Hull Stress Monitoring System

Fast ferry application

Presented by
CEO, PhD Alf Egil Jensen

FIBRE REINFORCED COMPOSITES
FiReCo
FIRE RESISTANT COMPOSITES

LIGHT STRUCTURES
Passion for Monitoring

E-LASS – Ulsteinvik, Norway , 13. Sept. 2022

FiReCo AS
Fiber Reinforced Composites
Fire Resistant Composites

- FiReCo established in 1991 in Fredrikstad, Norway
- 11 employees, mostly with PhD or MSc degrees

- Core business:
  - Structural design and analyses of large load carrying structures made with FRP composite materials. Usually together with fire related requirements

- The main markets for FiReCo services are within:
  - Naval ship design and services for the RNoN Navy
  - Commercial and military high-speed vessels
  - Offshore and sub sea structures
  - Fish farming (closed and semi-closed structures)
  - Infrastructure, like bridges, ferries, and passenger vessels

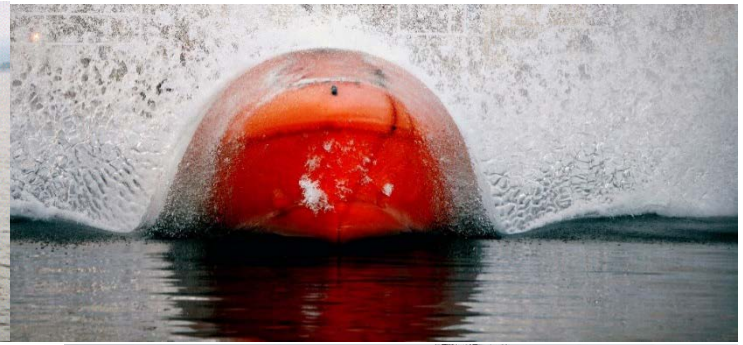

Brødrene Aa


Brødrene Aa / Palmer Johnson


Umoe Mandal / Sjøforsvaret

www.fireco.no

Markets & Structures

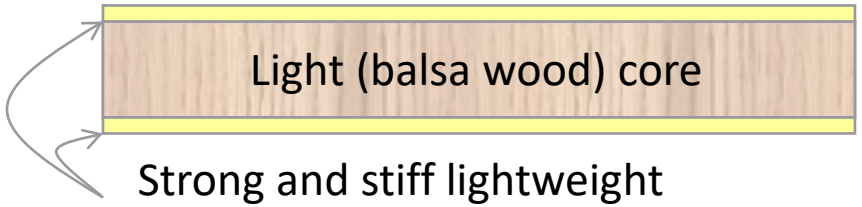


FIBRE REINFORCED COMPOSITES
FiReCo
FIRE RESISTANT COMPOSITES

R&D Composite structures

LASS/SAFEDOR – RISK BASED DESIGN

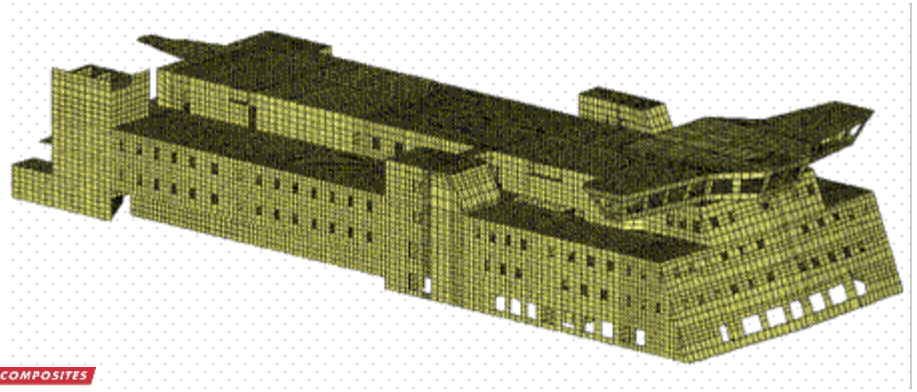
- ✓ Lightweight FRP sandwich structure
  - ✓ Stiff, strong, no secondary stiffeners, ease of assembly
- ✓ Simple structural lay-out
  - ✓ Ease of outfitting
- ✓ Equivalent interiors as for steel design:
  - ✓ Same cabin modules
  - ✓ All internal surfaces identical or better wrt. fire properties – min “A-60” eqv. composite structure all over



Strong and stiff lightweight composite faces

Saves 60% in structural weight compared to steel structure – incl. fire protection.

