEERING

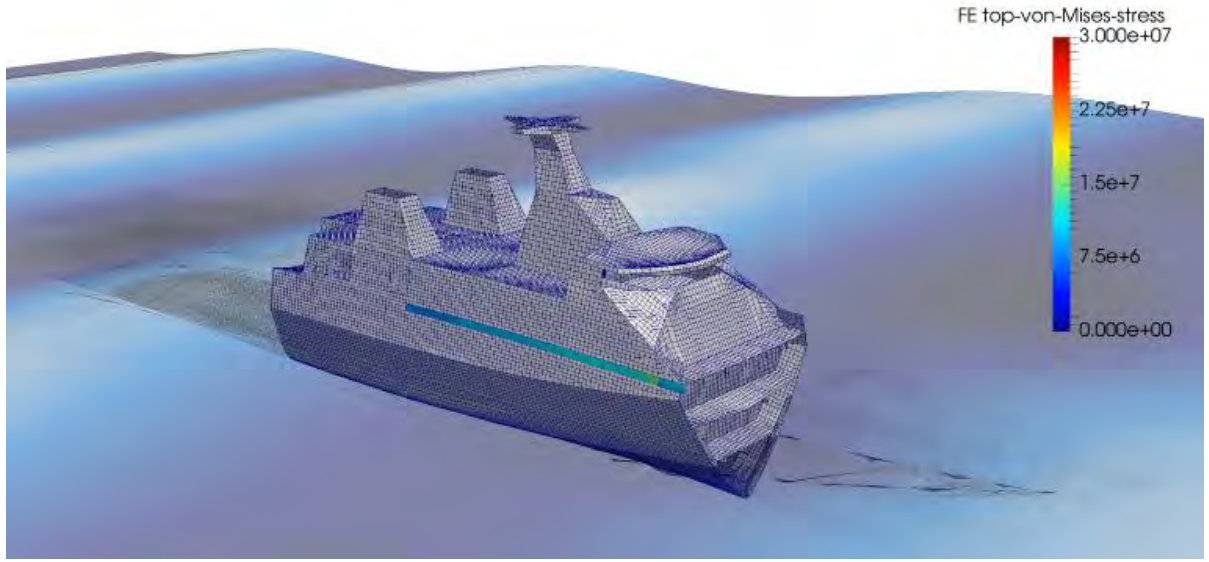


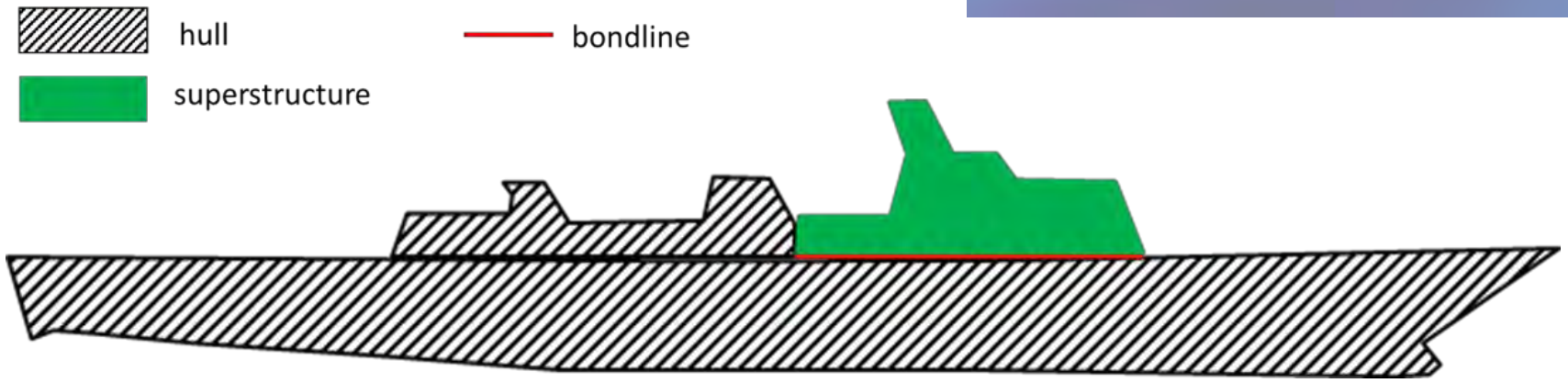
UTILITY

COM&SENS WITHIN QUALIFY

Technological innovation

- Monitoring system for the bondline between composite superstructure and metal hull
- Detect crack and map deformation versus disbond length
- Sensors fit for purpose





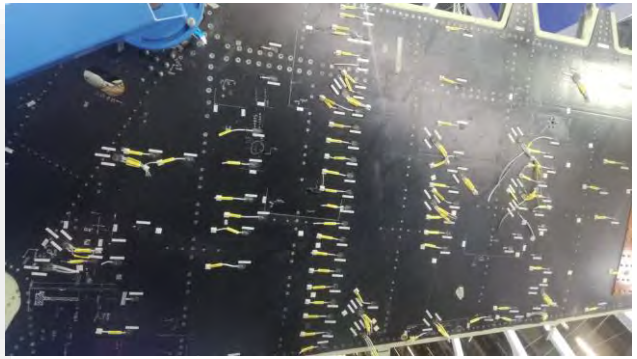
FIBER BRAGG GRATINGS – TECHNOLOGY WITHOUT COMPROMISES

Technological innovation

- Point sensor (semi-distributed)
- Absolute sensor properties
- Sensor is a passive component
- No electrical interference

- Simultaneous read-out: one fibre 20-40 sensors!
- Extensive sensor network

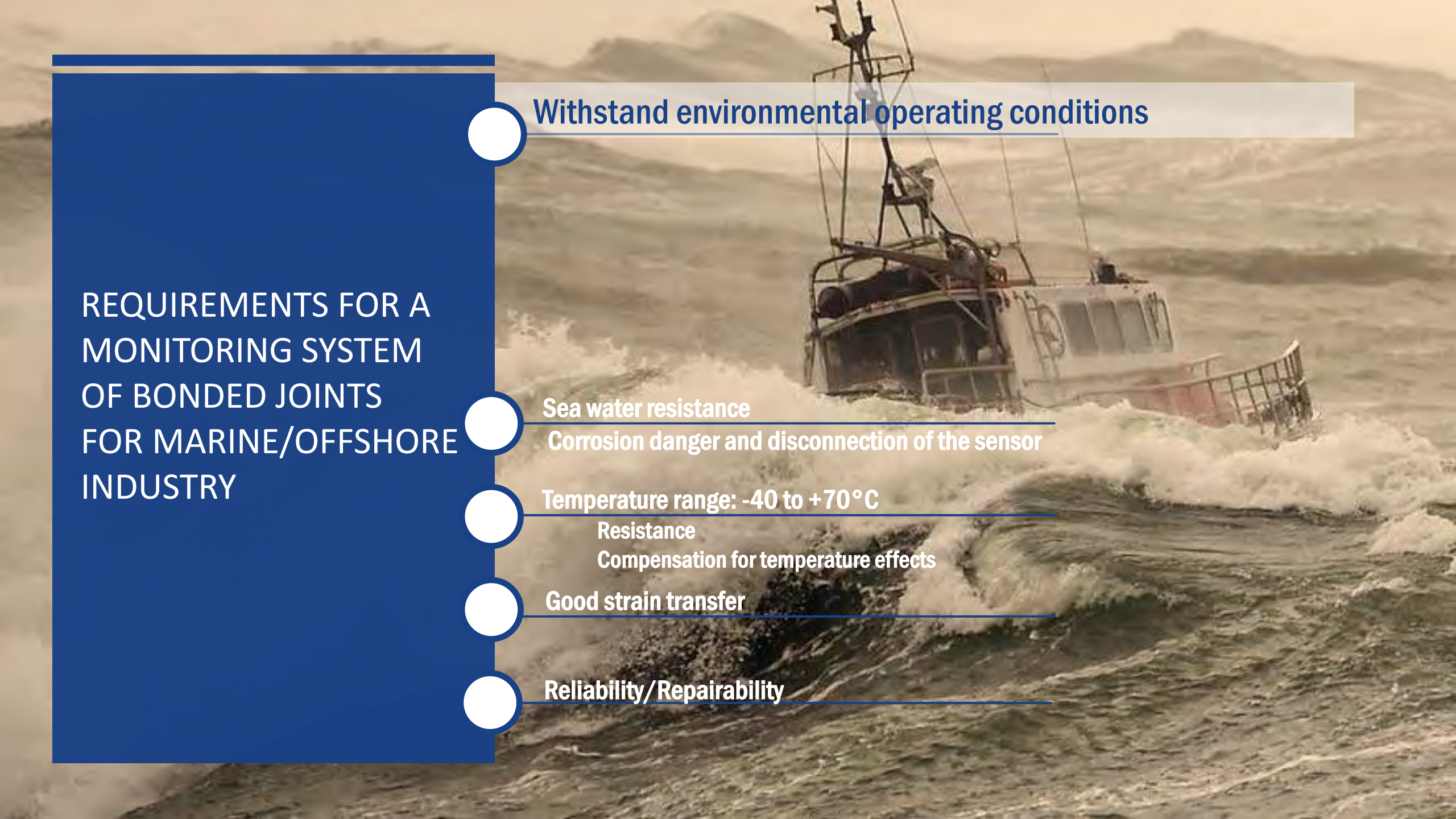
Sensor Principle



OFFICIAL DTG SOLUTION PARTNER

CONTENT

- Com&Sens at a glance
- **Requirements for a monitoring system of bonded joints in a marine environment**
- Monitoring of bonded hybrid joints laboratory and field testing
- Conclusions/future work



REQUIREMENTS FOR A MONITORING SYSTEM OF BONDED JOINTS FOR MARINE/OFFSHORE INDUSTRY

Withstand environmental operating conditions

Sea water resistance

Corrosion danger and disconnection of the sensor

Temperature range: -40 to +70°C

Resistance

Compensation for temperature effects

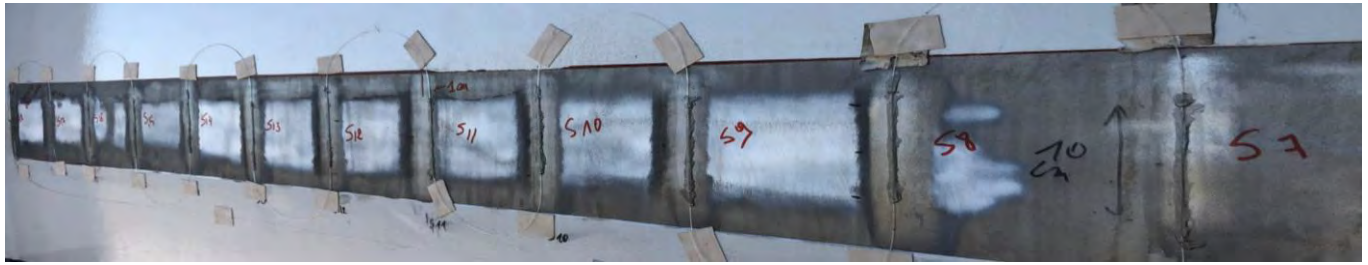
Good strain transfer

Reliability/Repairability

SENSOR SET-UP IN QUALIFY

Flat type (composite tape, ~5mm width)

Round type (composite rod, ~0.5mm – 2mm diam)



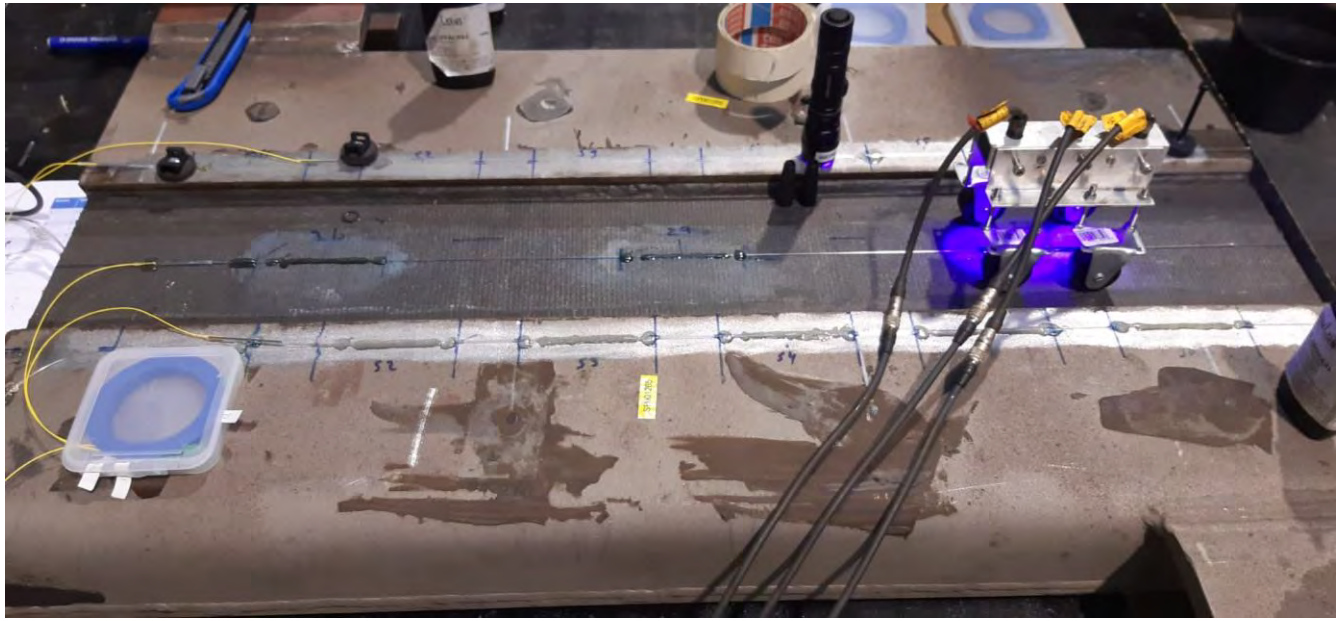
Sensing Tape based on a Rapid, reliable and easy Installation Procedure

