

*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:



FUEL-EFFICIENT FAST FERRIES IN CARBON FIBRE



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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:

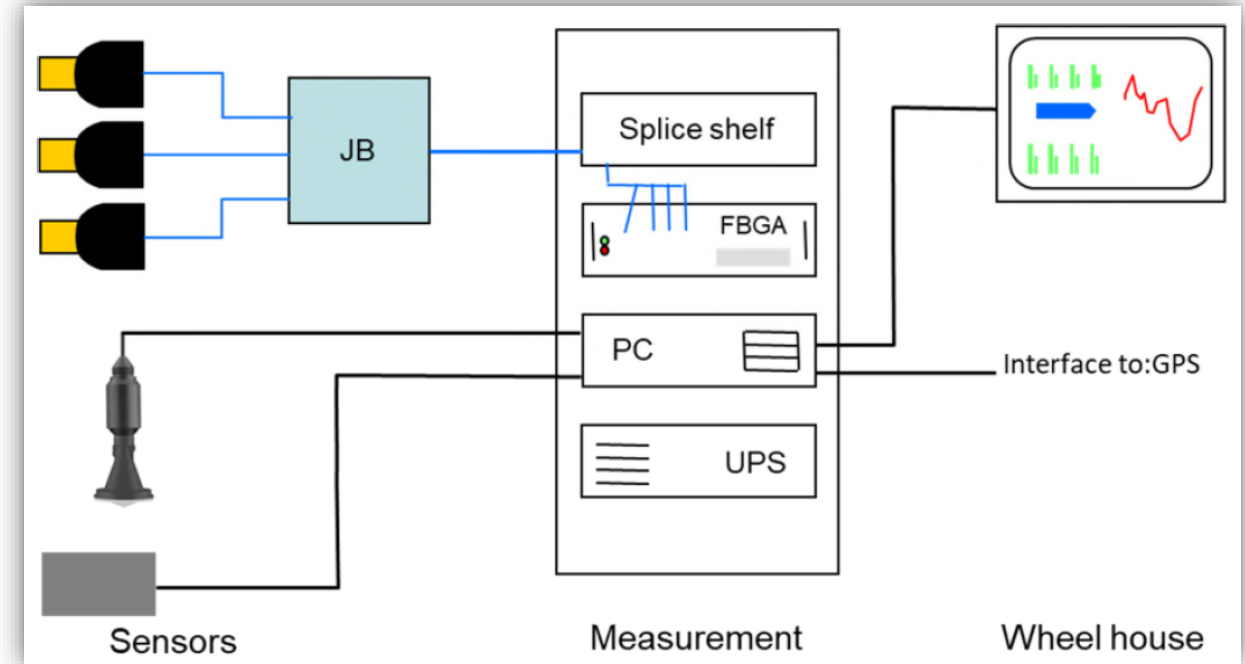
Real time presentation of loads and accelerations to the operators, along with data storage and post processing to document that the measurement approach is acceptable.

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

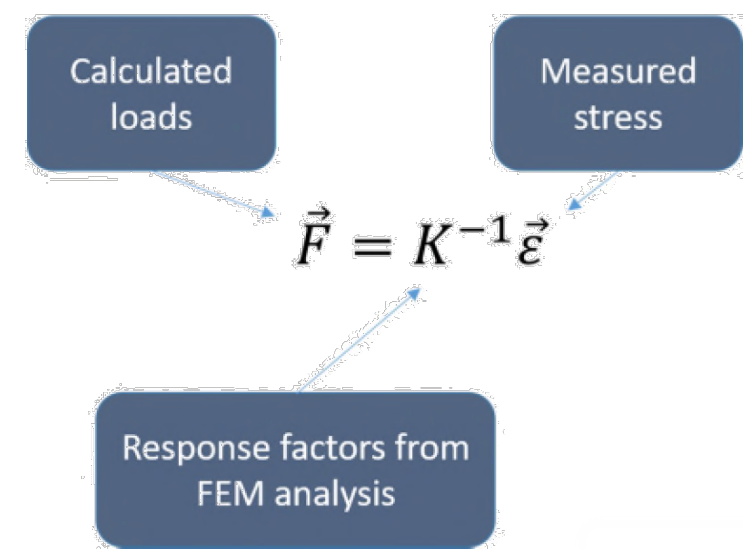
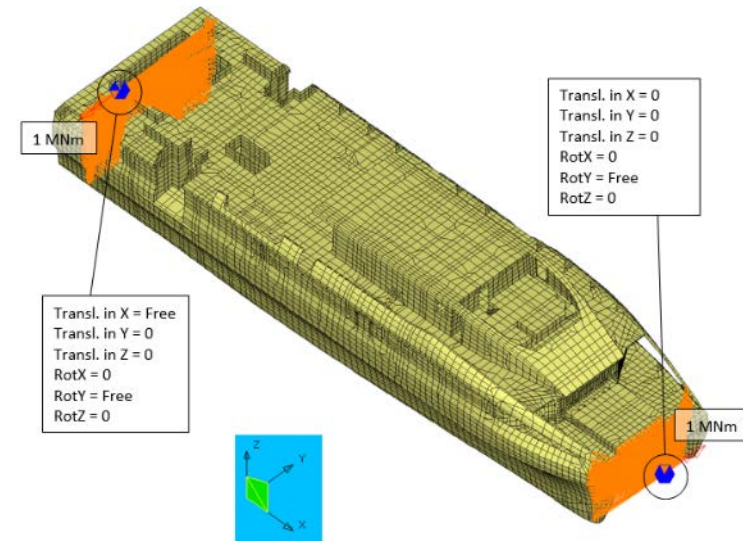
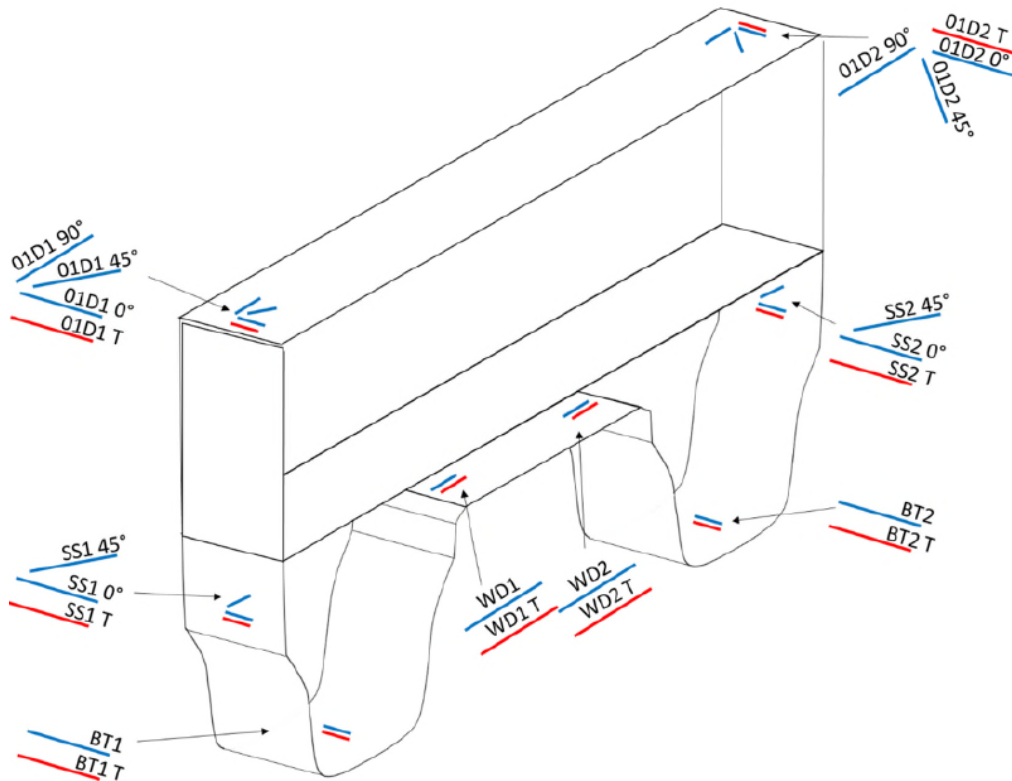
The system consists of the following main components:

- 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).

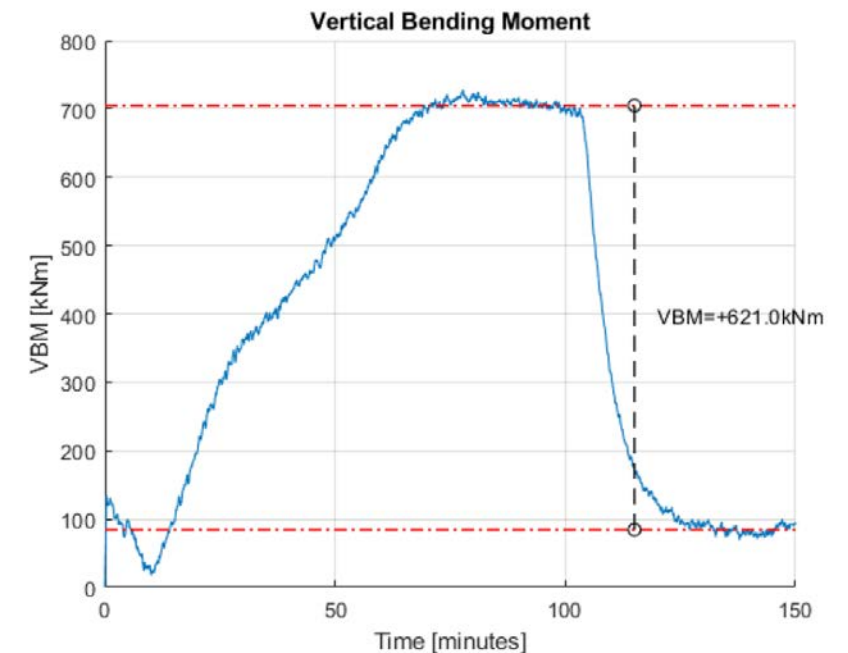
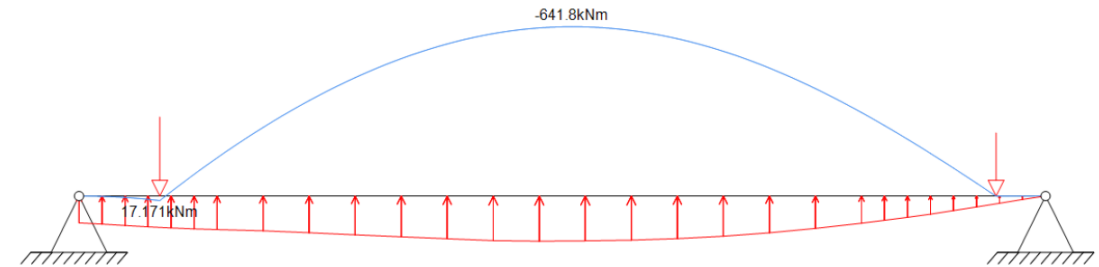


Commissioning and Test



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.