Payback time < 2 y

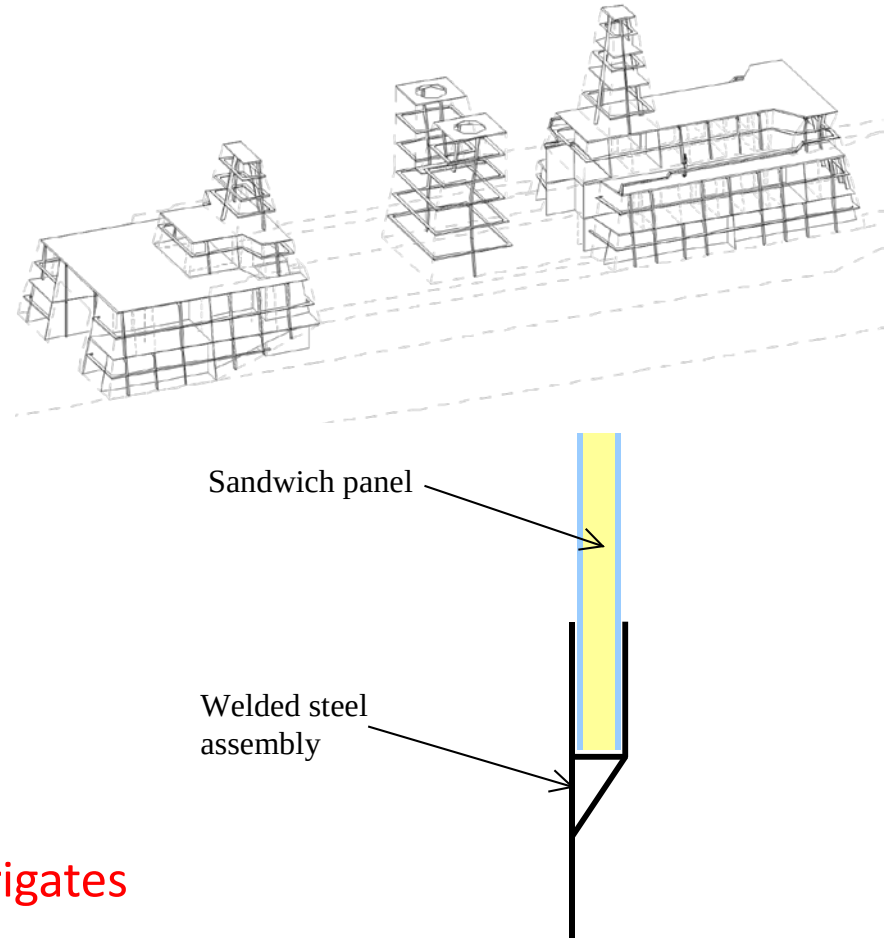


FIBRE REINFORCED COMPOSITES
FiReCo
FIRE RESISTANT COMPOSITES

R&D Composite structures–
Composite-to-steel joints

- ✓ Relevant for superstructures on steel hull, masts on steel structures, etc. (BONDSHIP)
- ✓ New developments within EUCLID RTP3.21 showed more than 200 % improvement (blast resistance, fire resistance, pullout).
- ✓ In CONVINCE project this has been improved further.. (700 kPa blast performance)

=> Applied in the new mast on the RNoN Nansen cl. frigates



FIBRE REINFORCED COMPOSITES FiReCo FIRE RESISTANT COMPOSITES

R&D Composite structures

Blast and fragment resistance-fire protection

Little damage on fire protection

=> Implemented in X-fire™ products (100% daughter company of FiReCo AS)

FIBRE REINFORCED COMPOSITES
FiReCo
FIRE RESISTANT COMPOSITES

Agenda

- System Philosophy
- System Design
- Sensor Array and Data Processing
- Commissioning and Test
- Graphical User Interface
- Statistical Analysis
- Journey Analysis

Hull Stress Monitoring System

Fast Ferry application

FIBRE REINFORCED COMPOSITES
FiReCo
FIRE RESISTANT COMPOSITES

System Philosophy

Goal:

- Establishing operational limitations based on measurements rather than design calculations and estimated sea state
- Improve regularity by increasing the range of conditions that are deemed acceptable for operation

Method:

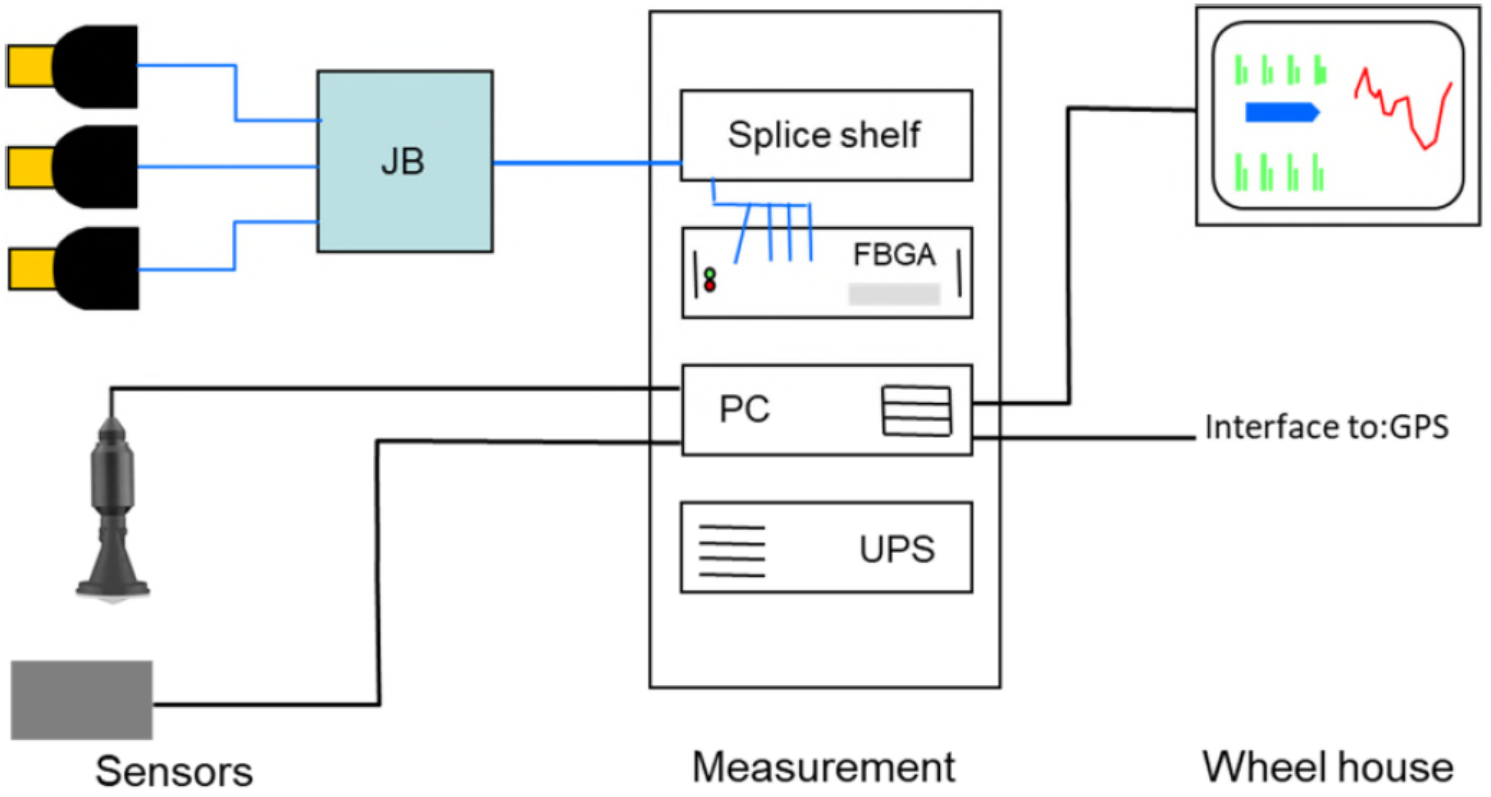
- Gather data to document that the measurement approach is acceptable to the authorities and have data input to adapt the analysis and presentation to the ship type in question

