Ship Hull Monitoring System applied as a Real Time Decision Support System on Fast Ferries

Christian Wines (M.Sc), FiReCo AS

Alf Egil Jensen (Ph.D), FiReCo AS

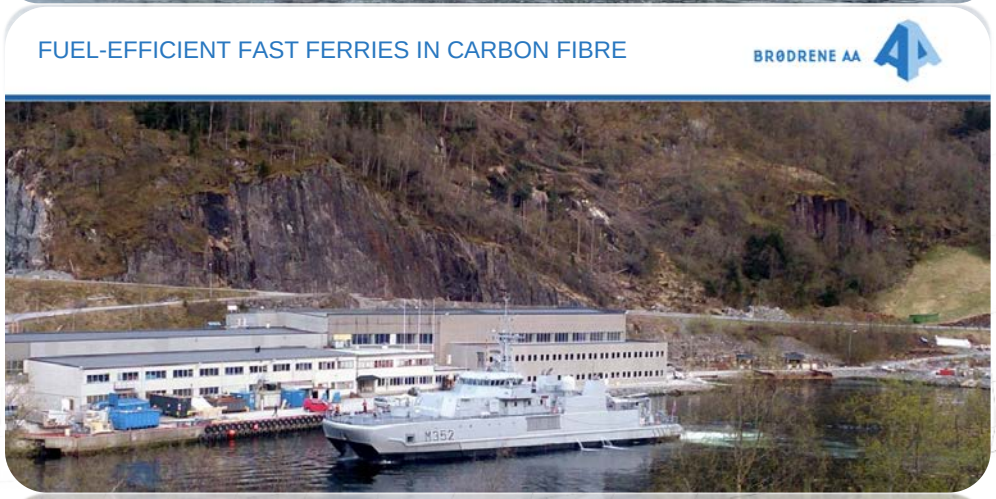
Geir Sagvolden (Ph.D), Light Structures AS

Agenda

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

Acknowledgements:

BOREAL BRØDRENE AA



System Philosophy

Goal:

Establishing operational limitations based on measurements rather than rule based limitations and estimated sea states

Improve regularity by increasing the range of conditions that are deemed acceptable for operation

Method:

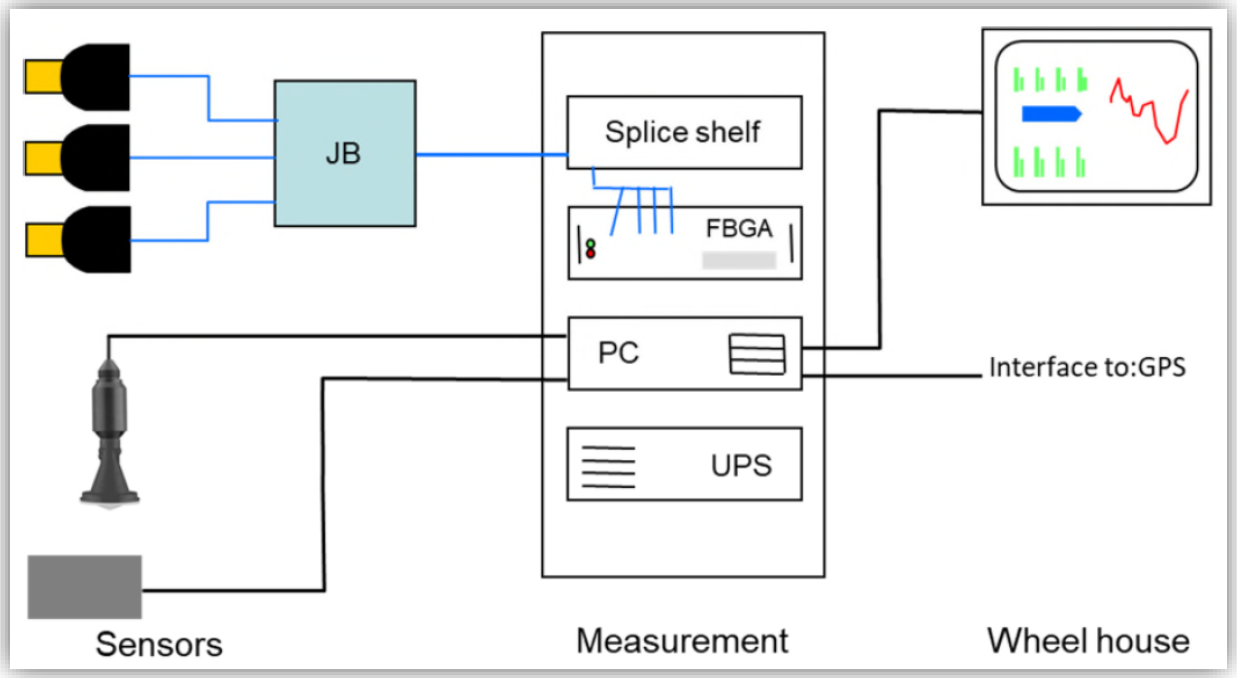
Real time presentation of loads and accelerations to the operators, along with data storage and post processing to document that the measurement approach is acceptable.

2.2.3 Upon agreement, the vertical design acceleration may be documented by direct calculations, model tests or full-scale measurements. For SWATH and craft with foil-assisted hull, accelerations shall normally be determined in accordance with direct methods.