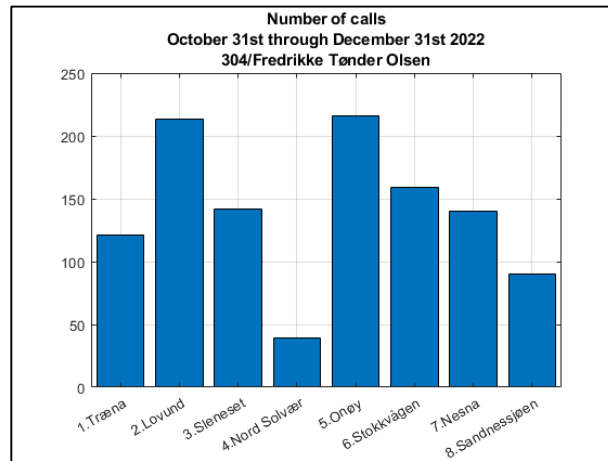
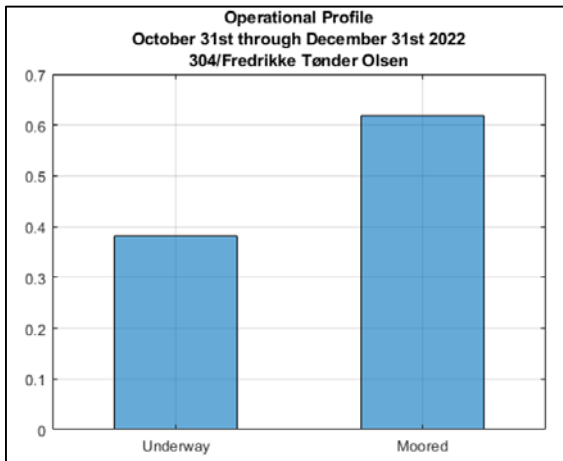
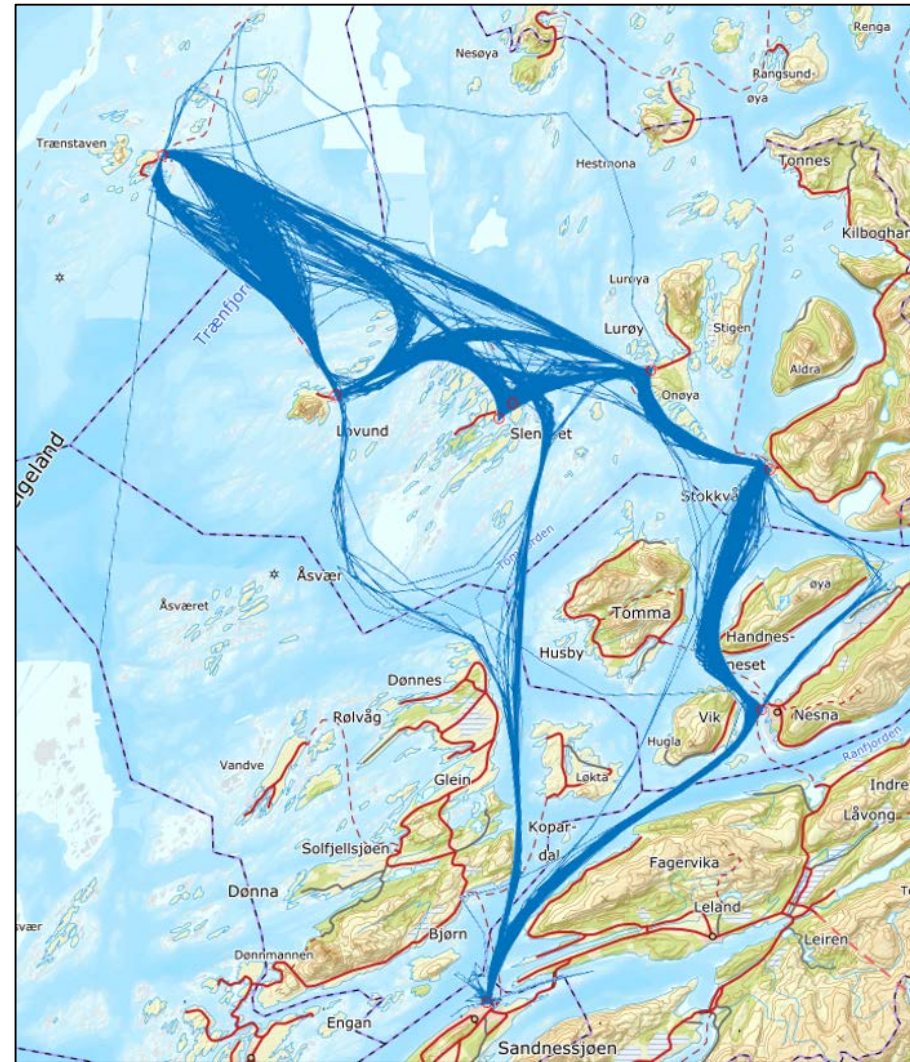
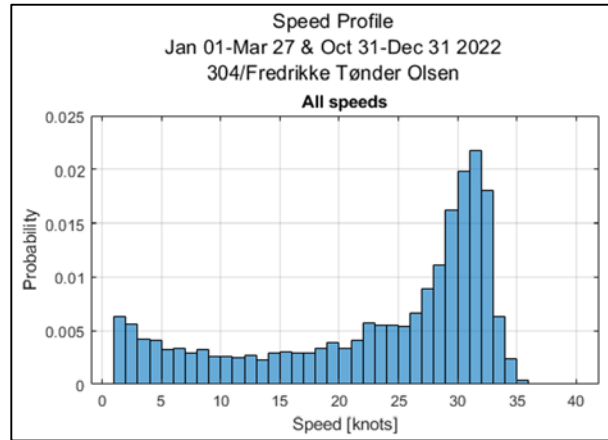
Graphical User Interface

The image shows a control room dashboard with a large screen displaying a graphical user interface (GUI) for vessel monitoring. The GUI is divided into several sections:

- Top Section:** Contains several control buttons for "Port Outer Jet", "Port Inner Jet", and "Starboard Inner Jet", each with "On/Off Control" and "Pushed" indicators.
- Main Monitoring Area:** Features six primary data displays:
 - Vertical bending moment compared to limits (VBM):** A bar chart showing a 5-minute peak (black bar) and current dynamic value (green bar).
 - Torsion compared to limits (Torsion):** A bar chart showing a 5-minute peak (black bar) and current dynamic value (green bar).
 - Vessel accelerations:** Two bar charts for "Vertical Acc" and "Hor Acc".
 - Wave height compared to limit (WaveProfile):** A bar chart showing wave profile data.
 - Slamming loads compared to limits (Slamming):** A bar chart showing slamming load data.
 - Slamming counter (Slam Count):** A bar chart showing counts for 15, 10, 5, and 0 minutes.
- Navigation and Controls:** A vertical menu on the right side includes:
 - General alarm indicator (red inverted triangle)
 - Main View (Return to main view)
 - Alarm Log (Alarm log)
 - Day/Night mode (Day/night color)
 - Statistics (Detailed statistics data)
 - Scope (Scope window w/ selectable sensors)
 - Help (This screen)
 - Maintenance (Expert functions, Data export, diagnose ++)
- Pending Alarms Log:** A large empty box for displaying alarm logs, with an "Acknowledge All" button at the bottom.
- Legend:** A collection of symbols and colors used for alarm states:
 - Red triangle up: HIHi alarm state
 - Yellow triangle up: Hi alarm state
 - Yellow triangle down: Lo alarm state
 - Red triangle down: LoLo alarm state
 - Yellow triangle: Warning; data input is temporarily missing
 - Black X: Sensor or computer process is offline
 - Green checkmark: Alarm acknowledged
 - Green circle: Status OK
 - Red square: Sensor currently in HIHI/LOLO state
 - Yellow square: Sensor currently in HI/LO state
 - Green square: Sensor in Normal state
 - White square: Undetermined. Missing data from sensor
- Footer:** Text at the bottom reads: "Please refer to LS18005MA001_UserManual_Rev0100.pdf for details. Maker: Light Structures AS | support@lightstructures.no".