- **COMPOSITE STRIP SENSOR**
  - Reinforced fibre optics
  - Embedding and surface mounting
  - In-house production
- **UNIQUE SELLING POINTS**
  - ROBUSTNESS
  - FAST INSTALLATION TIME
  - VERSATILE

Sensor set-up

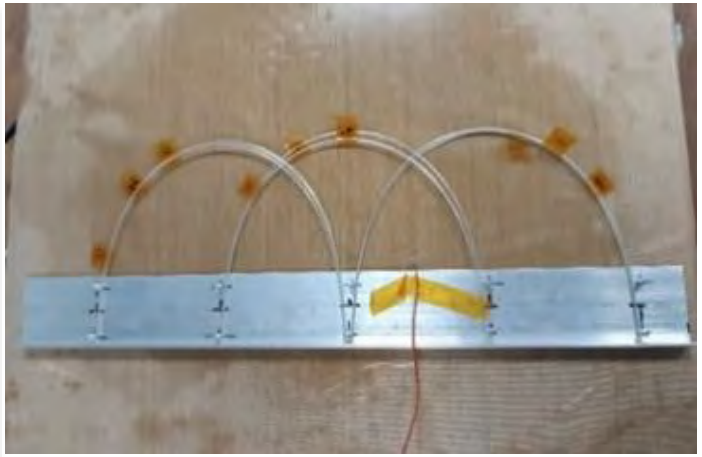
Technological innovation

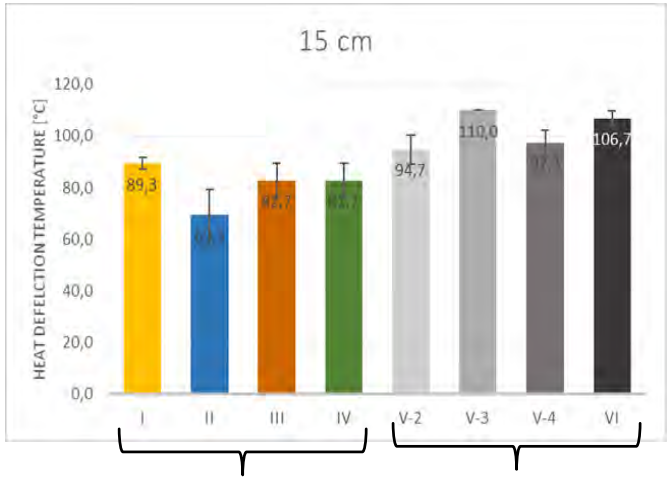
1. Surface treatment
   - Coarse sanding/Bristle blasting
   - Cleaning (Isopropanol)
2. Glue sensor
   - Put sensor line in place
   - Apply glue over 6 to10 cm
   - UV cure (3 min)
3. Protection:



TEMPERATURE

- **Buckling experiments with different resins for the STRIP sensor**
- **Heat deflection temperature (HDT) when buckling occurs**
  - Glass transition temperature
  - Curing degree
- **Qualify specifications of +70°C**





Average HDT @ different coil diameters:

Resin	15 cm	10 cm	6 cm
CS_2801R	81°C	51.4 °C	/
CS_2813R	102°C	/	47.2°C

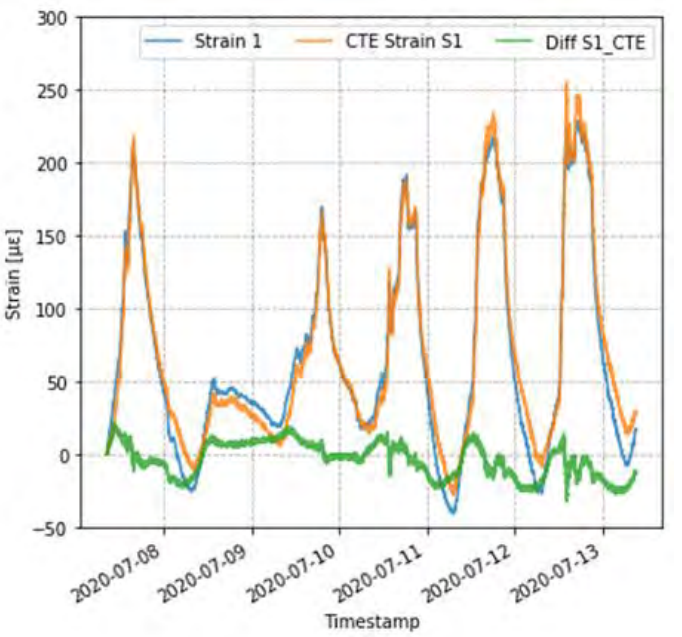
QUALIFY LIGHTWEIGHT

COM&SENS adding value by sensing

Temperature Compensation

Technological innovation

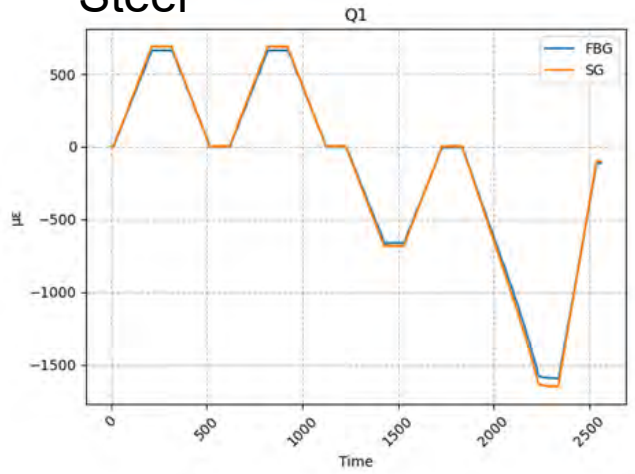
- **How to distinct between temperature induced strains and strains due to mechanical loads?**
- Different techniques
  - Temperature compensation plate
  - Using the CTE and compensate mathematically
- Different covering methods
  - No covering
  - Anti-corrosion tape
  - Anti-corrosion and reflective tape



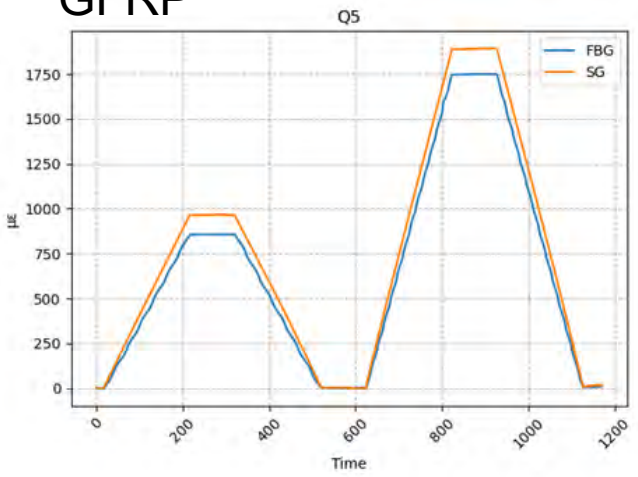
STRAIN TRANSFER

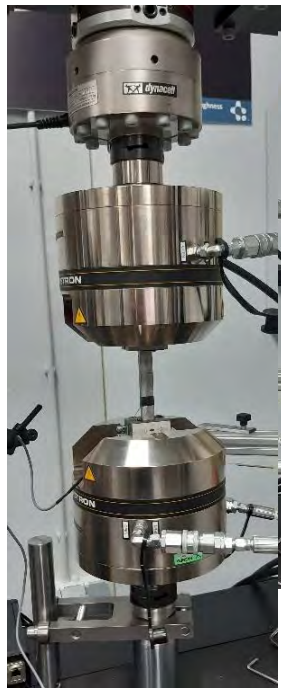
- **Question: How well is the strain of the structure transferred to the sensor?**
- Tested transfer between sensor fiber and:
  - Composite
  - Steel
- Used STRIP sensor:
  - Type: Rod
  - Resin: CS_2813R
  - Glue: CS_01

Steel



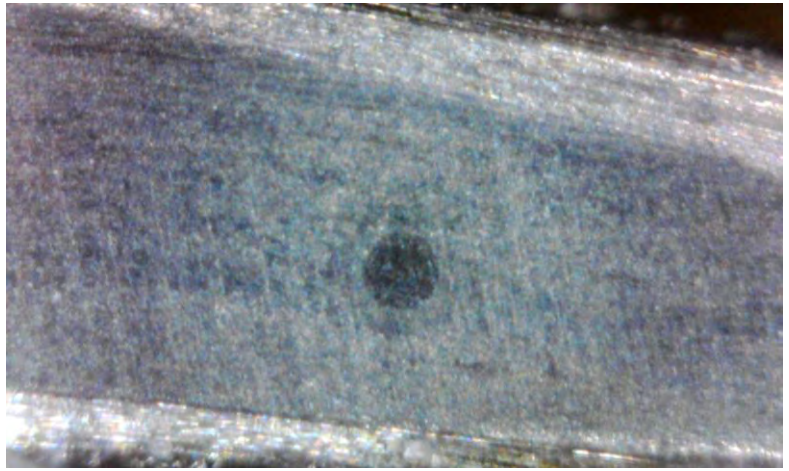
GFRP





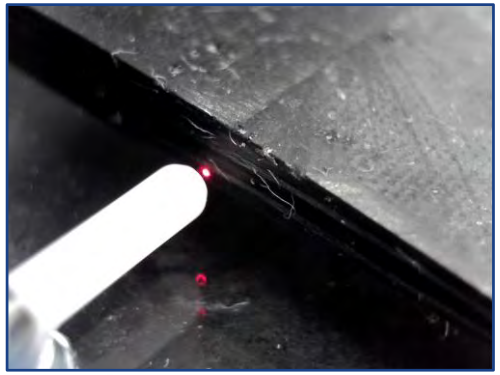
REPAIRABILITY

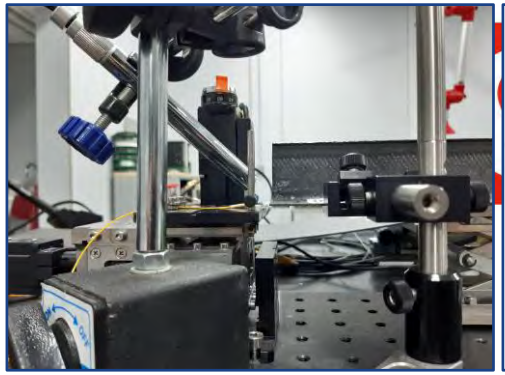
- Enabling the reparation of the egress point
- Based self written waveguide technology