System Design

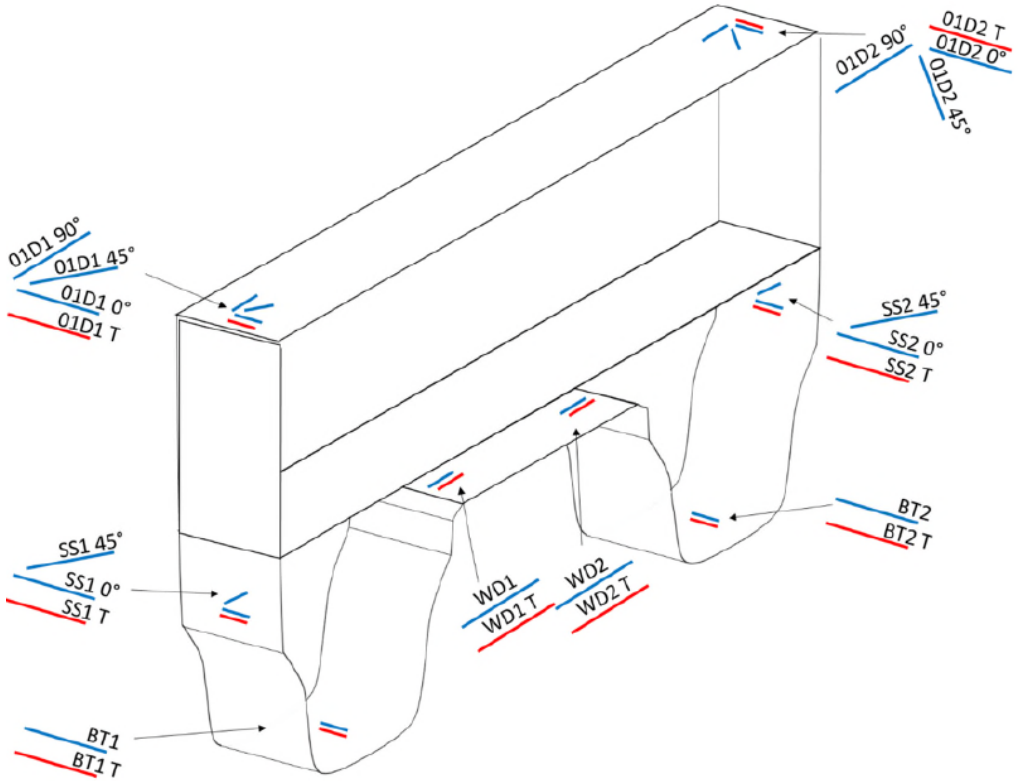
The system consists of the following main components:

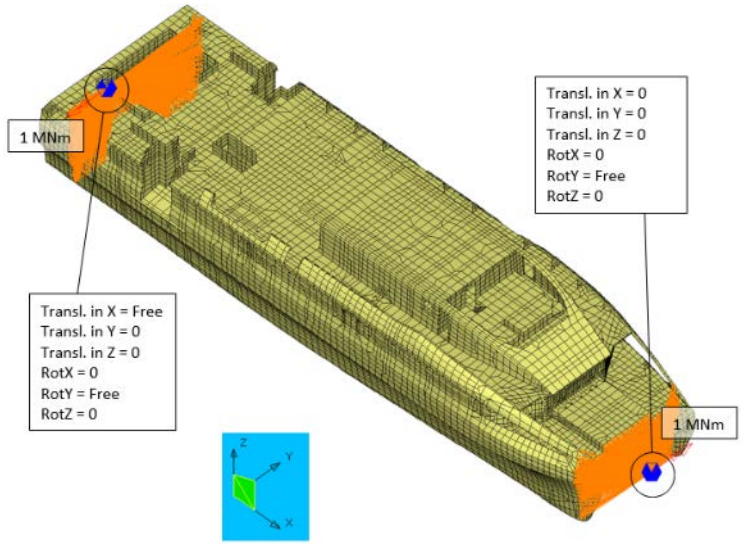
- Graphical user interface (GUI) on the bridge.
- Cabinet with measurement PC and cable termination in electric equipment room or similar.
- Fiber optic strain sensors placed at key positions on the hull for measuring loads/strain due to hull girder bending.
- A tri-axial accelerometer placed near the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



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).