System Design

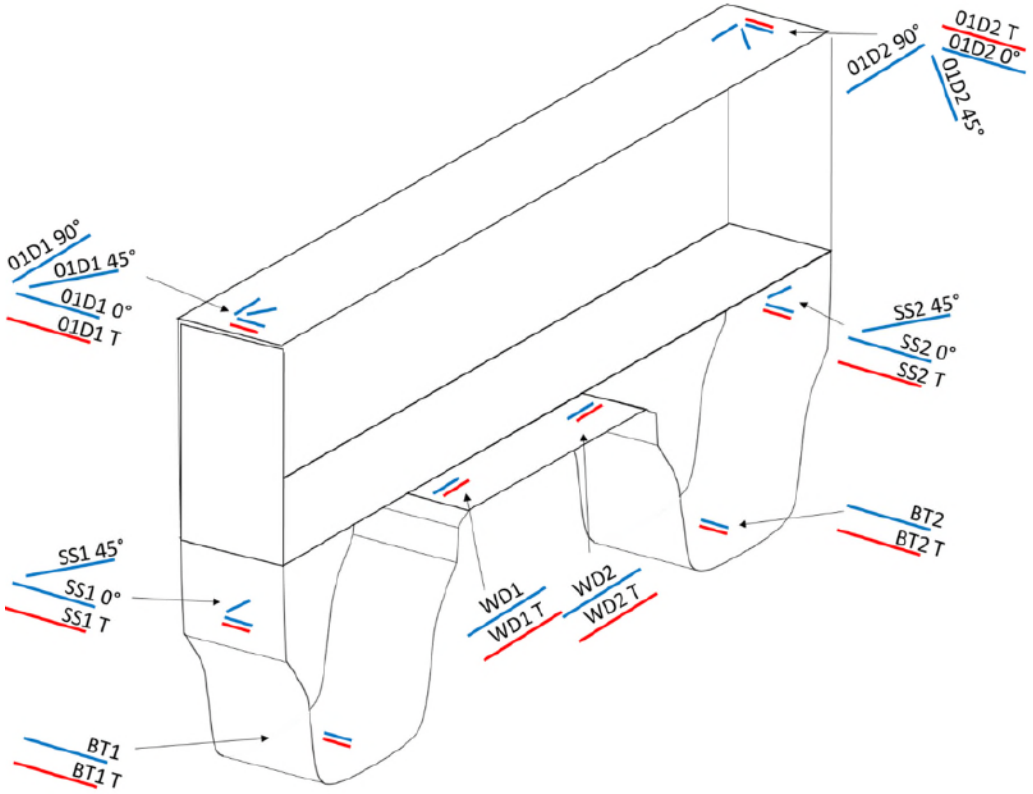
The system consists of the following main components:

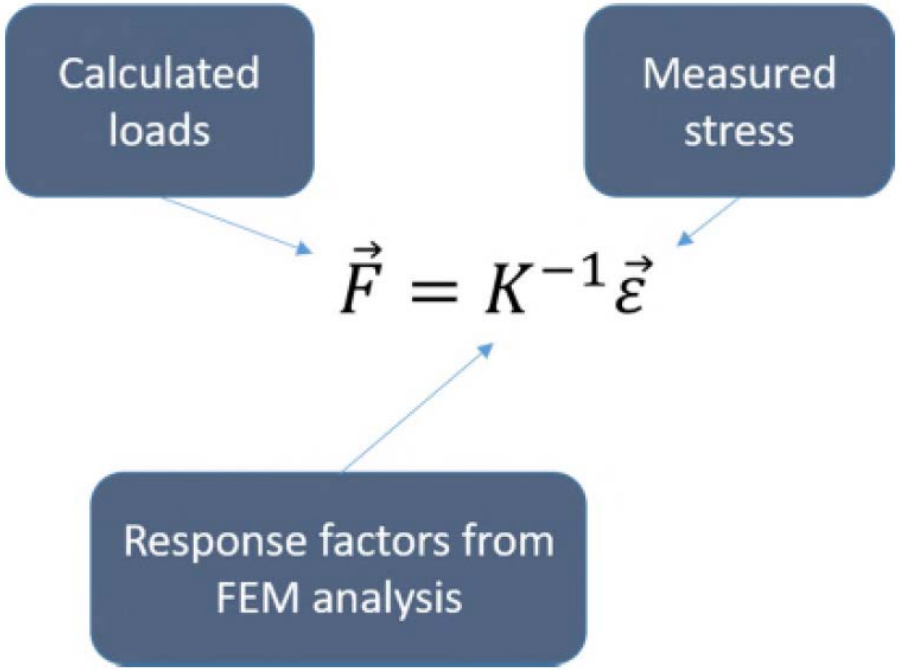
- Graphical user interface (GUI) on the bridge.
- Cabinet with measurement PC and cable termination in electric equipment room or similar.
- Fiber optic strain sensors placed at key positions on the hull for measuring loads/strain due to hull girder bending (Senor network).
- A tri-axial accelerometer placed near the centre of gravity to measure the vertical and horizontal accelerations.
- A Vegapuls Radar to measure the gap between the wet deck and the incident waves.

System Design



FIBRE REINFORCED COMPOSITES
FiReCo
FIRE RESISTANT COMPOSITES





Sensor Array and Data Processing

- Global loads are found from a vector of measured strains and a matrix with response factors from structural analysis (FE-model).