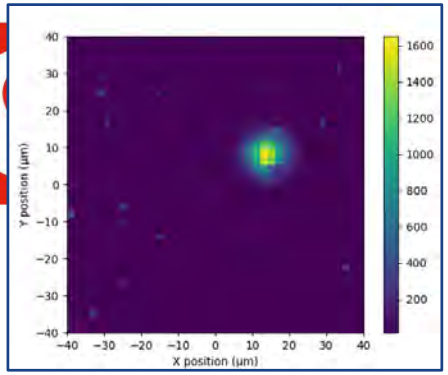


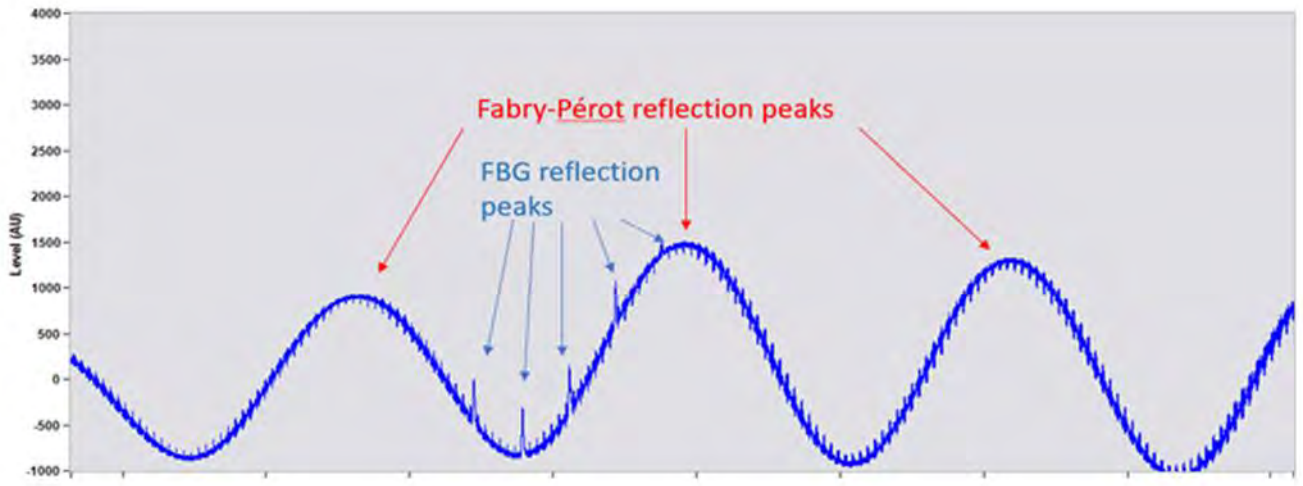
Repairability

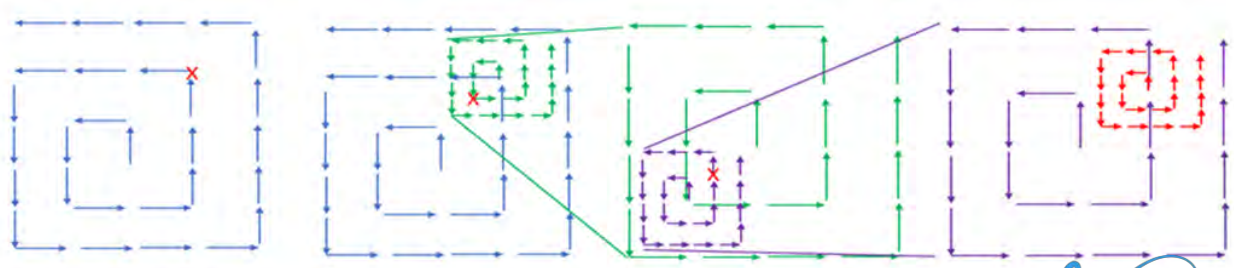
- Procedure:
  - Alignment of embedded/external
  - Make an optical connection
  - Add robust bracket
- Results:
  - Developed in a clean room (imec labs at UGhent)
  - Transfer to industrial lab (C&S facilities in Eke)
  - FBG peak detection Software
  - Automatic alignment











CONTENT

- Com&Sens at a glance
- Requirements for a monitoring system of bonded joints in a marine environment
- **Monitoring of bonded hybrid joints laboratory and field testing**
- Conclusions/future work

MONITORING BONDED JOINTS IN THE MARINE/OFFSHORE INDUSTRY

FOLLOW UP BONDED JOINT BEHAVIOUR

LABORATORY TESTING

IN FIELD APPLICATION

FOLLOW UP BONDED JOINT BEHAVIOUR

Technological innovation

- FROM LAB TO IN FIELD TESTING
  - Main results:
    - **<u>Lab testing</u>**
      - Crack detection and follow up of
        - Tensile sample
        - Arcan sample
    - FBG measurements compare to DIC measurements (not for this presentation)
    - **<u>In-Field testing</u>**
      - Succesfull installation
      - First promising results
  - Reported in: D2.1.1 Structural integrity assessment of the hybrid structure

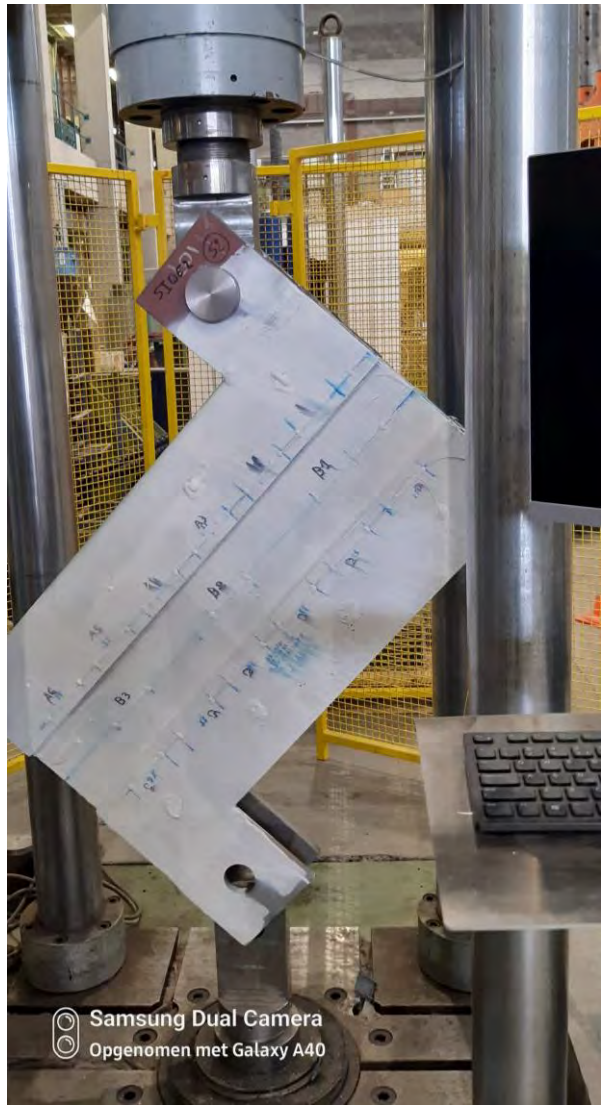
QUALIFY LIGHTWEIGHT

COM&SENS adding value by sensing

FOLLOW UP BONDED JOINT BEHAVIOUR

Technological innovation

- FROM LAB TO IN FIELD TESTING
  - Main results:
    - **<u>Lab testing</u>**
      - Crack detection and follow up of
        - Tensile sample
        - Arcan sample
    - FBG measurements compare to DIC measurements (not for this presentation)
    - **<u>In-Field testing</u>**
      - Succesfull installation
      - First promising results
  - Reported in: D2.1.1 Structural integrity assessment of the hybrid structure



COM&SENS
adding value by sensing

FOLLOW UP BONDED JOINT BEHAVIOUR

Technological innovation

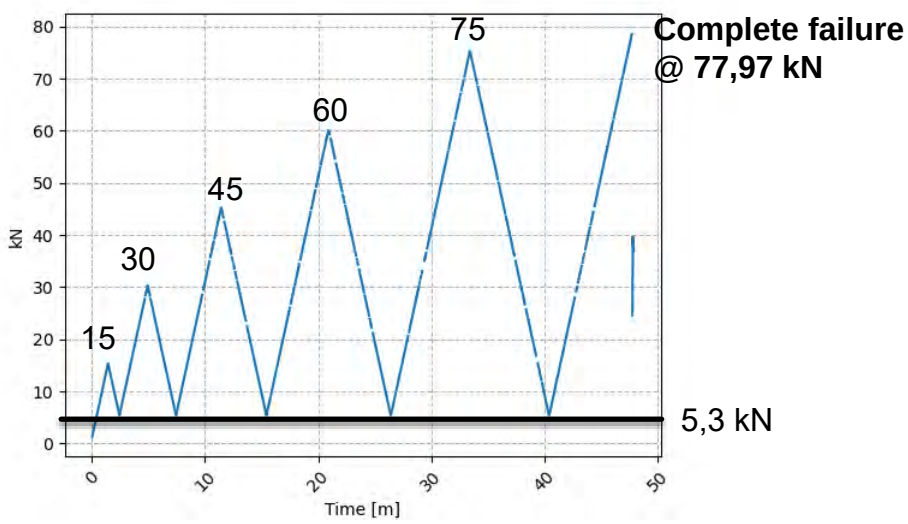
- FROM LAB TO IN FIELD TESTING
  - Main results:
    - **<u>Lab testing</u>**
      - Crack detection and follow up of
        - Tensile sample
        - Arcan sample
    - FBG measurements compare to DIC measurements (not for this presentation)
    - **<u>In-Field testing</u>**
      - Succesfull installation
      - First promising results
  - Reported in: D2.1.1 Structural integrity assessment of the hybrid structure