Calculated loads

Measured stress

$$\vec{F} = K^{-1}\vec{\varepsilon}$$

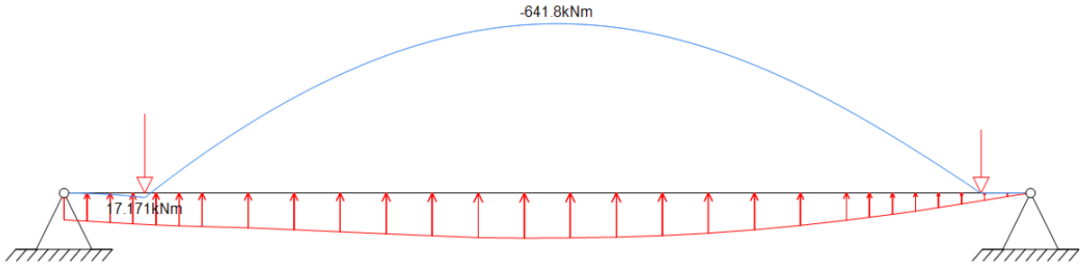
Response factors from FEM analysis

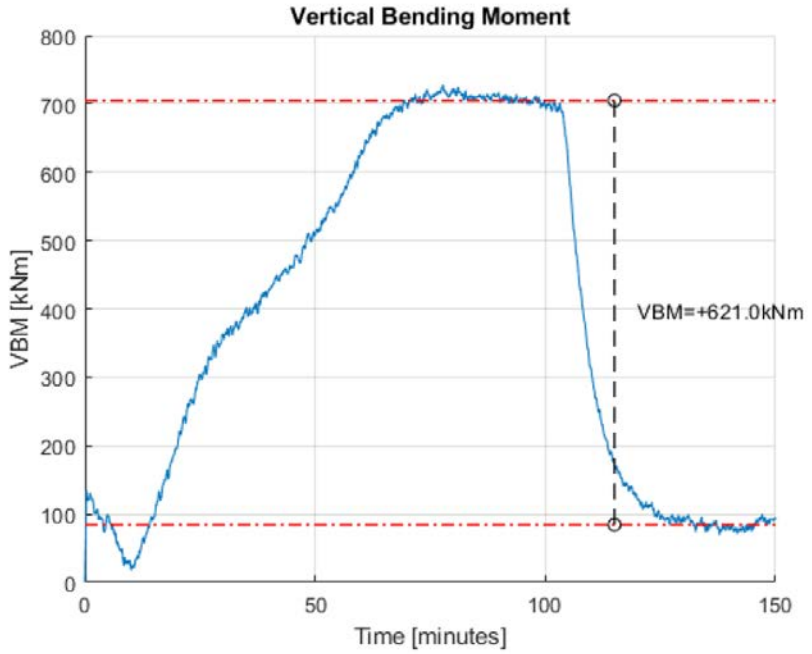
FIBRE REINFORCED COMPOSITES FiReCo FIRE RESISTANT COMPOSITES

LIGHT STRUCTURES Passion for Monitoring

Commissioning and Test

Water was filled into portable ballast tanks to apply the load



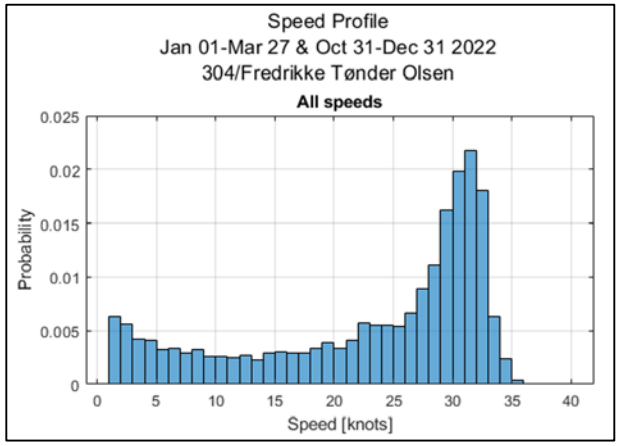


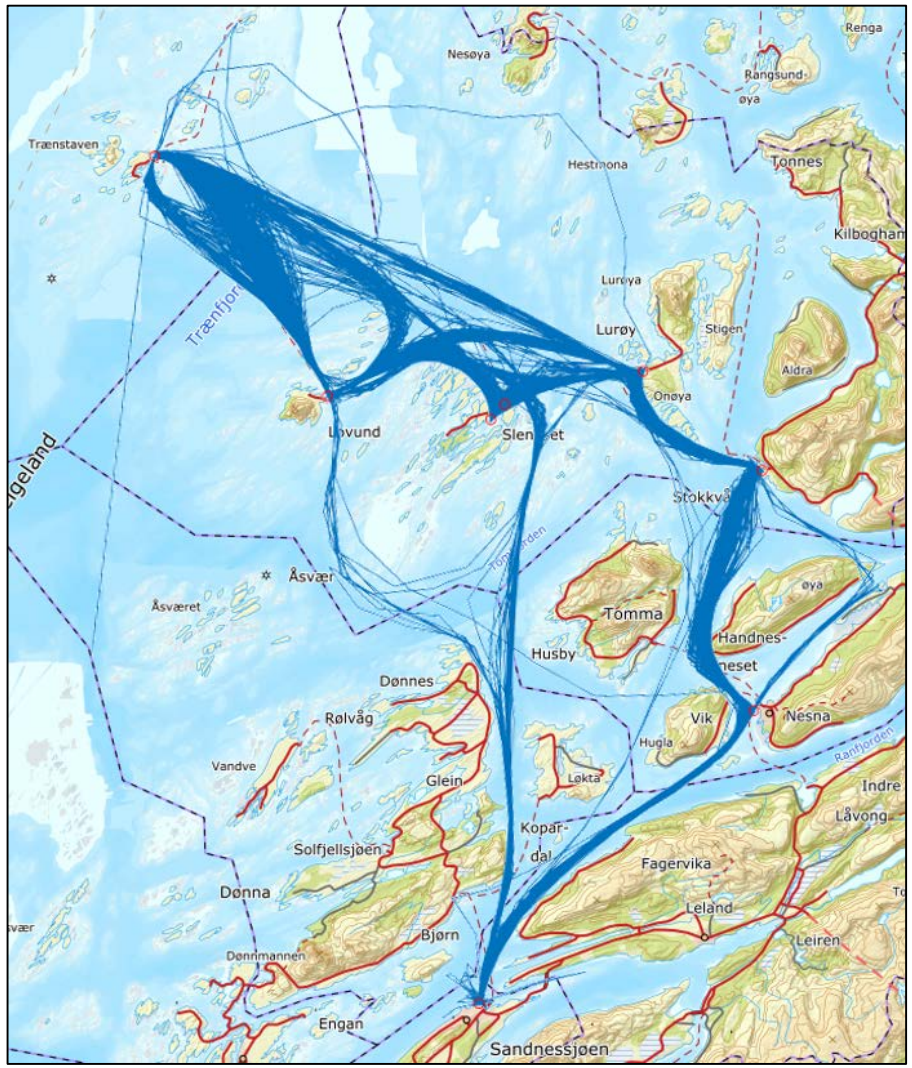
- In order to validate the load matrix a validation/calibration test is necessary.
- Such a test is required by DNVGL-RU-SHIP Pt.6 Ch.9 Sec 4
- It is considered sufficient to validate / calibrate the measurement of Vertical Bending Moment only, as this by all practical means also validates the correct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

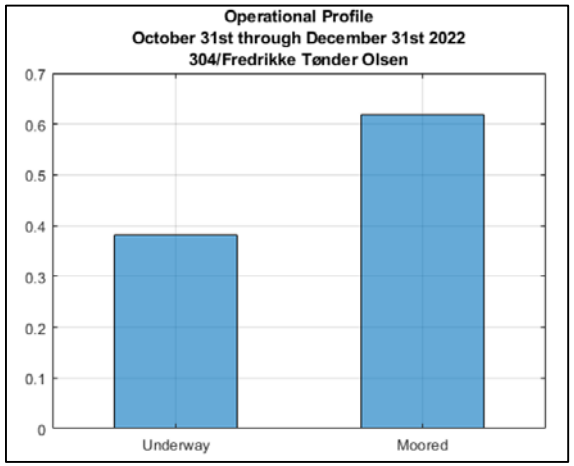
Graphical User Interface

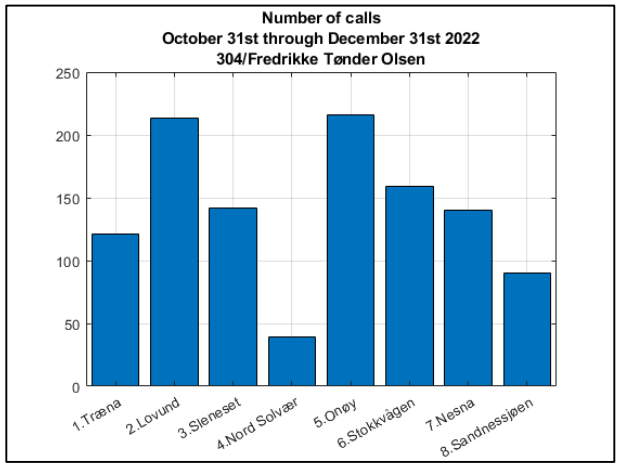
Data Analysis

- Operational information
- Accelerations
- Wave Profile
- Global loads
- Slamming