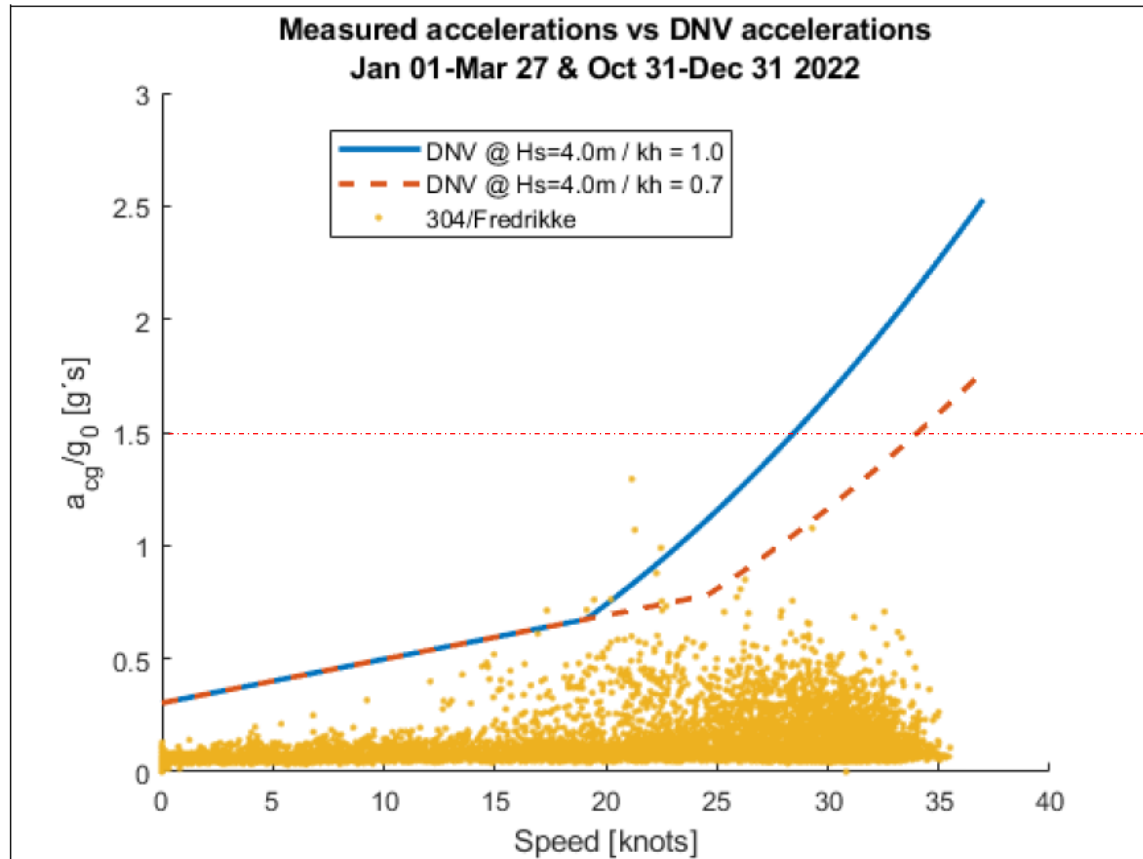
Data Analysis

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

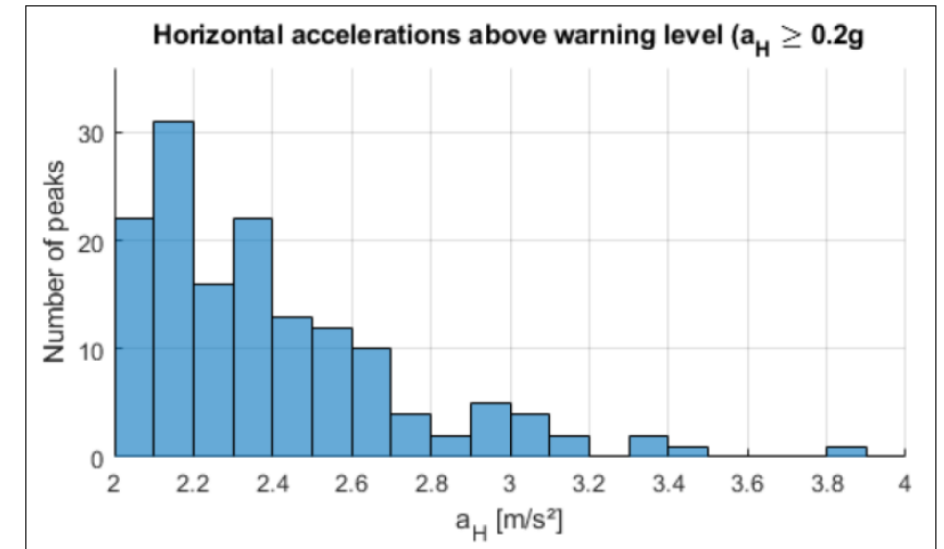


Data Analysis – Accelerations

Vertical:



Horizontal:

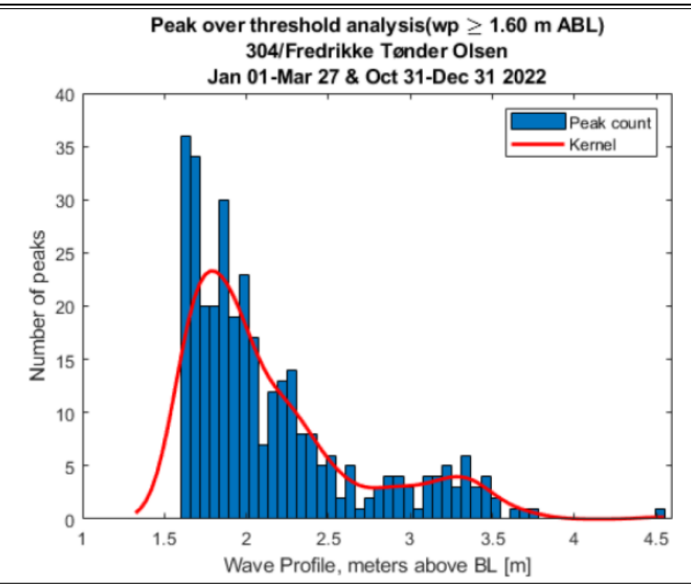
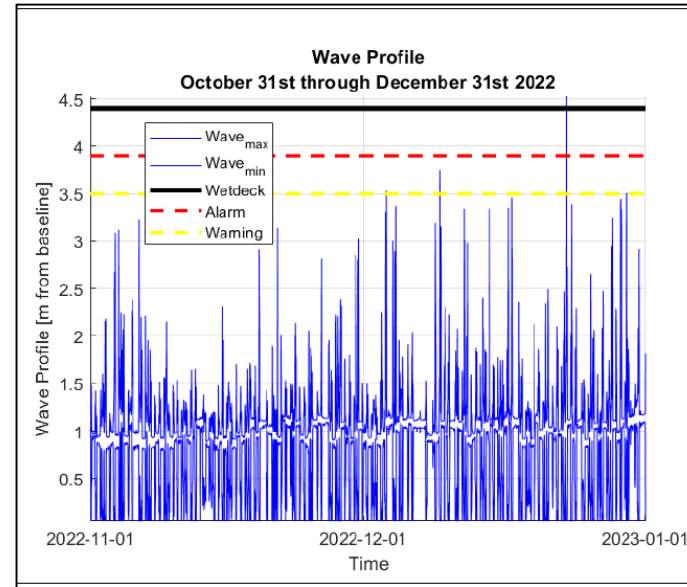
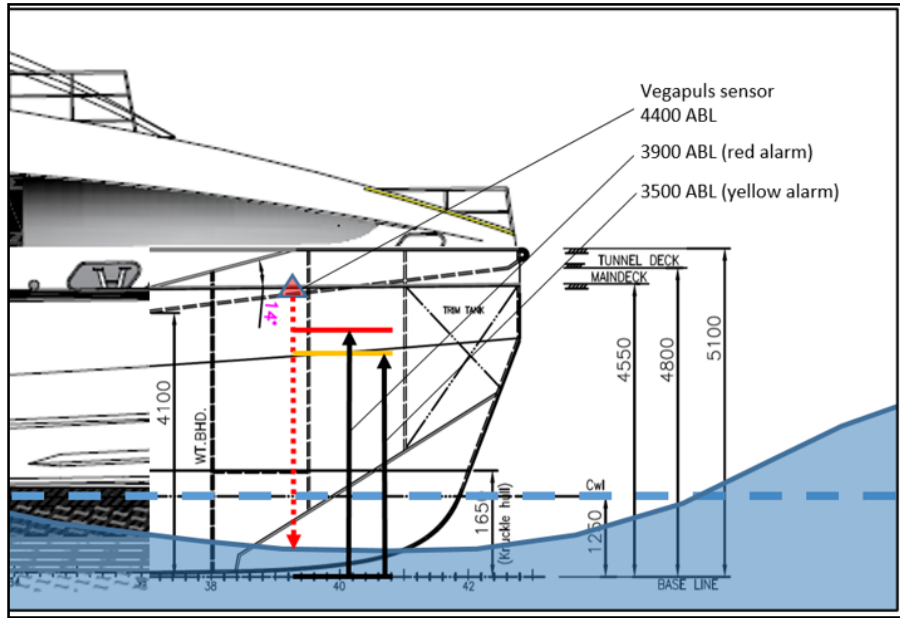