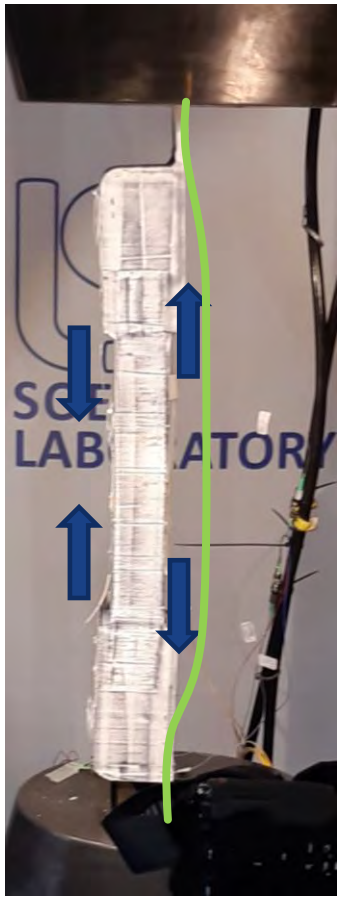
QUALIFY LIGHTWEIGHT

COM&SENS adding value by sensing

TENSILE TEST

- Quasi static tensile test@ Ugent
- Progressive loading cycles



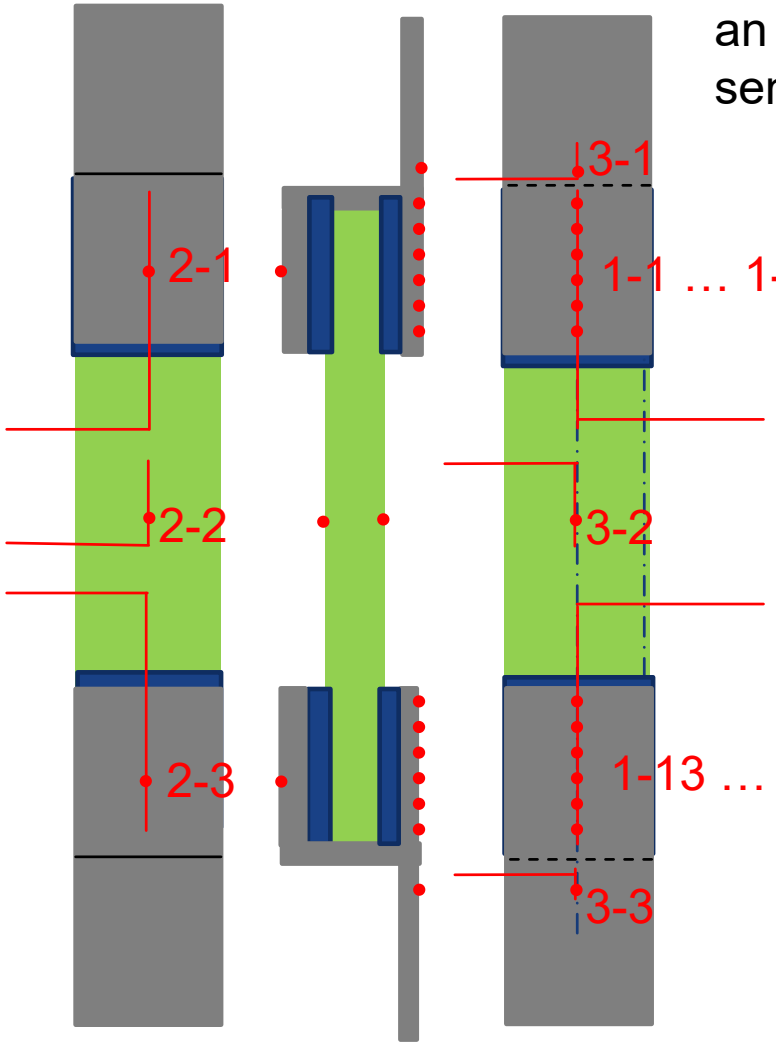


UNIVERSITEIT GENT

QUALIFY LIGHTWEIGHT

COM&SENS adding value by sensing

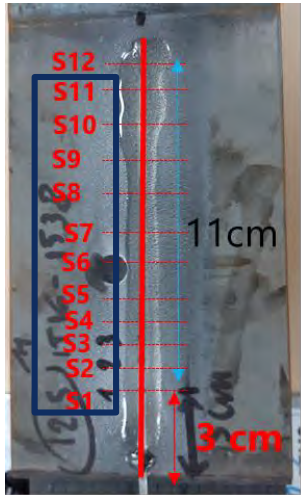
Sensor configuration



Every cm an FBG sensor

1-1 … 1-12 →

1-13 … 1-26 →



Technological innovation

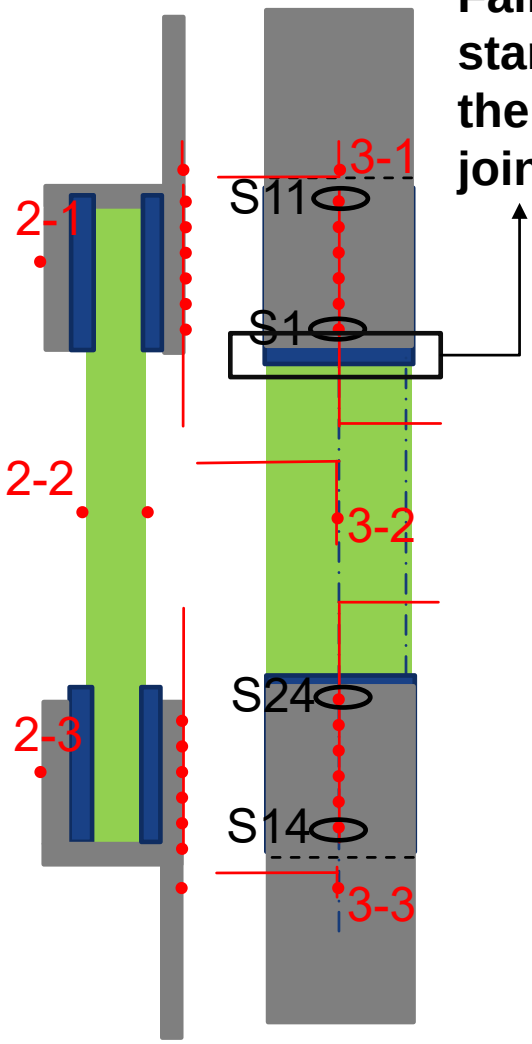
UNIVERSITEIT GENT

QUALIFY LIGHTWEIGHT

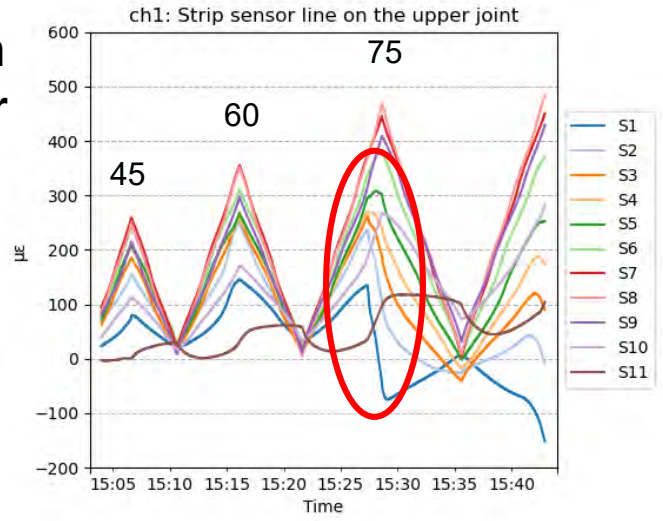
COM&SENS adding value by sensing

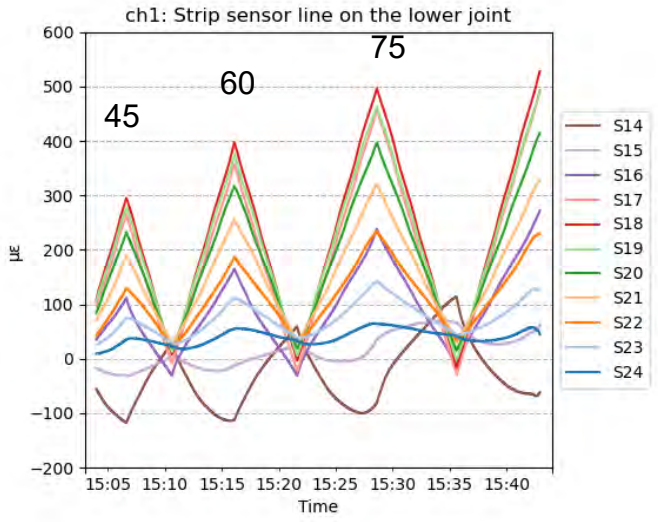
Strain results

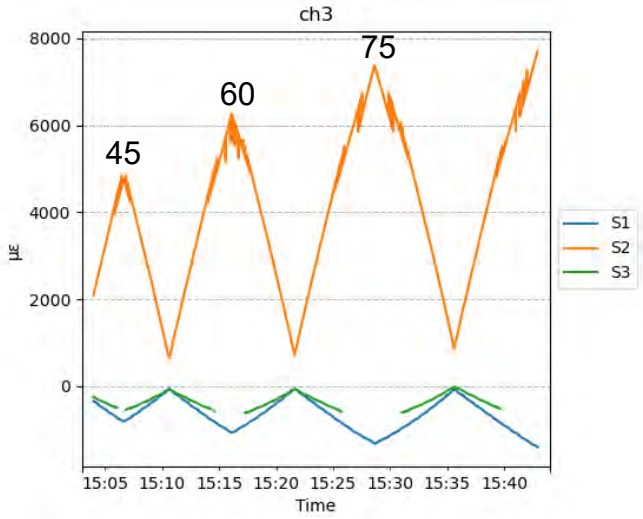
Technological innovation

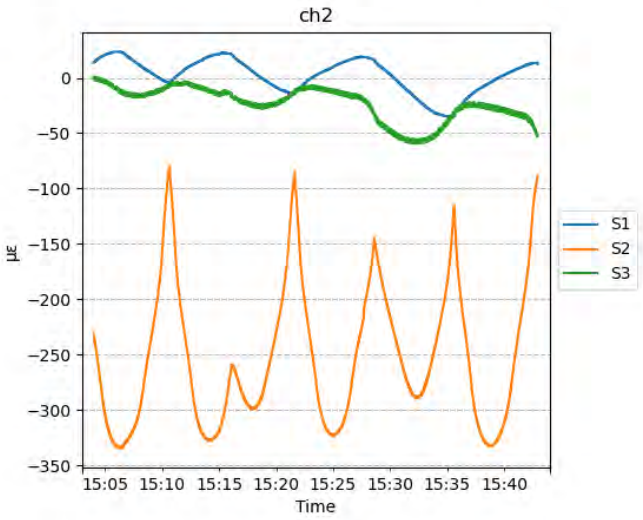


Failure started in the upper joint









UNIVERSITEIT GENT

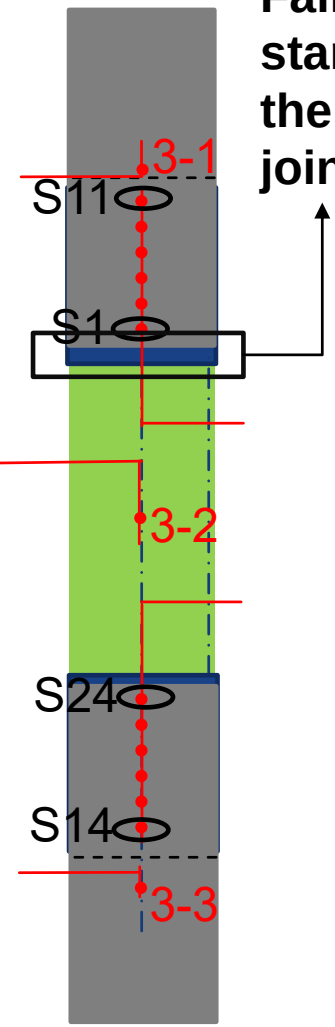
QUALIFY LIGHTWEIGHT

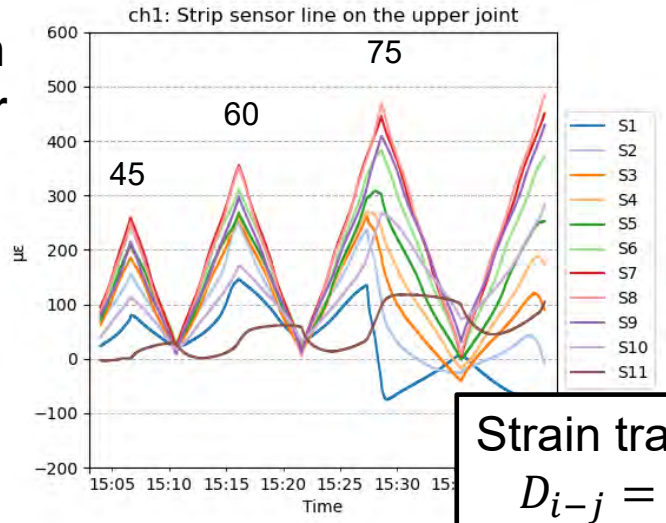
COM&SENS adding value by sensing

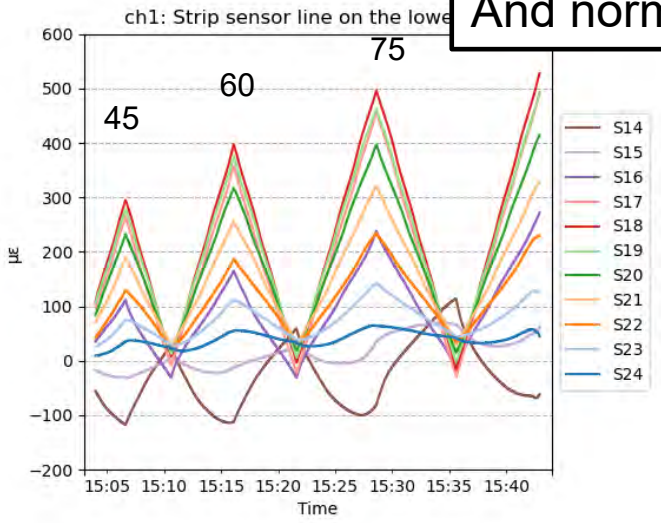
Processed strain results – shear transfer

Technological innovation

Failure started in the upper joint



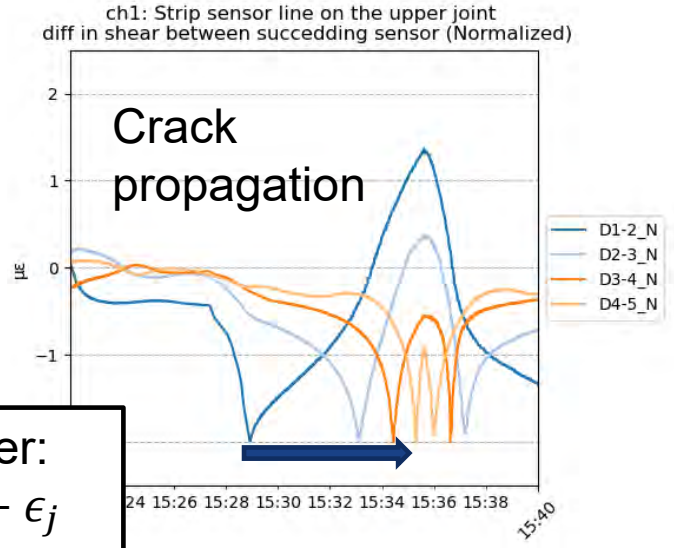


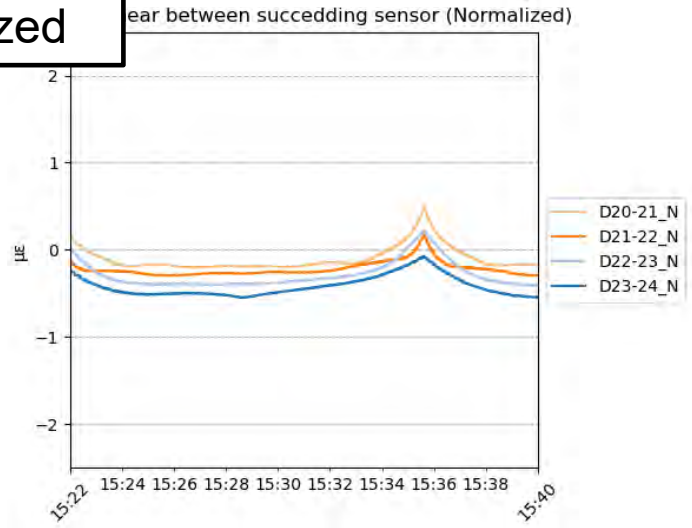


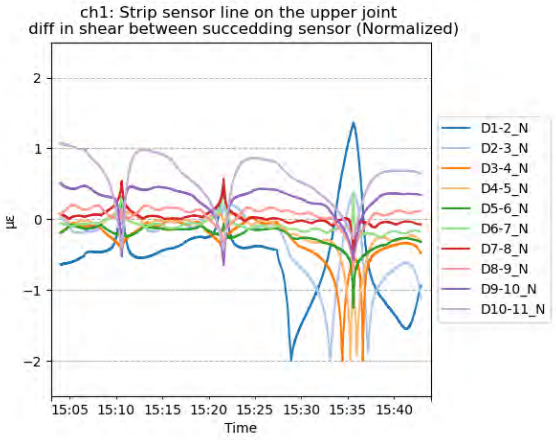
Strain transfer:

$$D_{i-j} = \epsilon_i - \epsilon_j$$

And normalized







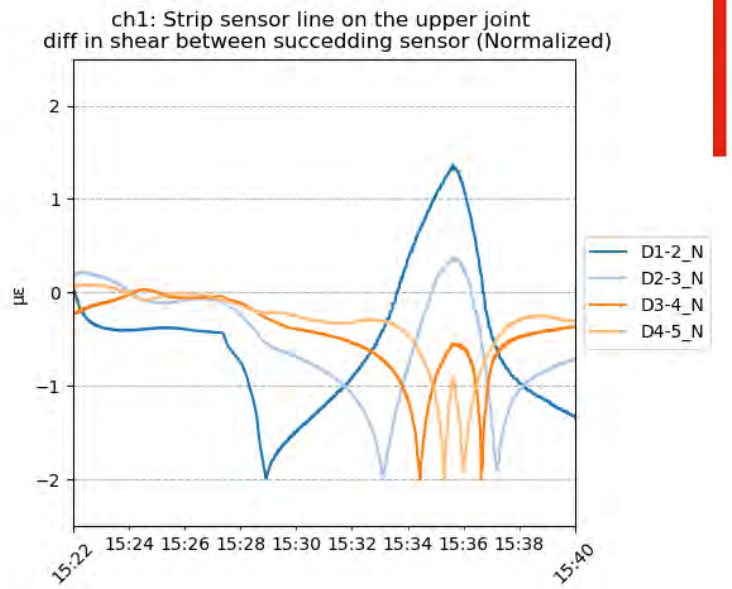
UNIVERSITEIT GENT

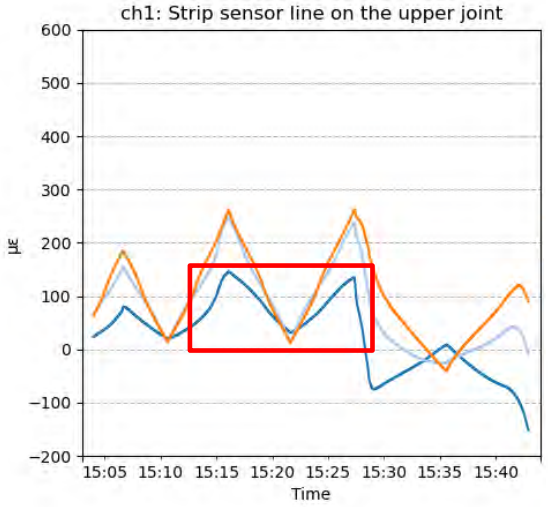
QUALIFY LIGHTWEIGHT

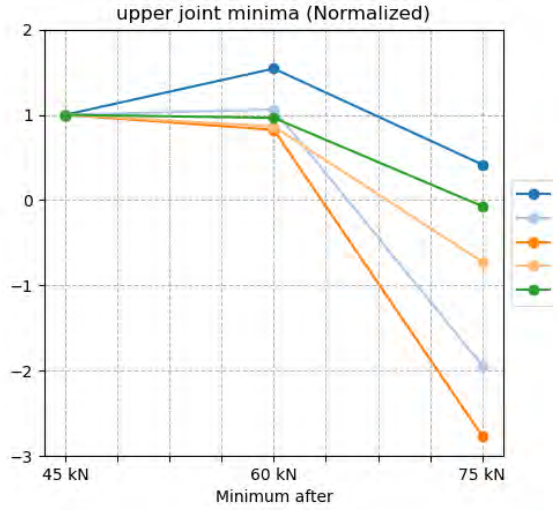
COM&SENS adding value by sensing

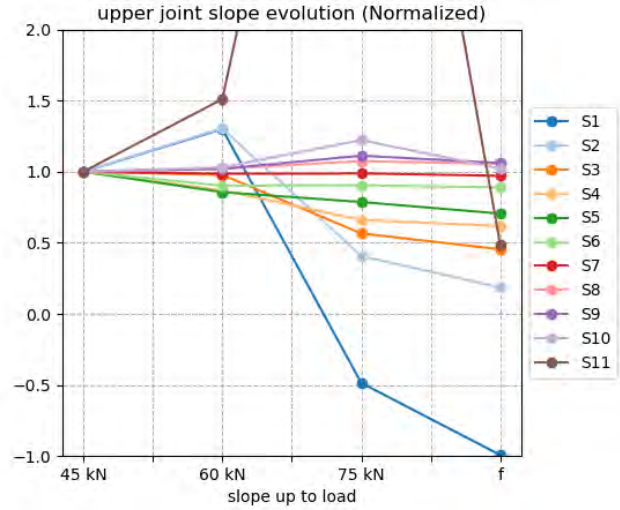
Processed strain results – different methods

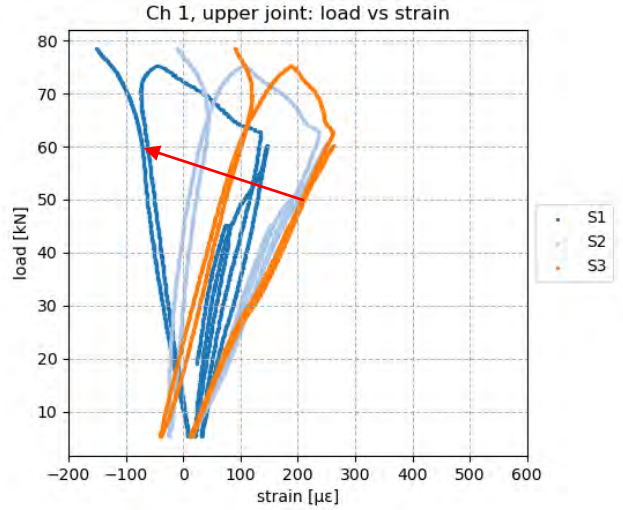
- **Crack propagation** can be followed by looking at the shear transfer
- Different representations and all show a clear crack detection
- **Strain vs time** data contains **signature** of crack propagation





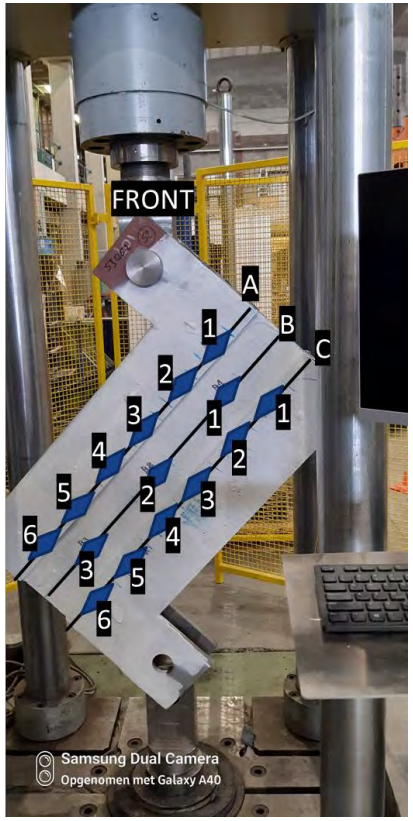


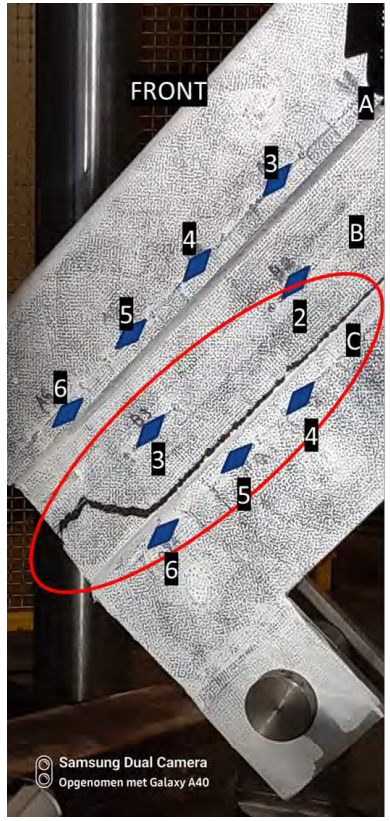


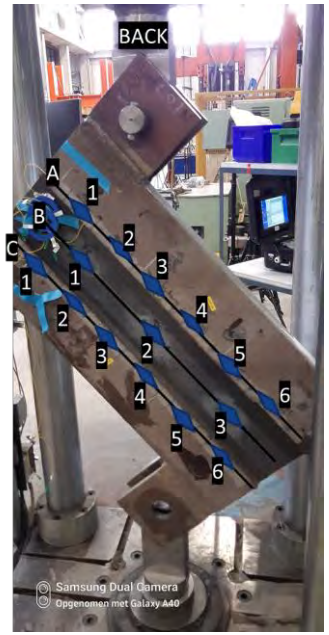


ARCAN TEST

- **Quasi static arcan test@ Ugent**
- **Configuration:**
  - 4 sensor lines on the steel flanges with 15 cm spacing
  - 3 reference sensors on each side with 30 cm spacing