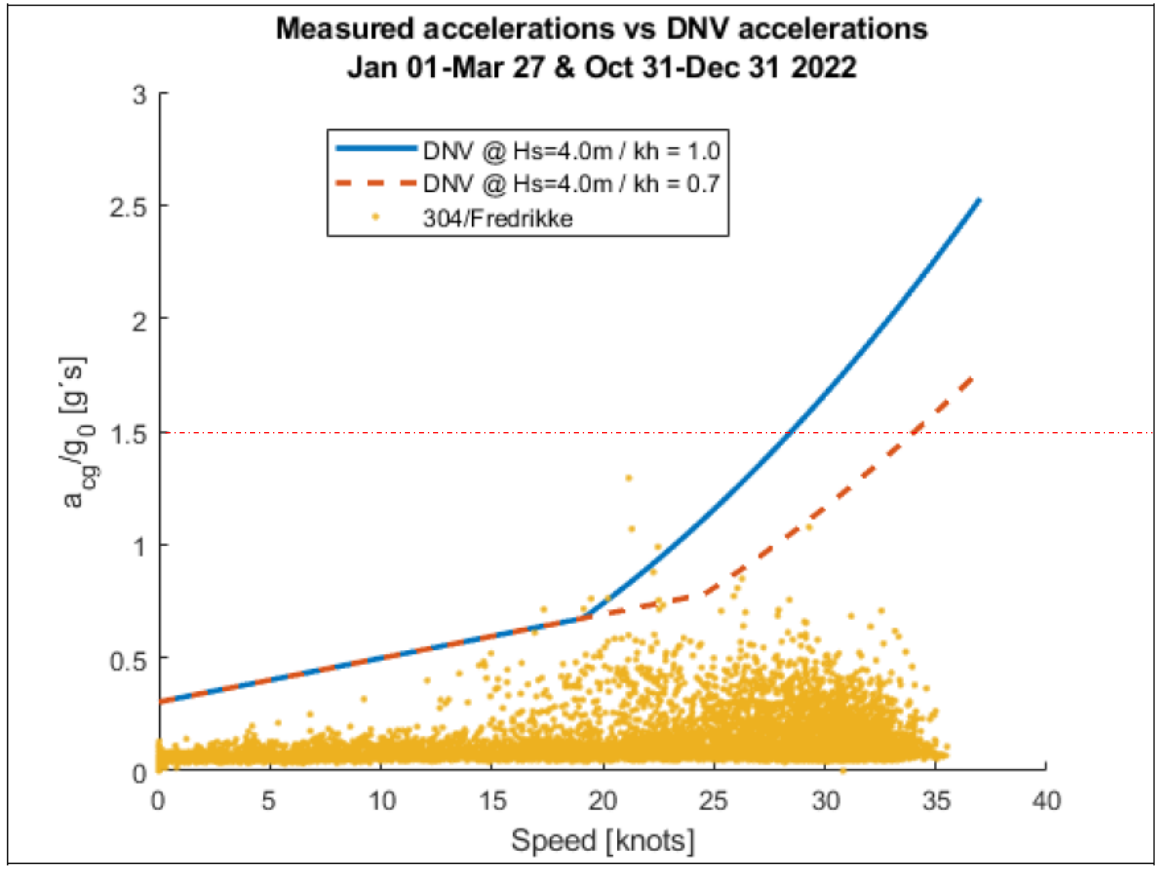




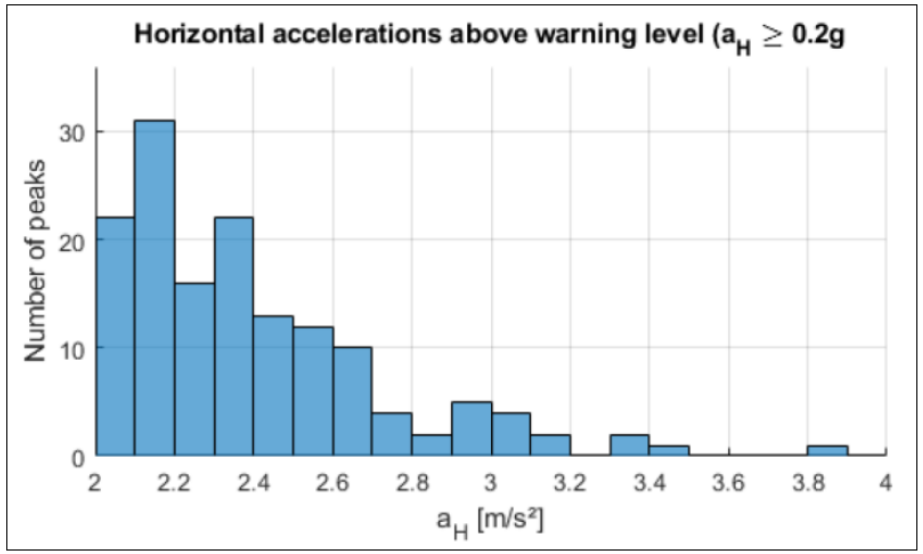


Data Analysis – Accelerations

Vertical:



Horizontal:

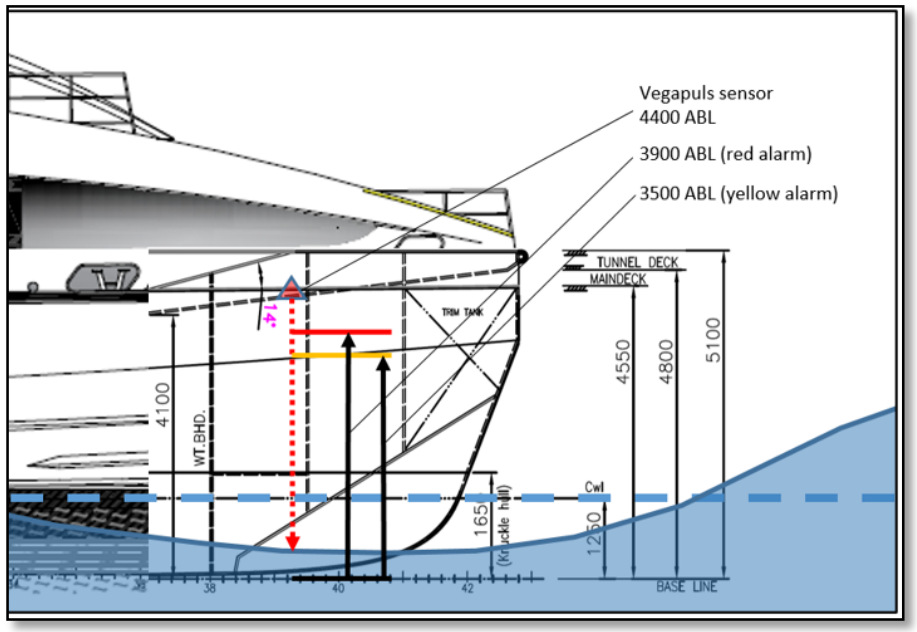


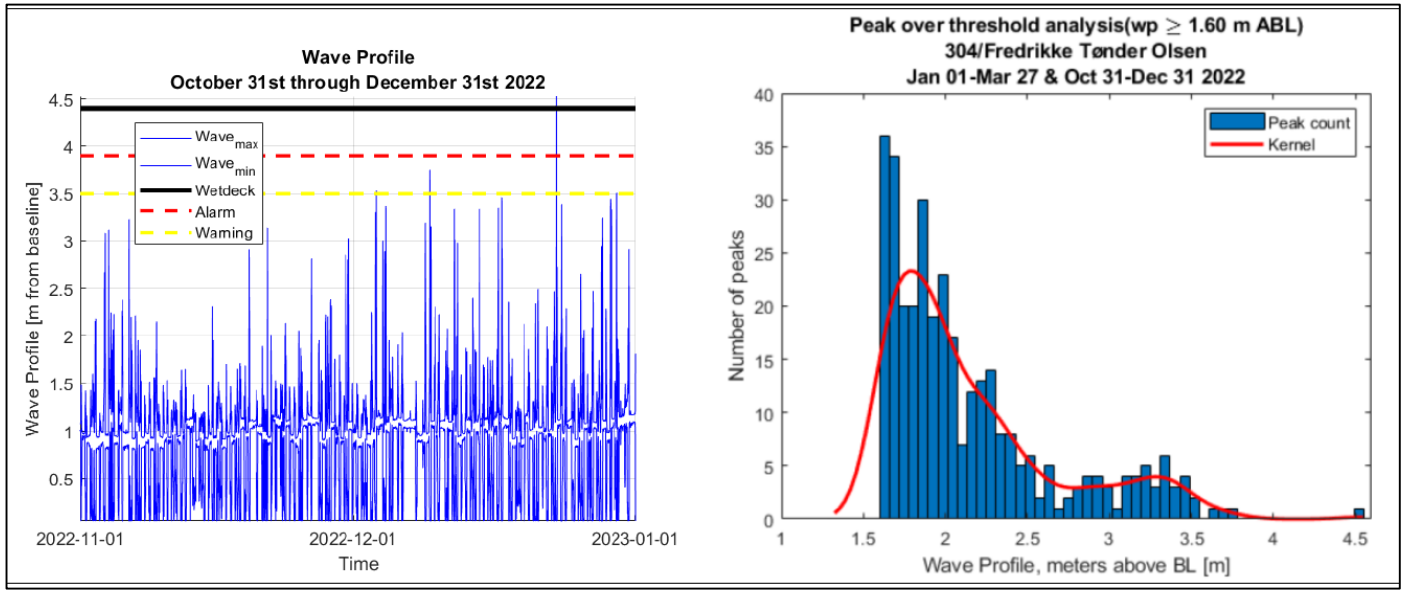
Level 1 – Minor effect: < 0.20g

Level 2 – Major effect: < 0.35g

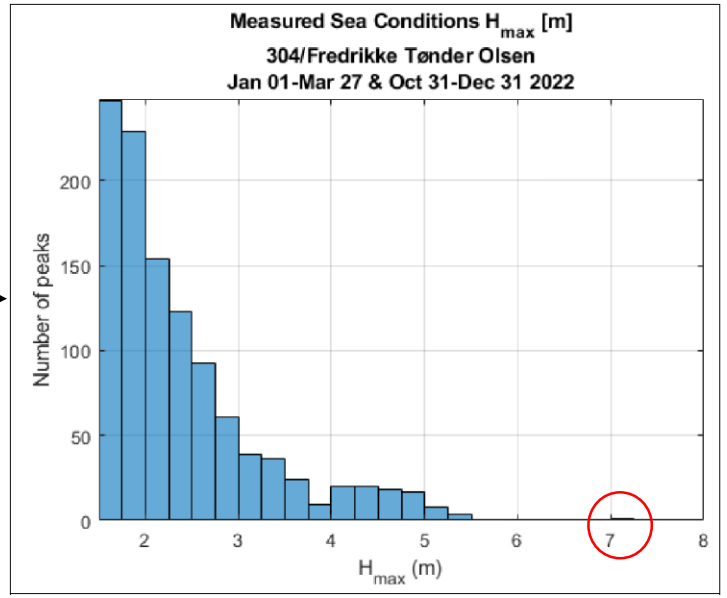
Level 3 – Hazardous effect: ≥ 0.35g