FIBRE REINFORCED COMPOSITES
FiReCo
FIRE RESISTANT COMPOSITES

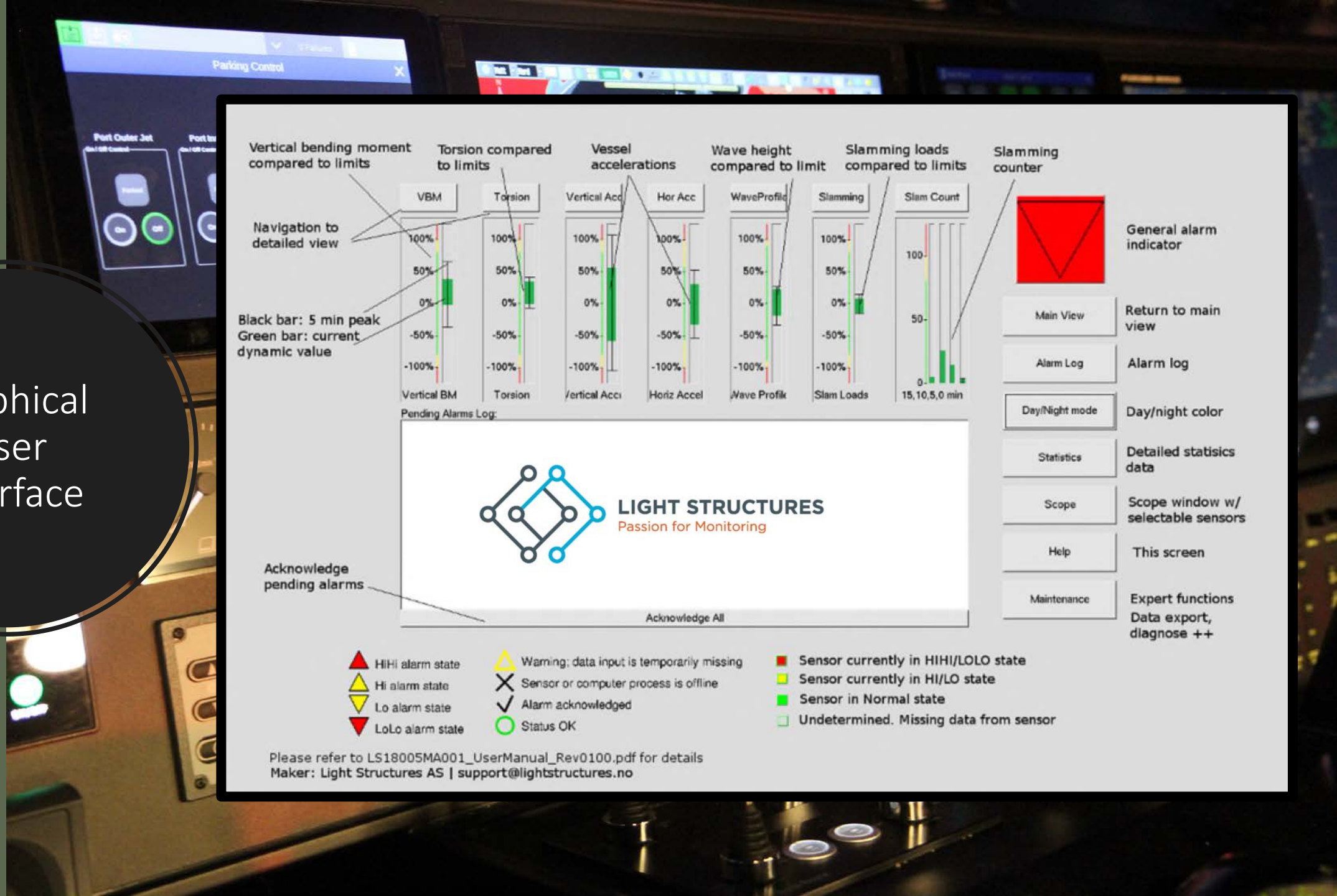
Water was filled into portable ballast tanks to apply the load

Commissioning and Test

- In order to validate the load matrix a validation/calibration test is necessary.
- Such a test is required by DNVGL-RU-SHIP Pt.6 Ch.9 Sec 4
- It is considered sufficient to validate / calibrate the measurement of Vertical Bending Moment only, as this by all practical means also validates the correct setup of the strain sensor array from which all global hull loads are derived.