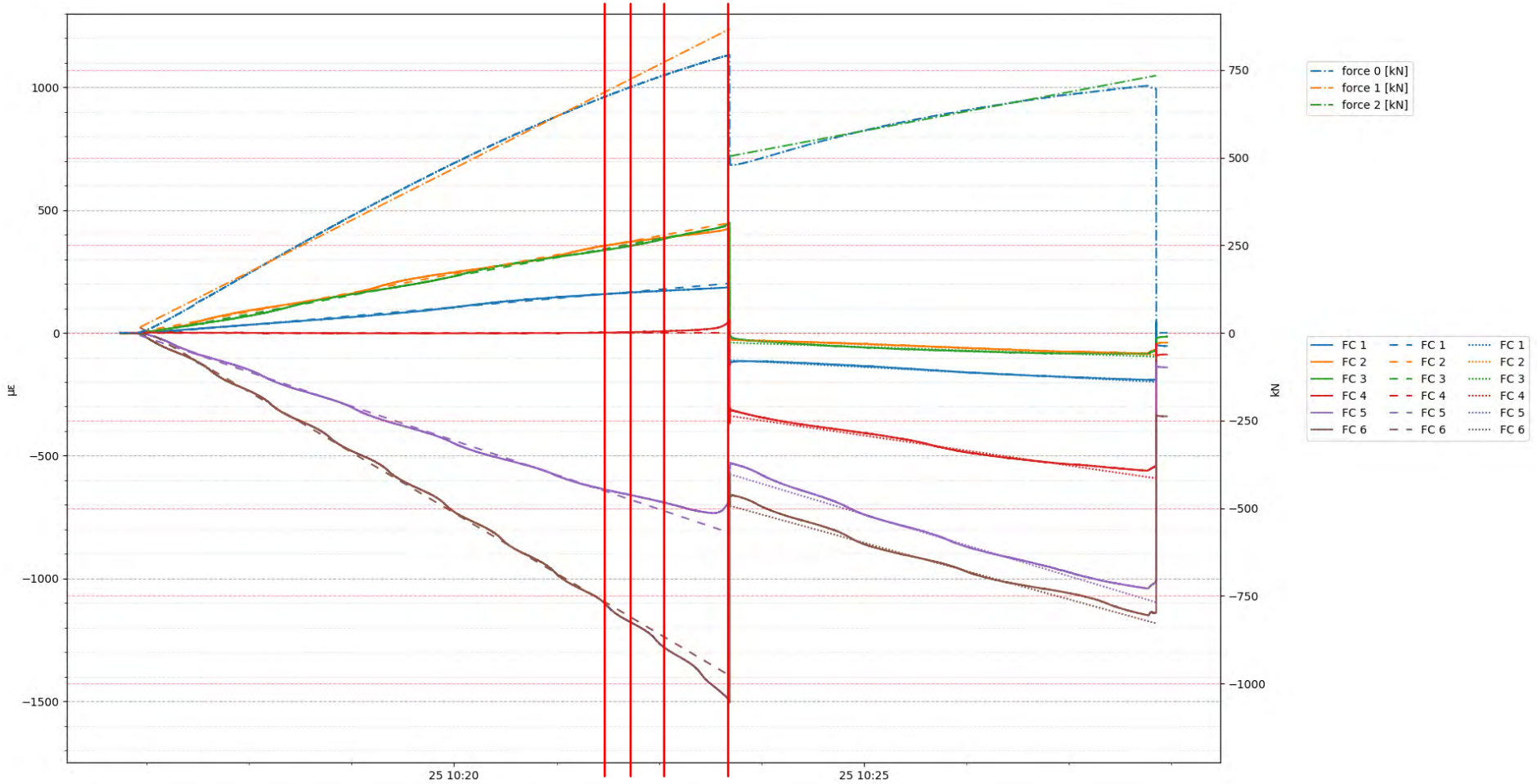


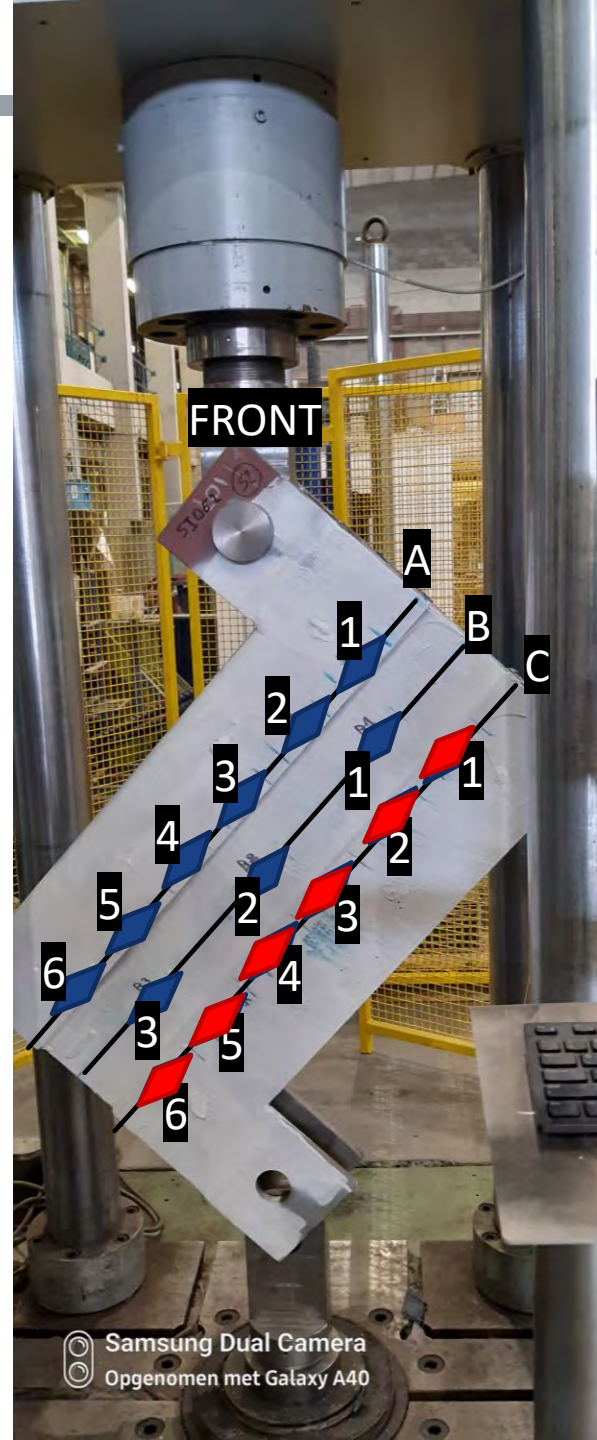
UNIVERSITEIT GENT

QUALIFY LIGHTWEIGHT

COM&SENS adding value by sensing

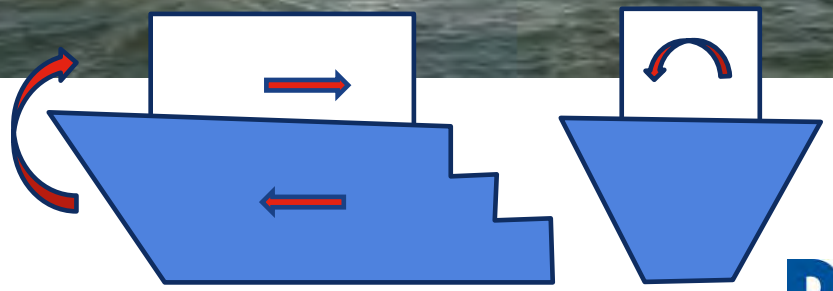
Arcan test – Crack propagation



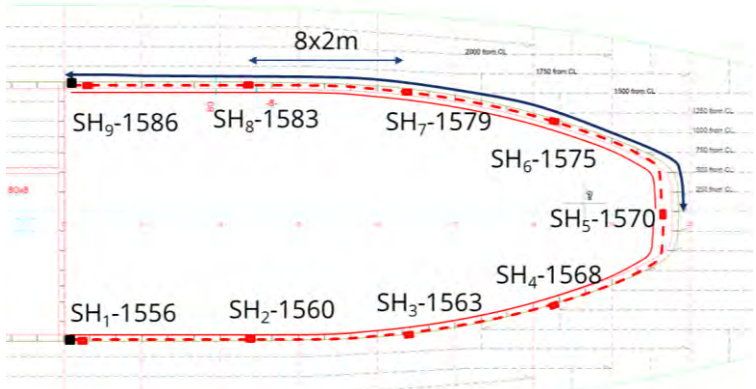


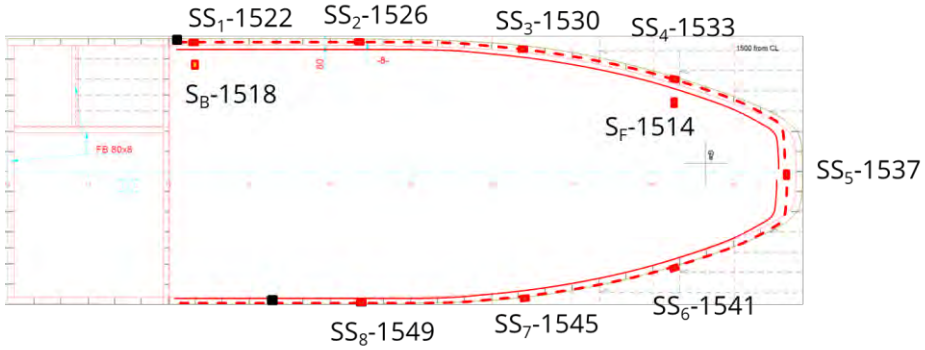
IN FIELD APPLICATION

- **DAMEN SHIP**
- **Configuration:**
  - 2 sensor lines on the steel flang and composite flange
  - 2m spacing

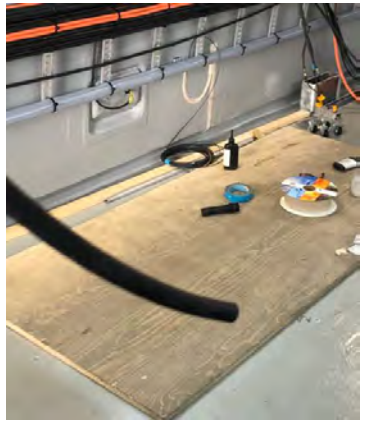


Installation on the (aluminium) hull and Superstructure of the ship





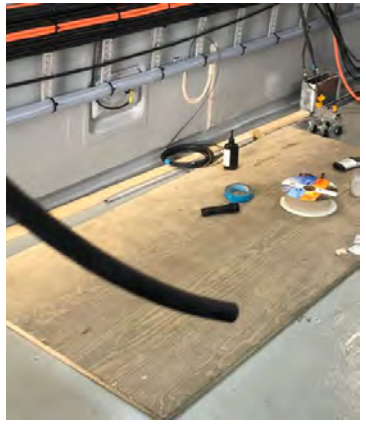
INSTALLATION TIME LAPSE



QUALIFY LIGHTWEIGHT

DAMEN COM&SENS adding value by sensing

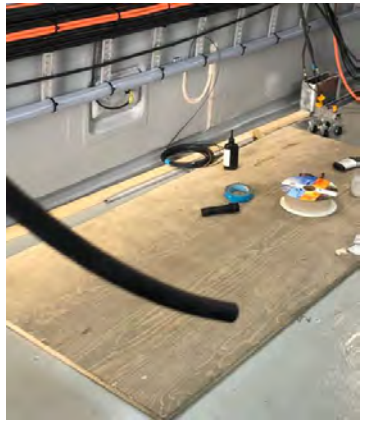
INSTALLATION TIME LAPSE



QUALIFY LIGHTWEIGHT

DAMEN COM&SENS adding value by sensing

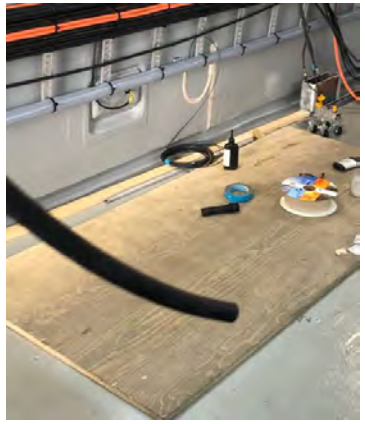
INSTALLATION TIME LAPSE



QUALIFY LIGHTWEIGHT

DAMEN COM&SENS adding value by sensing

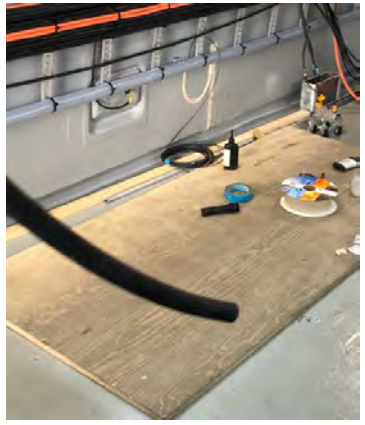
INSTALLATION TIME LAPSE



QUALIFY LIGHTWEIGHT

DAMEN COM&SENS adding value by sensing

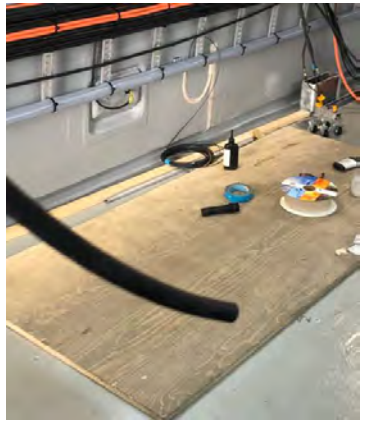
INSTALLATION TIME LAPSE



QUALIFY LIGHTWEIGHT

DAMEN COM&SENS adding value by sensing

INSTALLATION TIME LAPSE



QUALIFY LIGHTWEIGHT

DAMEN COM&SENS adding value by sensing

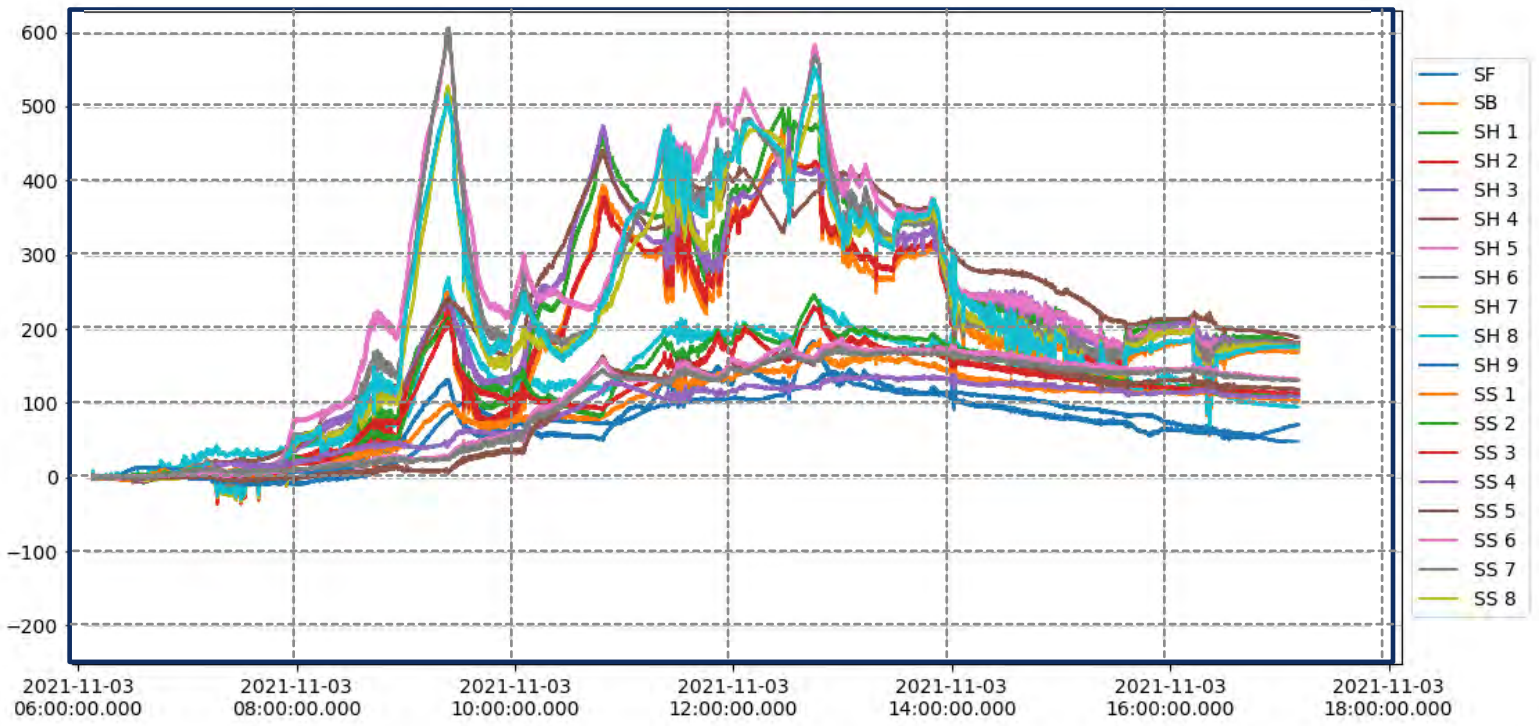
Cable routing and FBG system installation