Data Analysis – Wave Profile

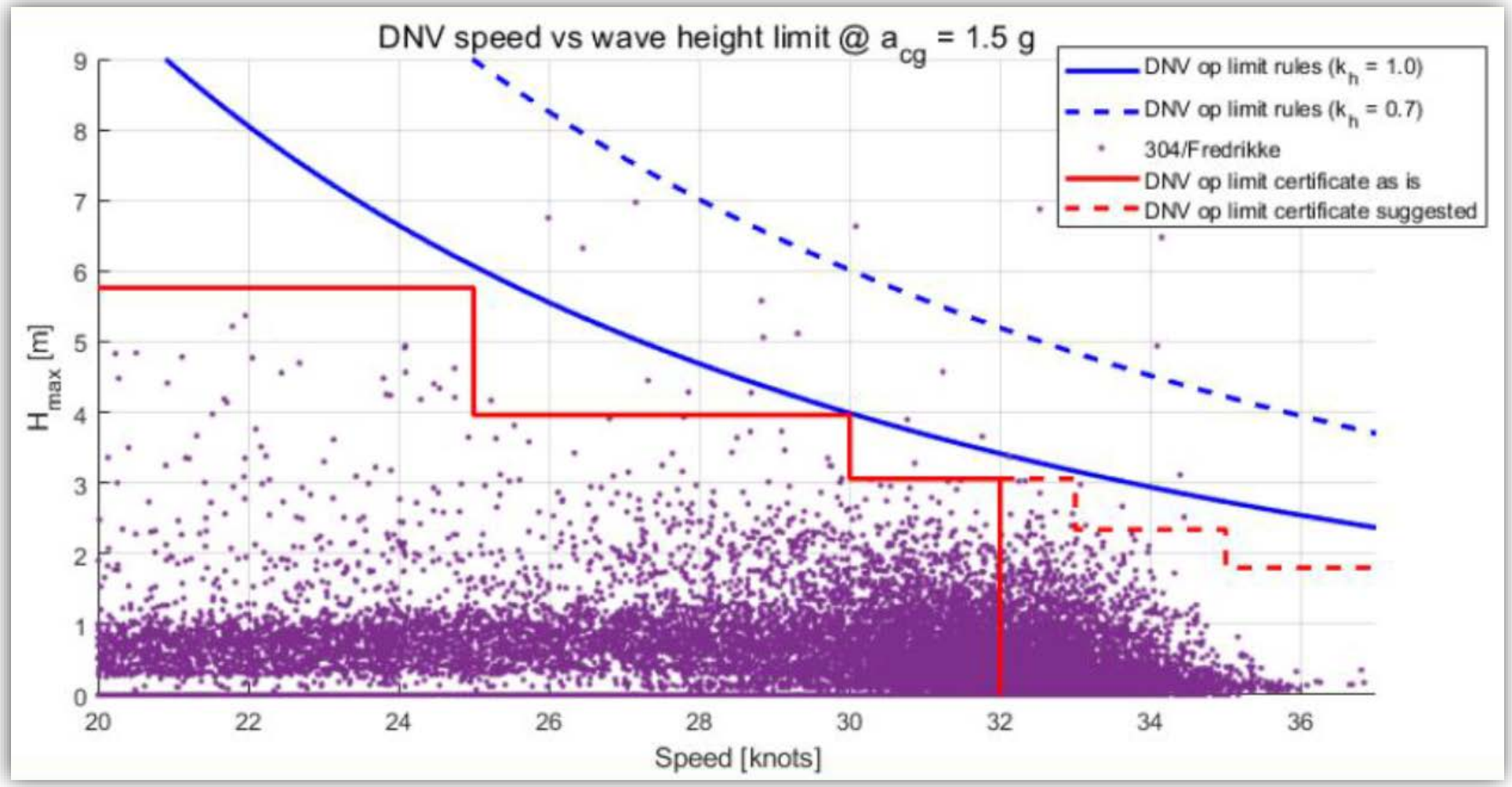




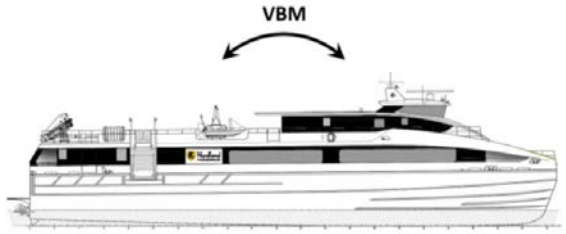
$$H_{Max} \approx 2 \times [(\text{wave profile}) - (\text{mean value})]$$