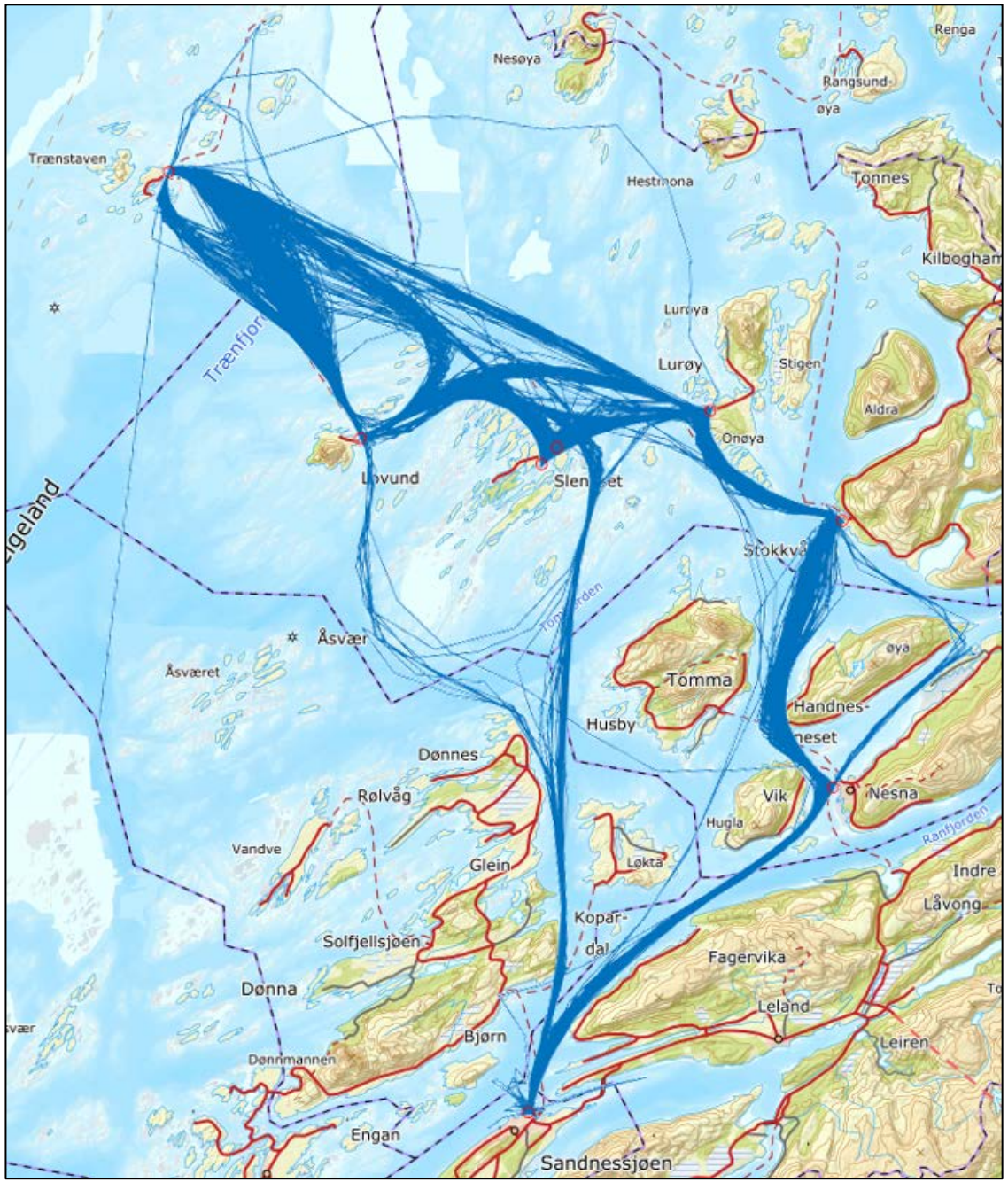
FIBRE REINFORCED COMPOSITES
FiReCo
FIRE RESISTANT COMPOSITES

Graphical User Interface



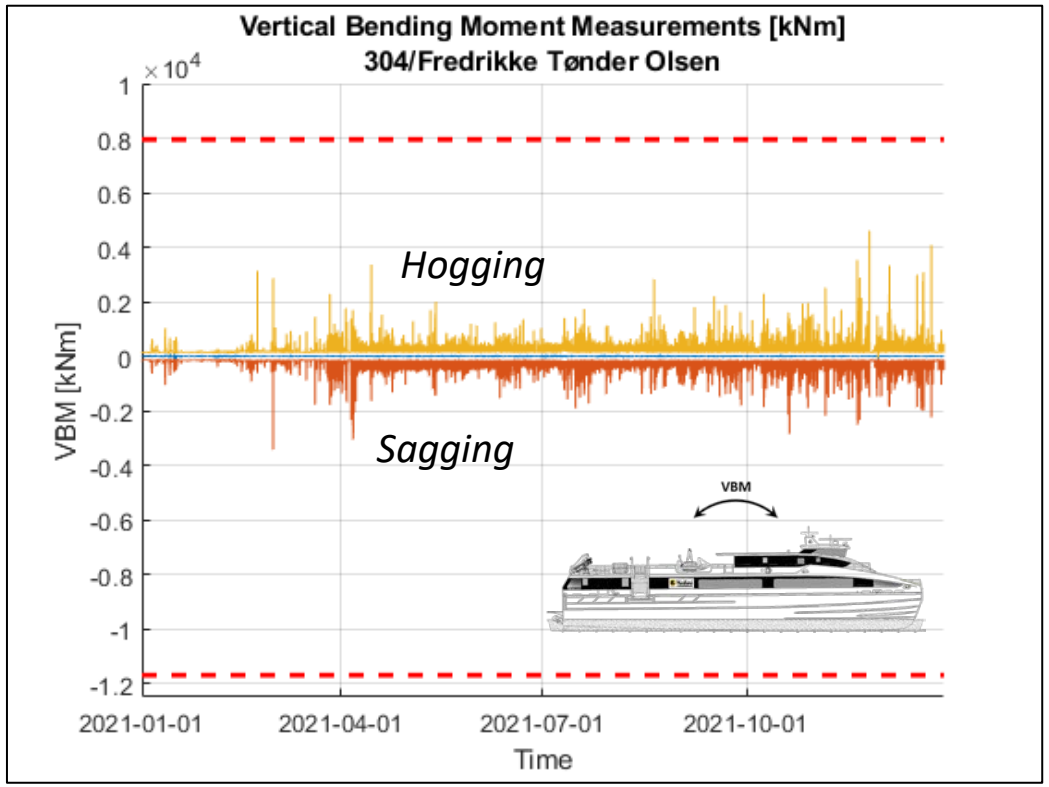
Data Analysis

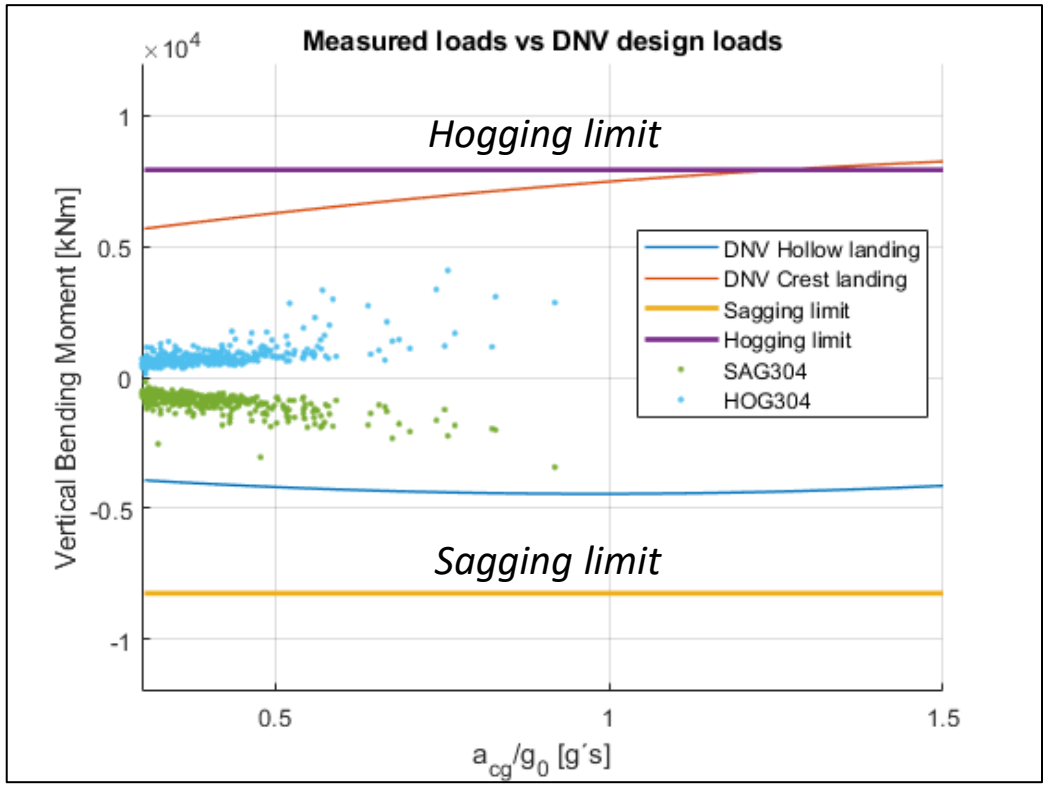
- Global loads
- Accelerations
- Slamming (Local loads)
- Wave Profile