Level 1 – Minor effect: $< 0.20g$

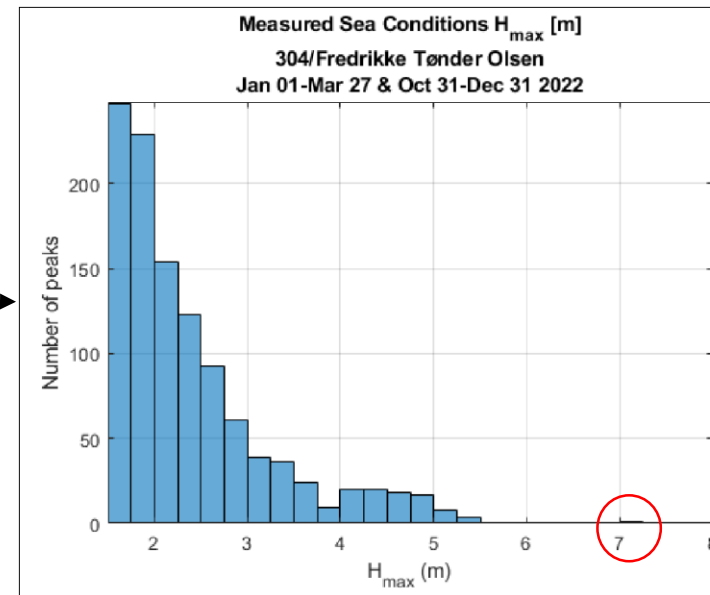
Level 2 – Major effect: $< 0.35g$

Level 3 – Hazardous effect: $\geq 0.35g$

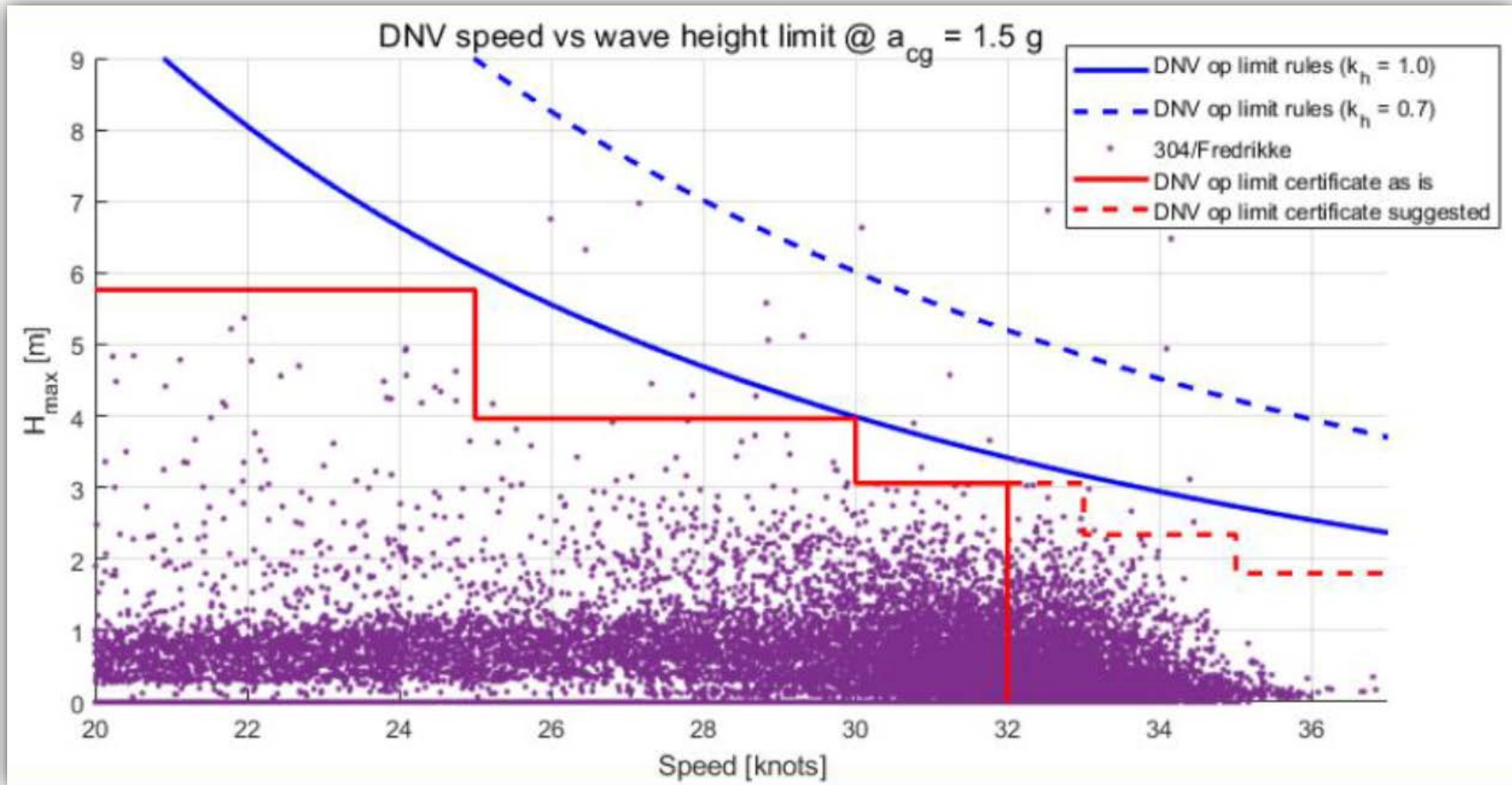
Data Analysis – Wave Profile



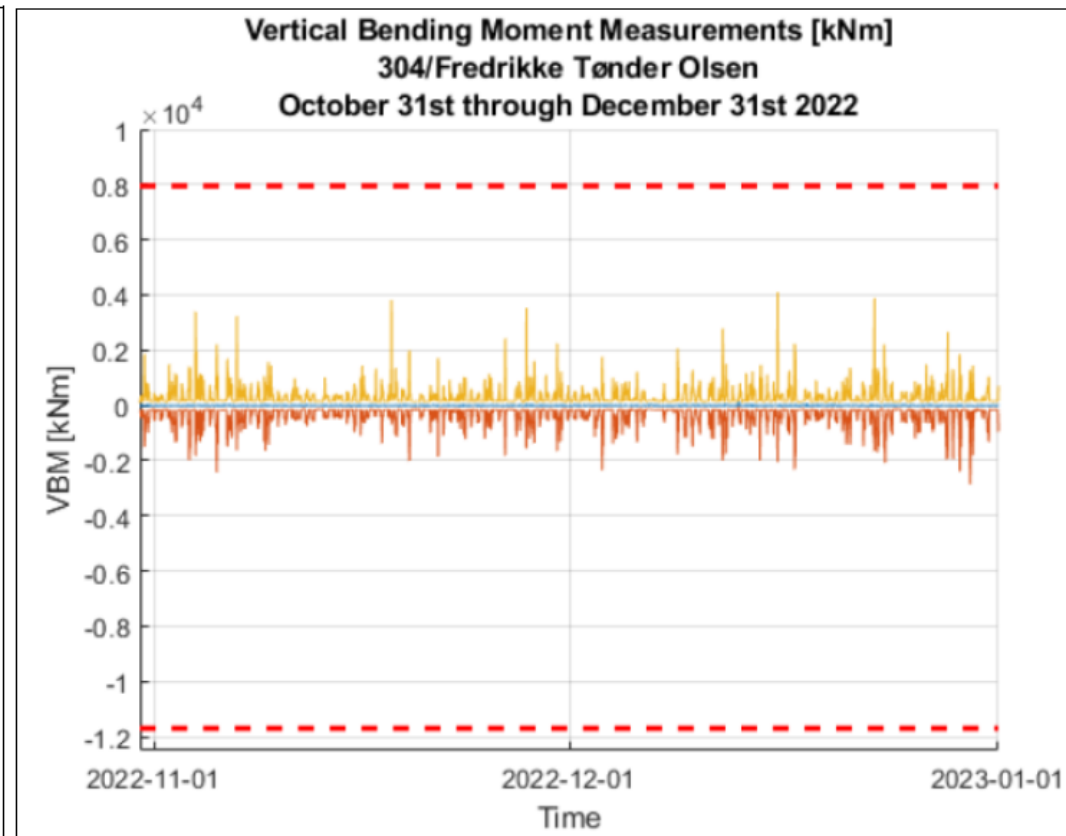
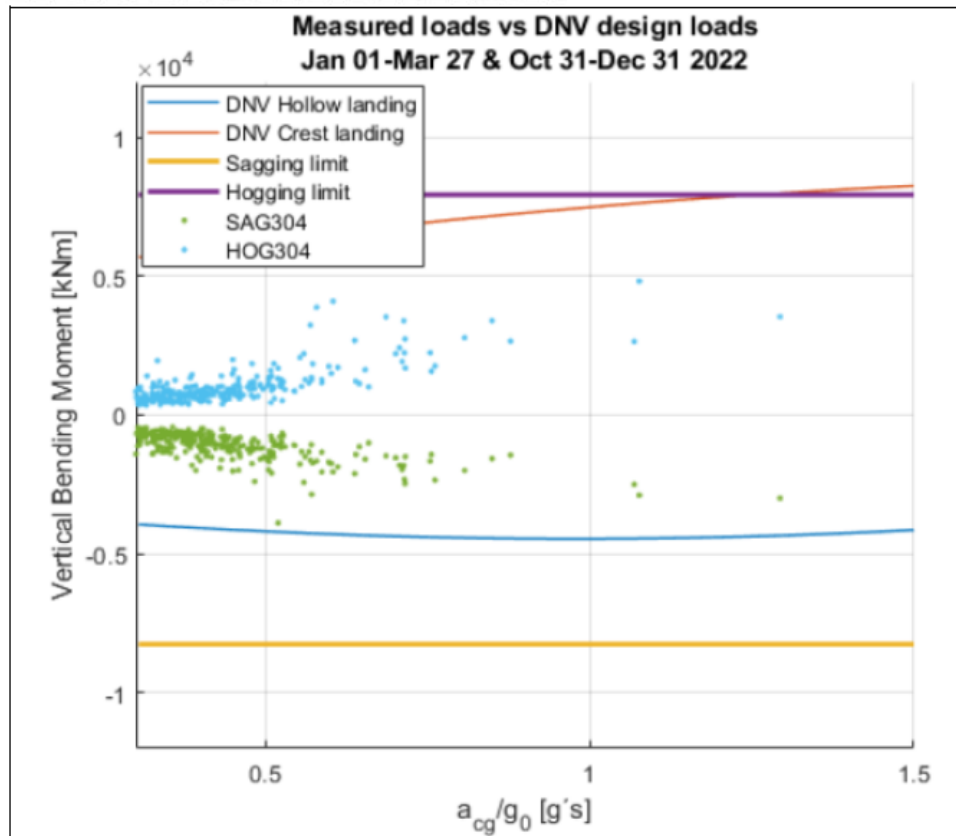
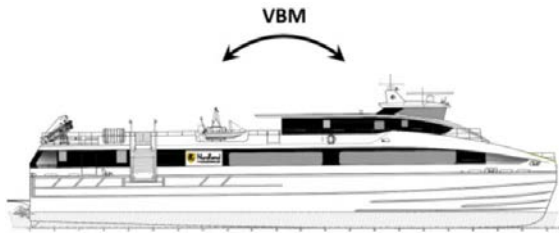
$$H_{Max} \approx 2 \times [(wave\ profile) - (mean\ value)]$$