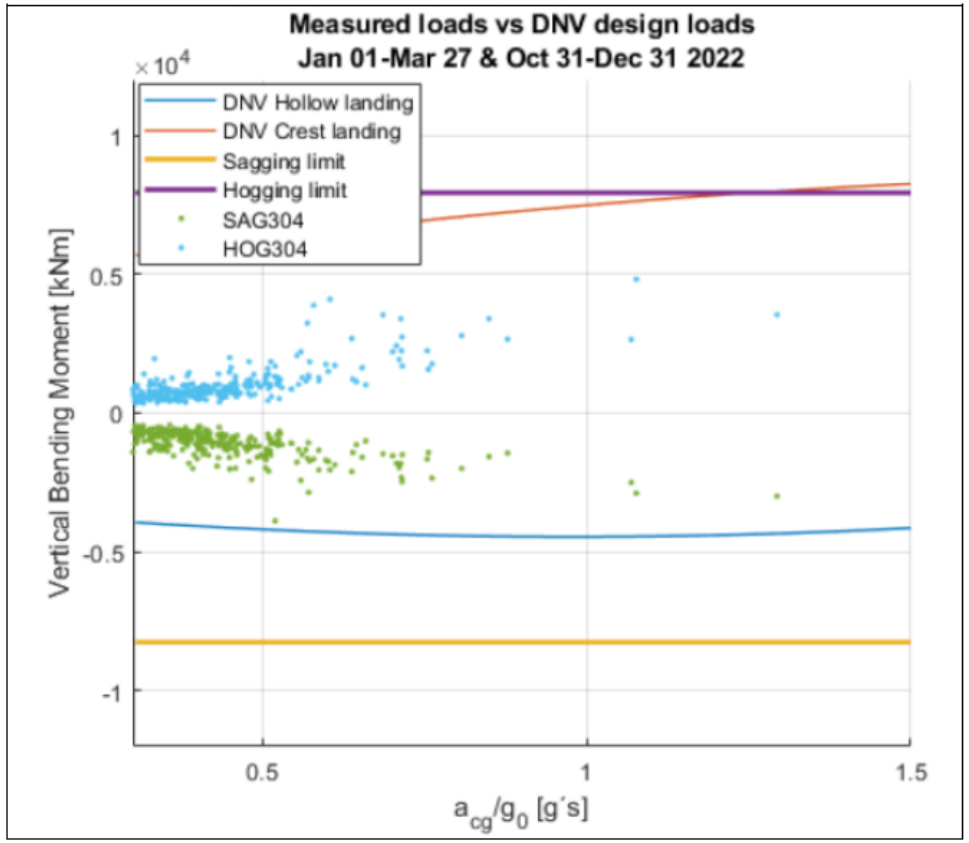


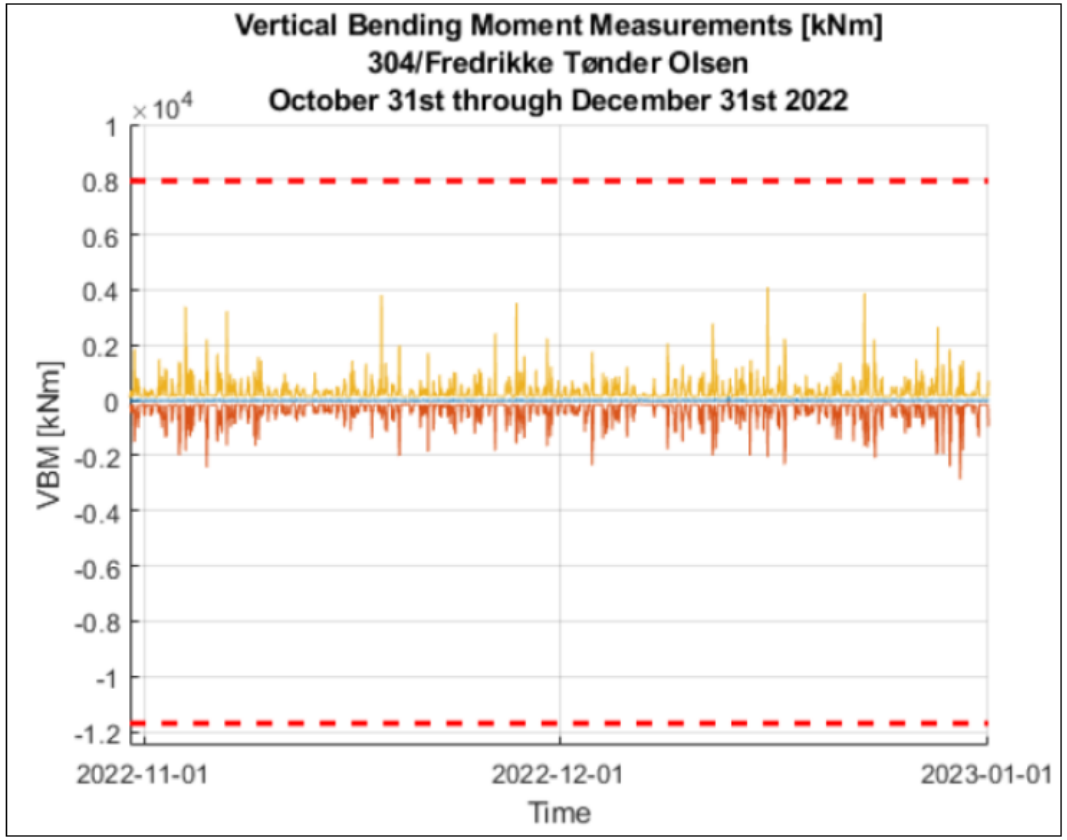
Data Analysis – Combinations of Speed and Wave Height