MS Fredrikke Tønder Olsen on «Helgelandspendelen» throughout 2021

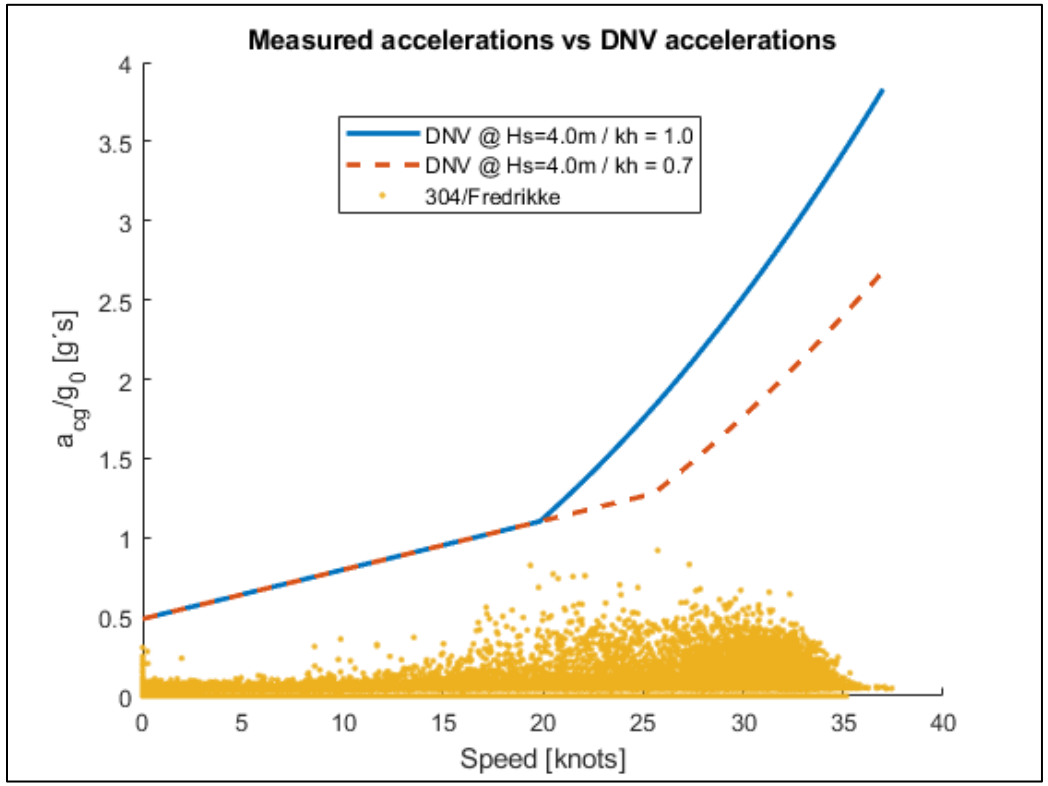
Journey Analysis – global loads



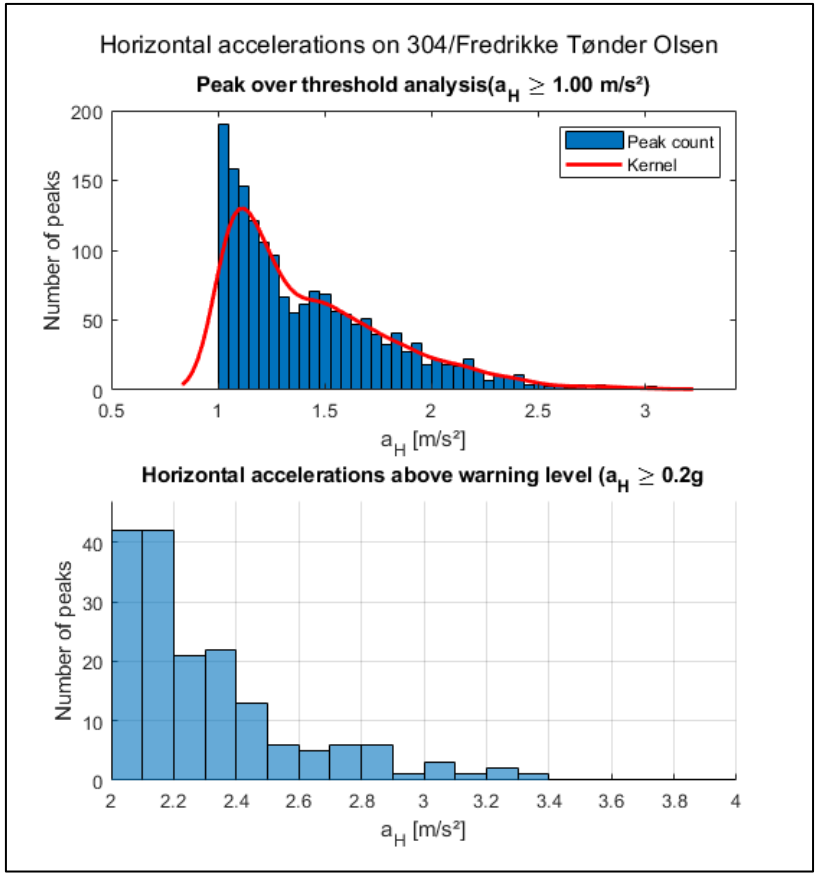


FIBRE REINFORCED COMPOSITES
FiReCo
FIRE RESISTANT COMPOSITES

Journey Analysis - accelerations

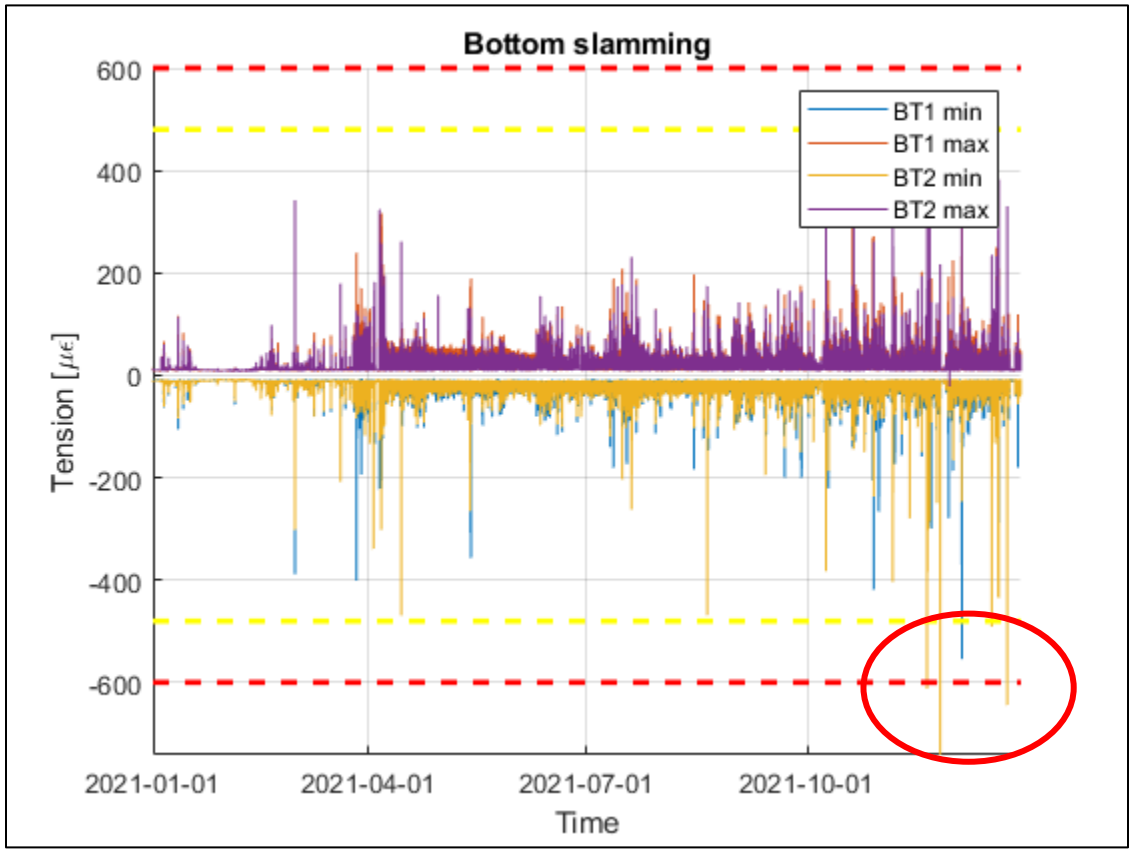