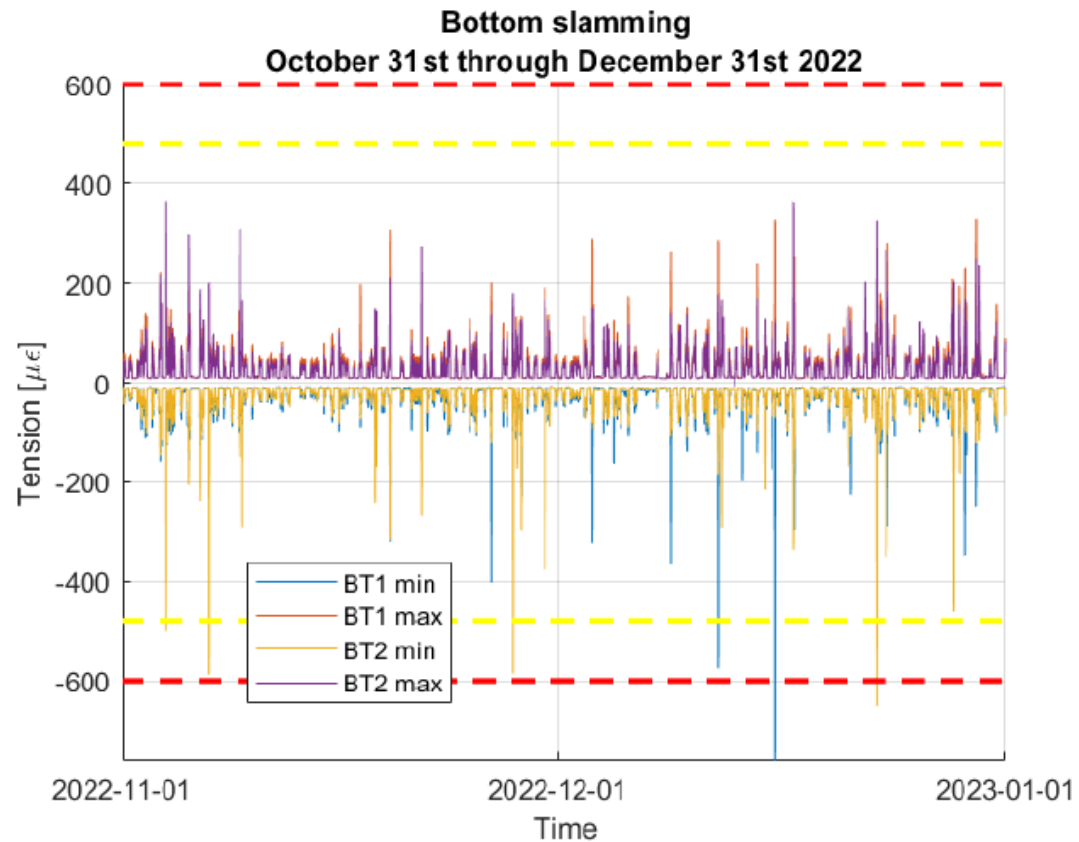
Data Analysis – Combinations of Speed and Wave Height