- The Com&Sens FBG System is placed in the battery compartment

- System contains:
- FBGS read-out unit (interrogator)
- PC
- Cloudgate for internet connection
- Power conversion units
- Temperature measurement to control the ventilation

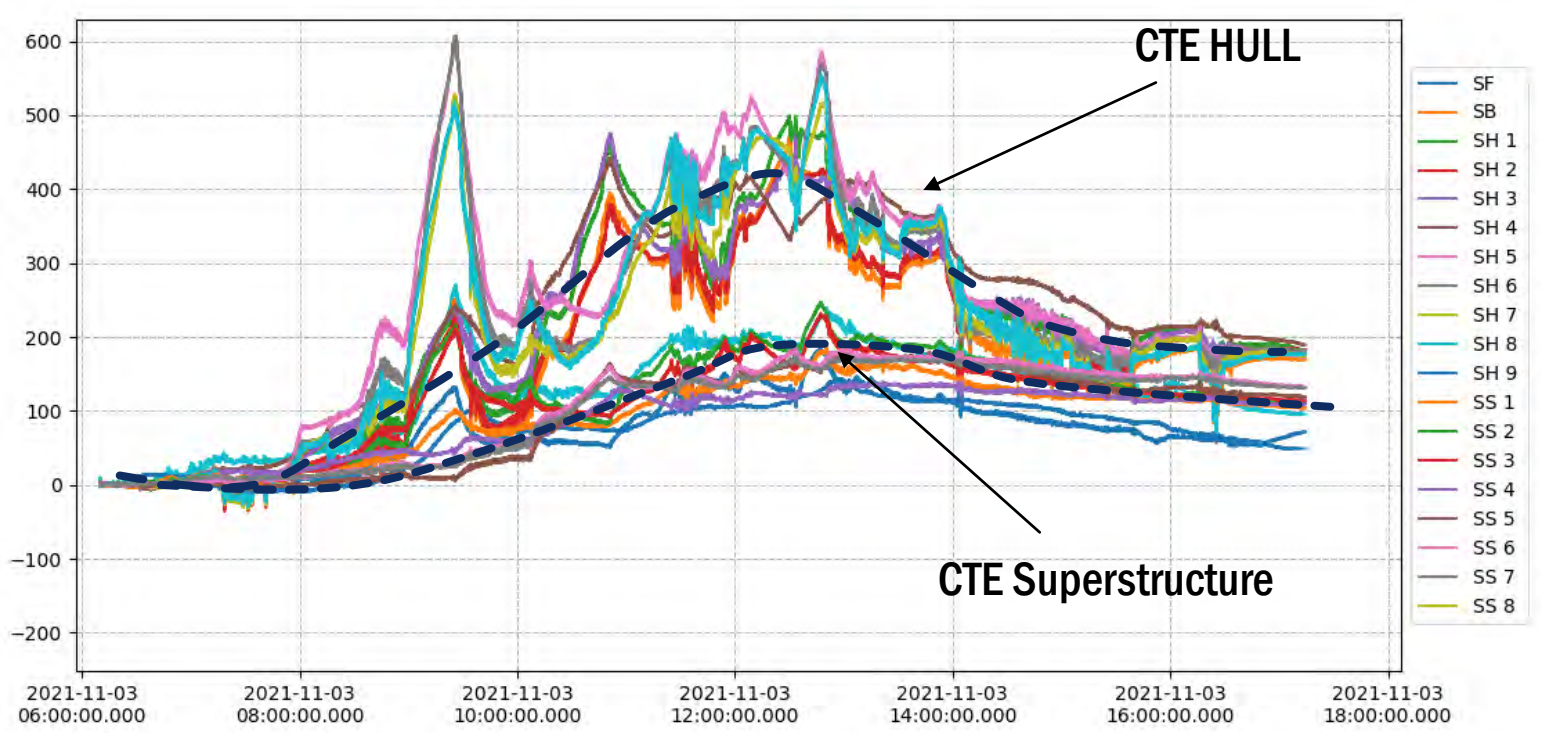
IN FIELD APPLICATION ALL RESULTS

- Succesfull measurements during sea trials
- Syncing with other signals
- Relate strain with events



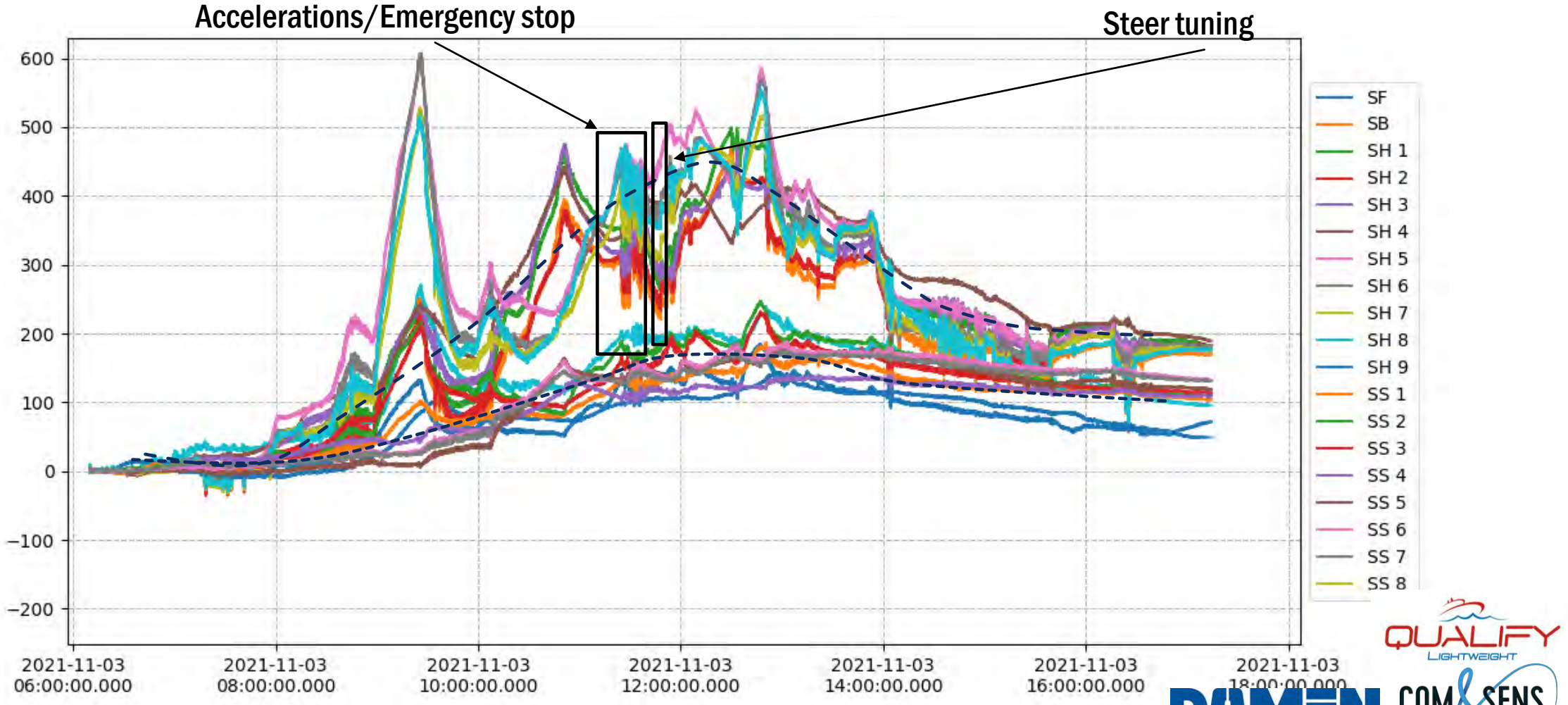
IN FIELD APPLICATION – TEMPERATURE EFFECT

- Temperature effect
- Heating up of the engine/hold compartment
- Different CTE's of joint materials
- $CTE_{ALU} > CTE_{GFRP}$
- Look at event monitoring