Measured vertical accelerations vs DNV Design accelerations

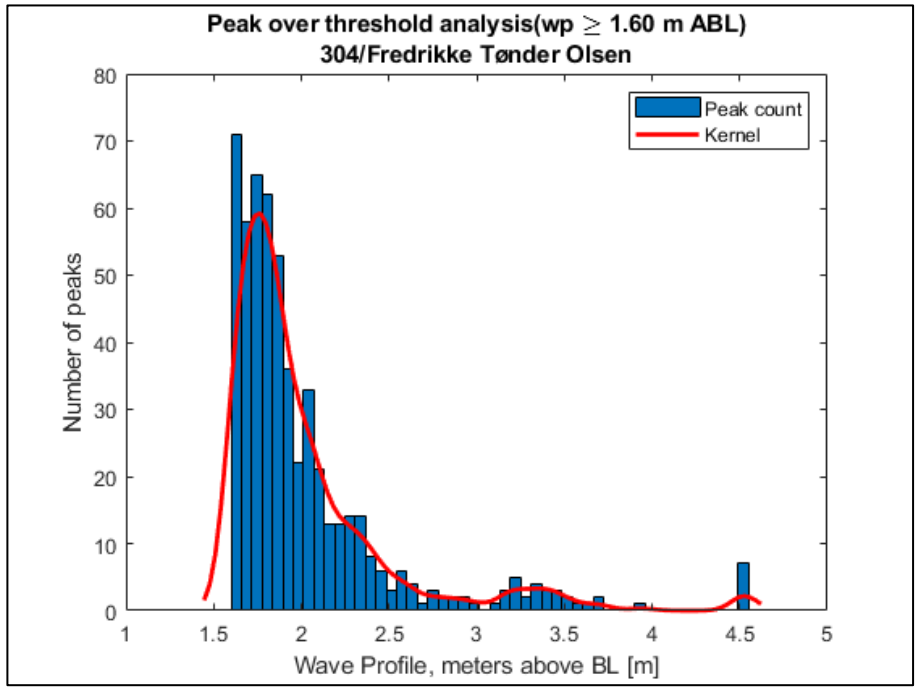


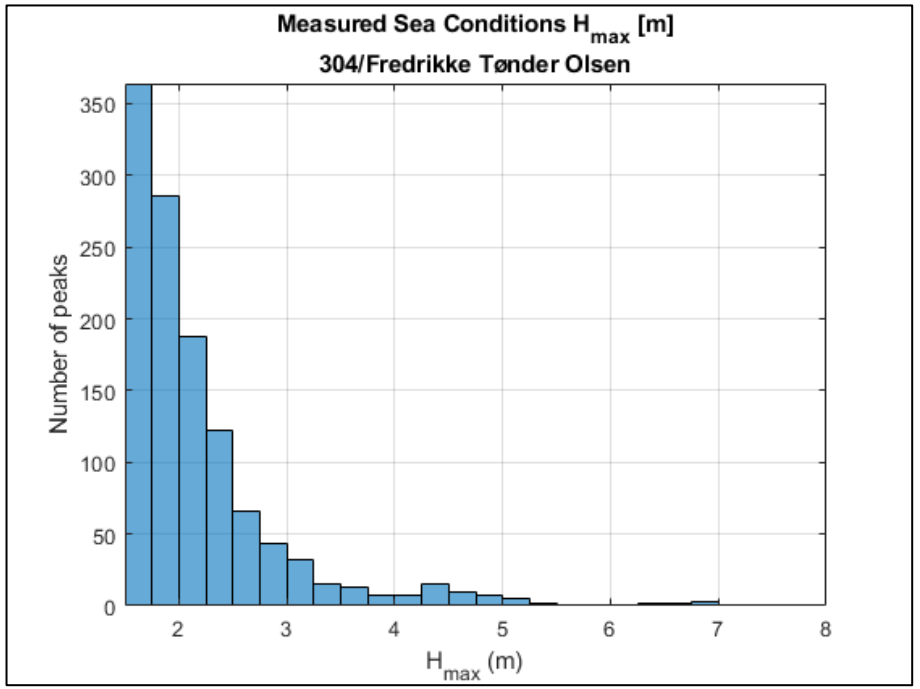
POT analysis for Horizontal accelerations

Journey Analysis - slamming



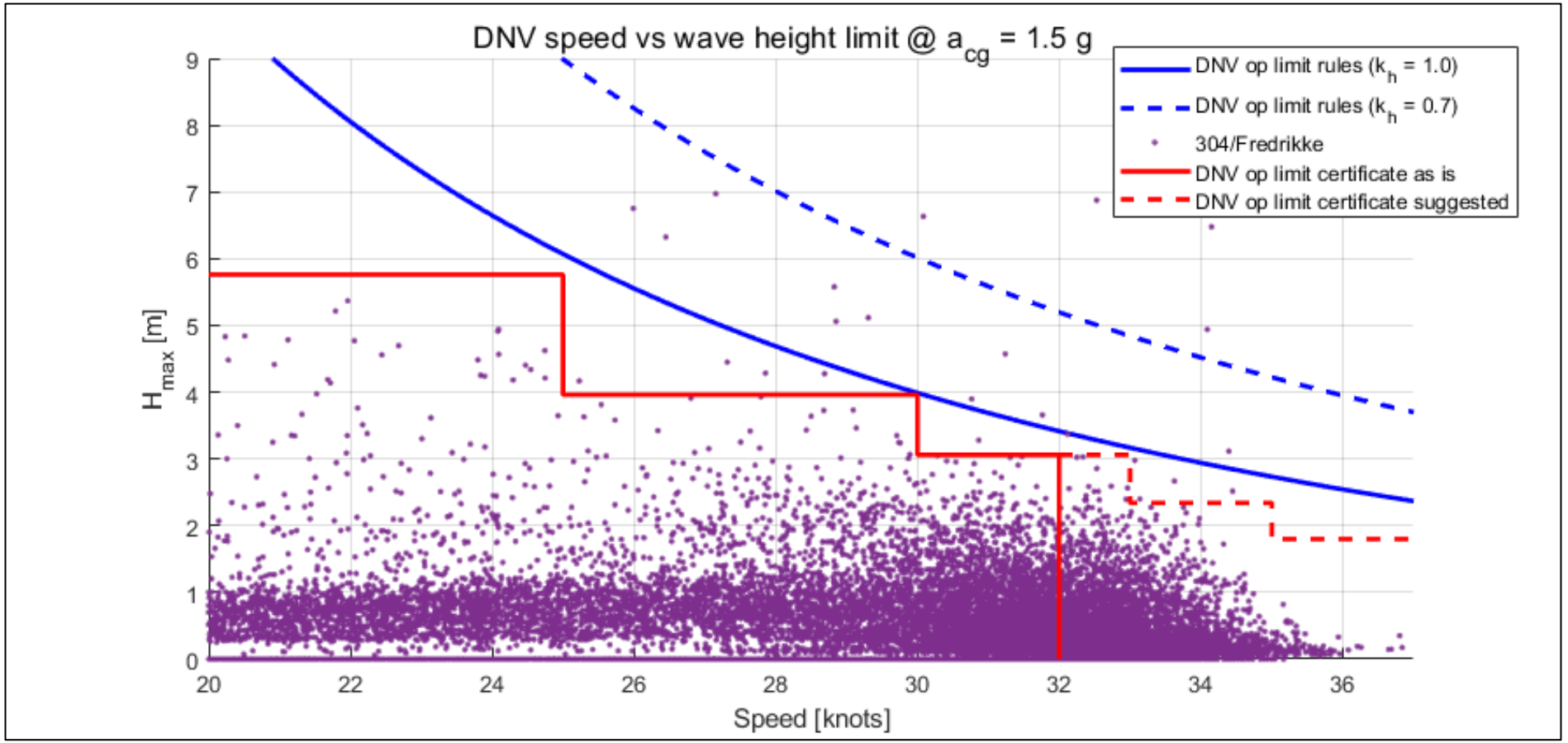
Journey Analysis – wave profile





$Note: Assuming\ that\ H_{max} \sim 2 \cdot [Wave\ profile - Mean\ value]$

Journey Analysis – operational limits



Example Installation
MS «Elsa Laula Renberg»

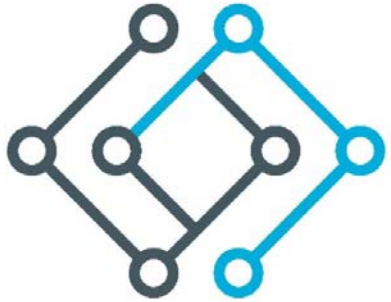
LIGHT STRUCTURES
Passion for Monitoring

FIBRE REINFORCED COMPOSITES
FiReCo
FIRE RESISTANT COMPOSITES

FIBRE REINFORCED COMPOSITES

FiReCo

FIRE RESISTANT COMPOSITES



LIGHT STRUCTURES

Passion for Monitoring