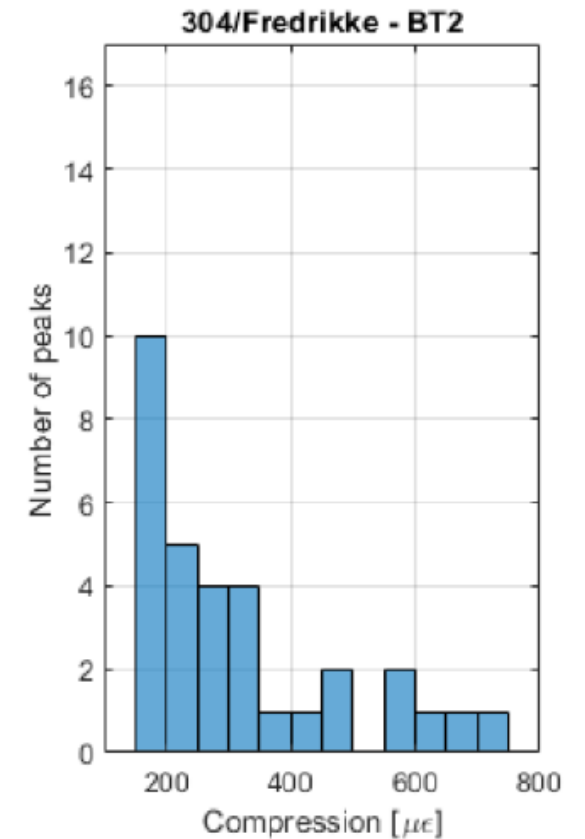
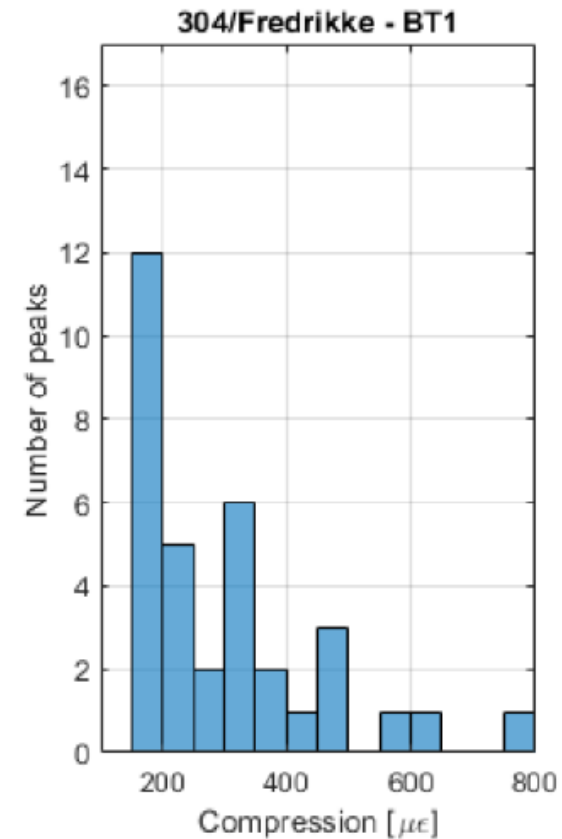
Data Analysis – Global Loads



Data Analysis – Slamming



Peak over threshold analysis (BT# $\leq -150\mu\epsilon$).
Jan 01-Mar 27 & Oct 31-Dec 31 2022



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

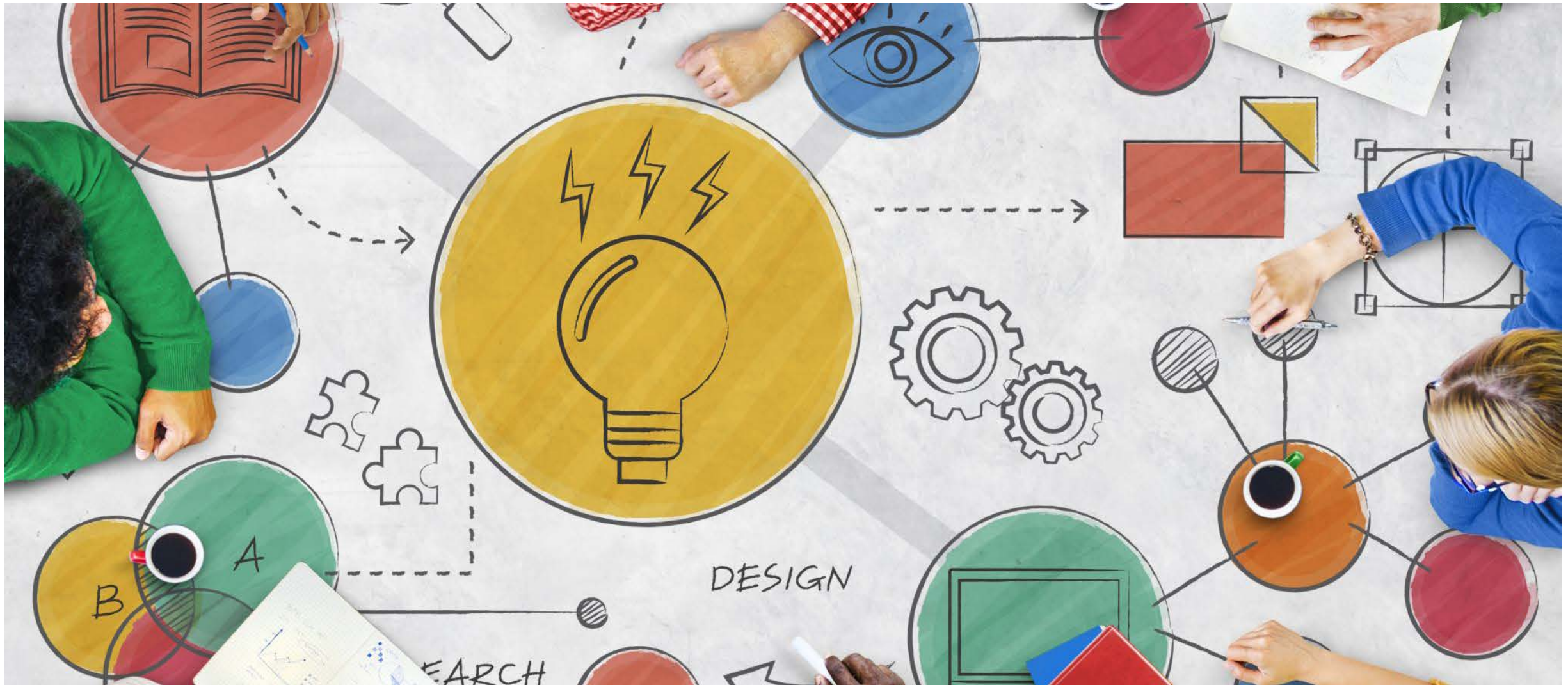


allows establishing predictive models for the limiting parameters, providing a pre-warning of load exceedance risk during operations



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!