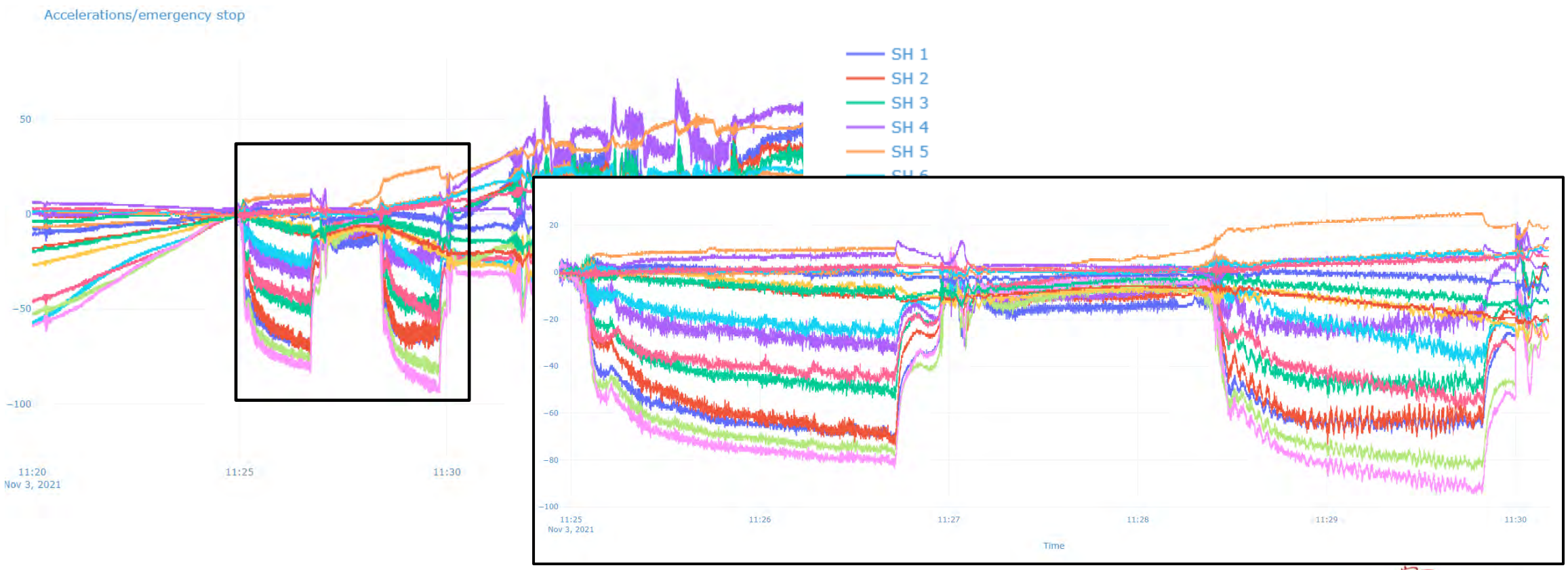


Slow effect – no temperature readings present
Event detection

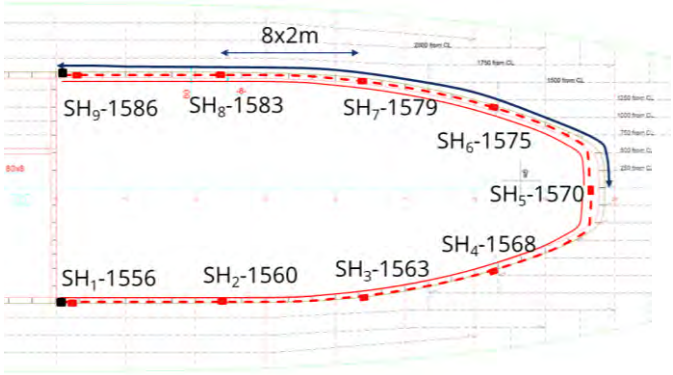
IN FIELD APPLICATION – EVENTS

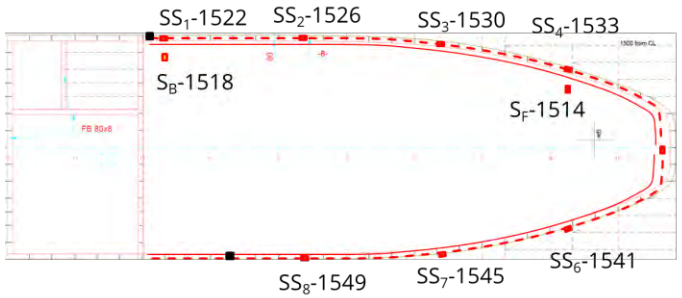


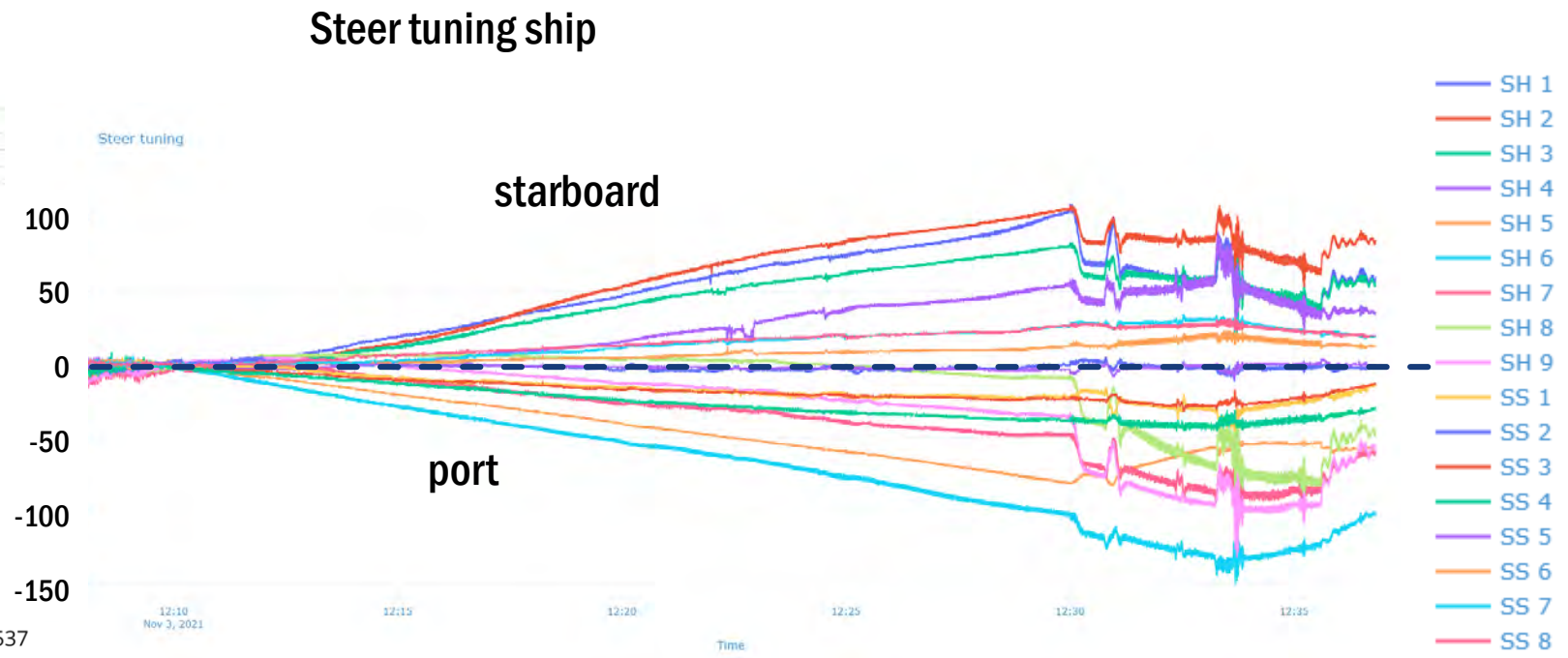
IN FIELD APPLICATION – ACCELERATIONS/EMERGENCY BREAKS



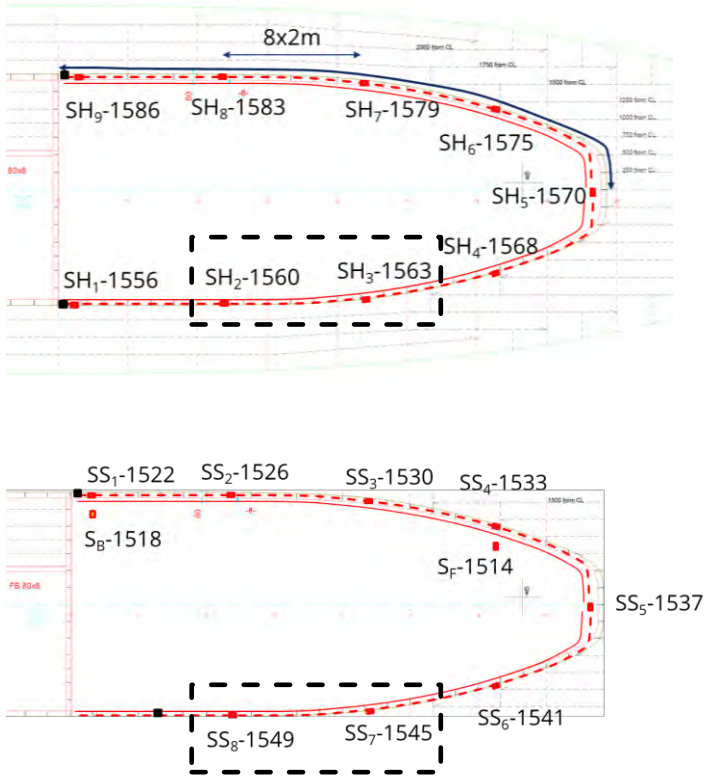
IN FIELD APPLICATION- STEER TUNING SHIP



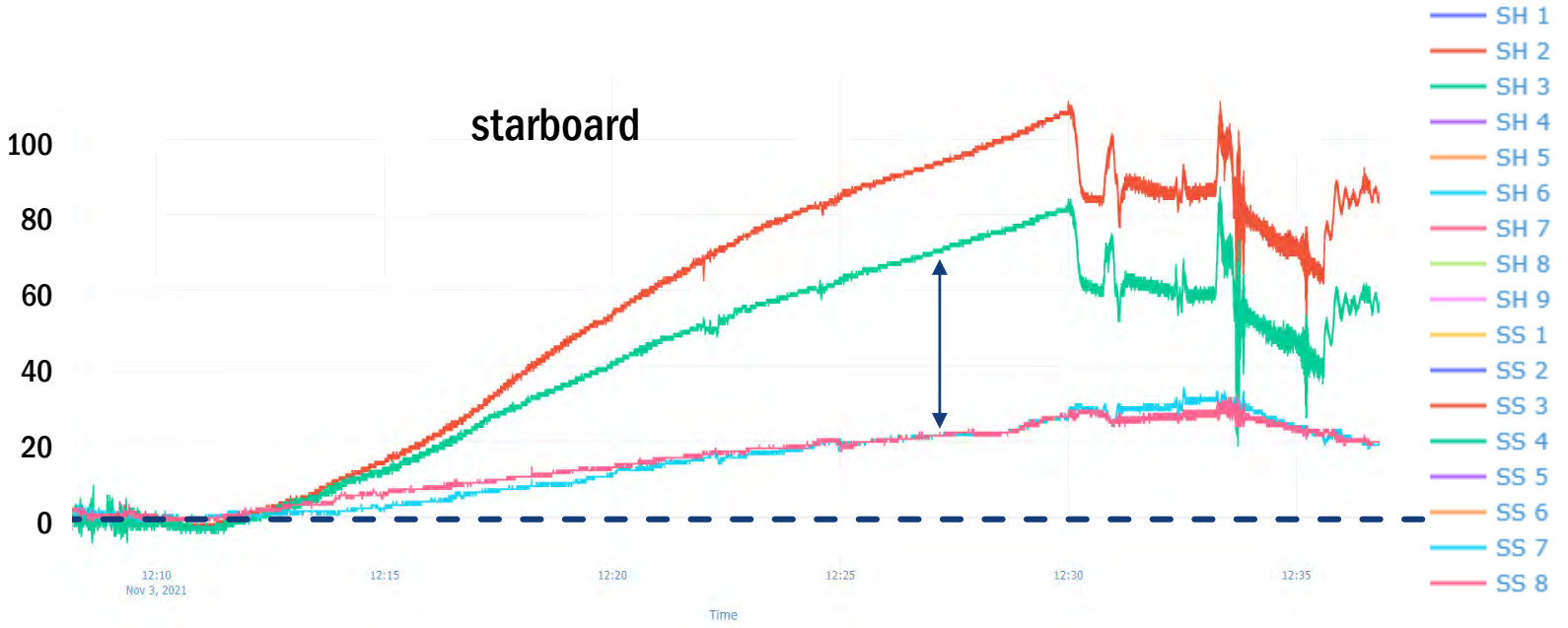




IN FIELD APPLICATION- STEER TUNING SHIP



Steer tuning ship



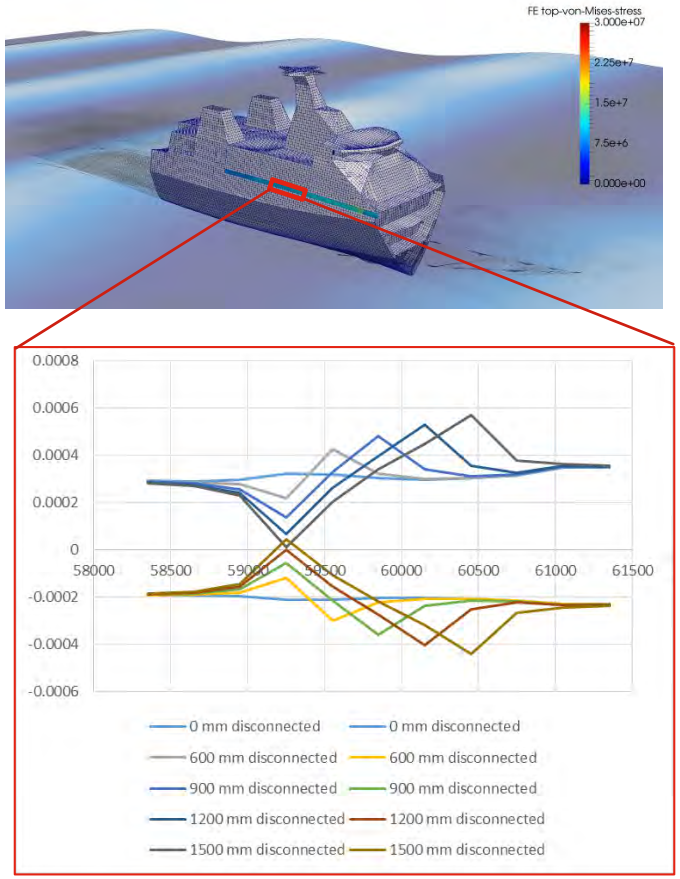
Effect betweeen superstructure and Hull

CONTENT

- Com&Sens at a glance
- Requirements for a monitoring system of bonded joints in a marine environment
- Monitoring of bonded hybrid joints laboratory and field testing
- **Conclusions/future work**

CONCLUSION/FUTURE WORK

- **Marine requirements** are met - new sensor raw materials (sea water, temperature, strain transfer)
- Promissing technology for **repairing** of embedded OF sensors
- Succesfull **monitoring of cracks** in bonded joints
- **SHM filosofy** developped
  - Better understanding of position of sensors
  - Use of FE to understand joint behaviour
  - Data handling
- **Future work:** long term monitoring of already installed monitoring system



FOLLOW US ON LinkedIn

www.com-sens.eu

QUALIFY LIGHTWEIGHT

DAMEN

This research was carried out within the project "QUALIFY – Enabling Qualification of Hybrid Joints for Lightweight and Safe Maritime Transport", co-funded by the INTERREG 2SeasMers Zeeën programme
http://www.interreg2seas.eu/qualify