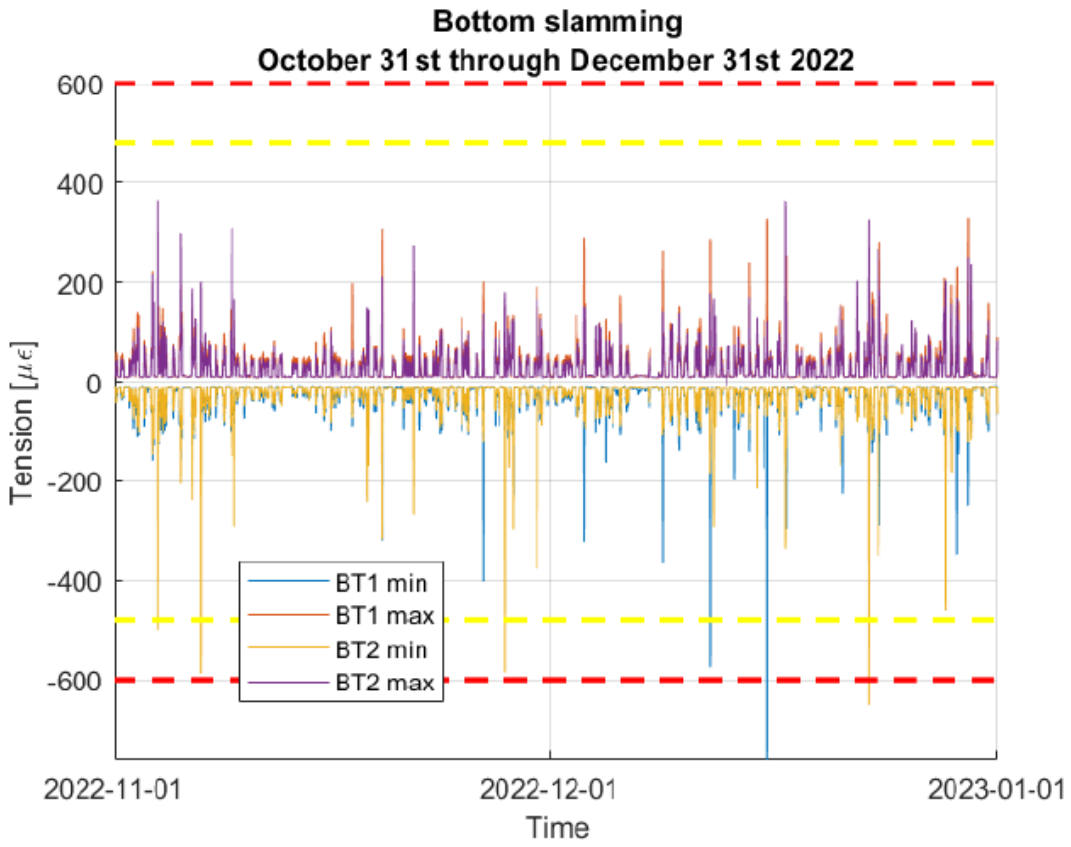
Data Analysis – Global Loads

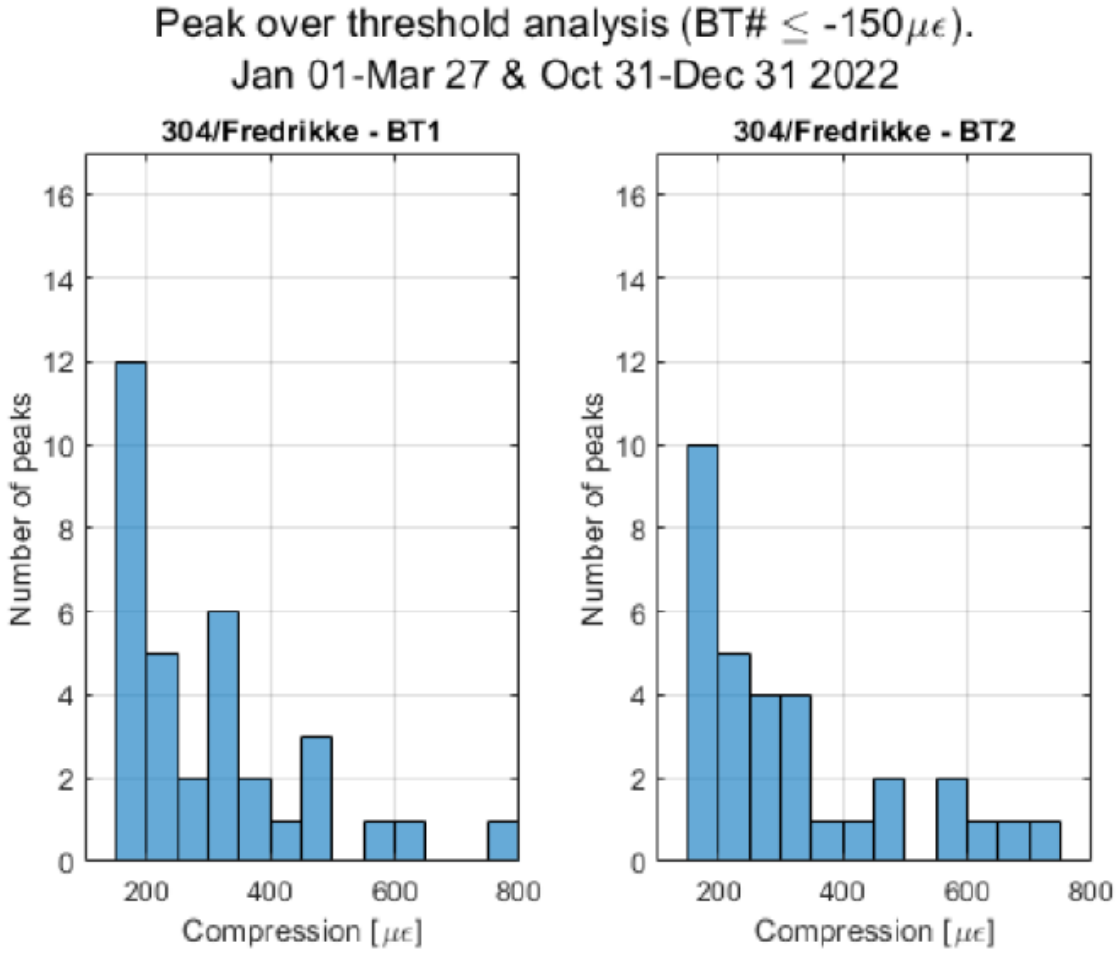






Data Analysis – Slamming

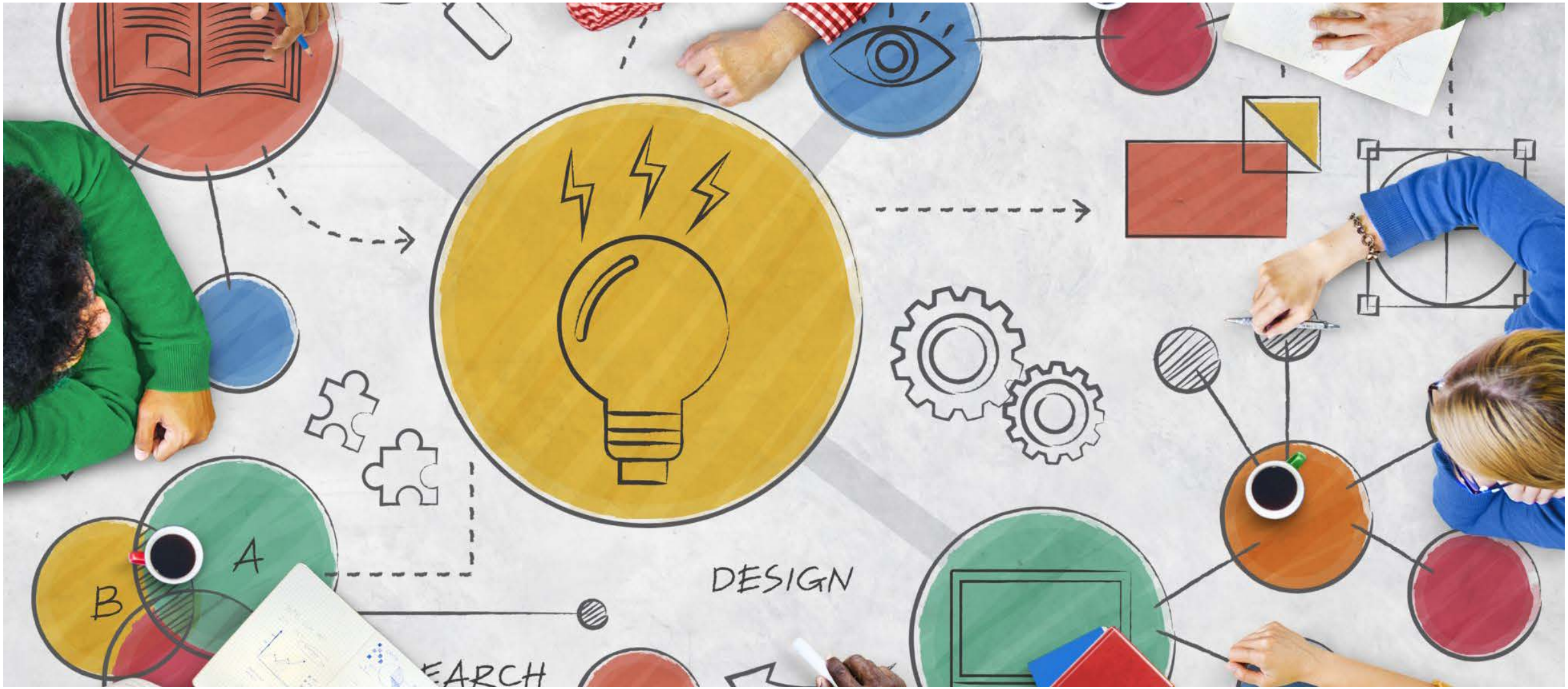




Conclusions

- Leaner, faster and cheaper vessel
- Increased regularity
- better tool to ensure operation within the design limits than the operation envelope given in the class certificate
- allows establishing predictive models for the limiting parameters, providing a pre-warning of load exceedance risk during operations
- the digital twin allows detailed analysis of any future load exceedance events, providing indications of when and where to inspect for possible damages, potentially reducing inspection and maintenance cost while increasing the overall safety and integrity of the structure

Other Ideas for Application



Thank you for your attention!