LIGHT STRUCTURES

Structural Monitoring Systems with applications to Ice Response Monitoring

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DP2010 Houston

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Structural Monitoring Systems - Outline

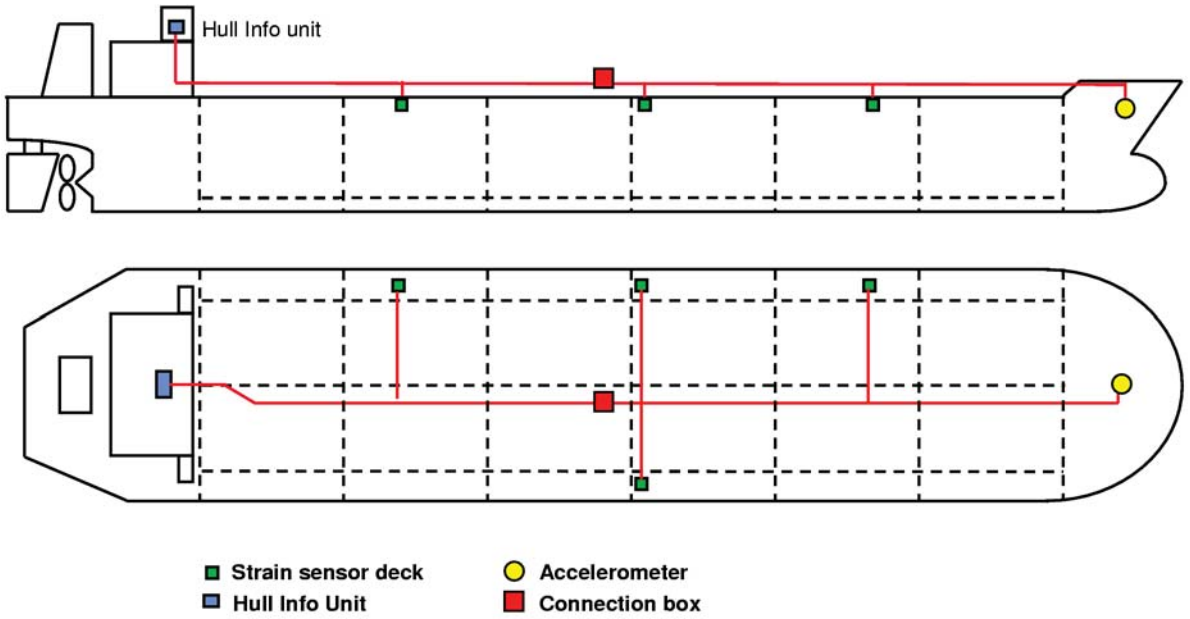
Hull Stress Monitoring Systems

Structural response theory

Ice Load Monitoring

Conclusions and Outlook

Standard minimum arrangement



HMON ShipRight SEA HM MON-HULL

Overload warning

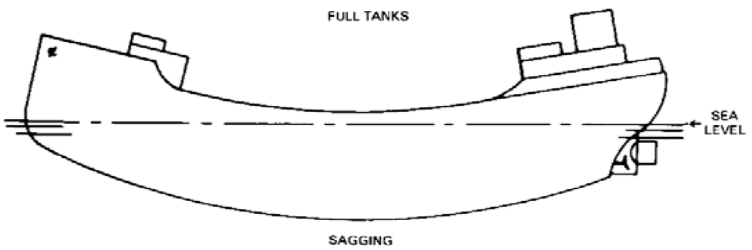
Std arrangement: hull vertical bending moment (VBM)

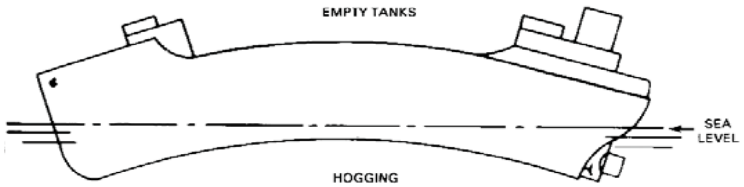
Overload from Cargo and Ballast operations

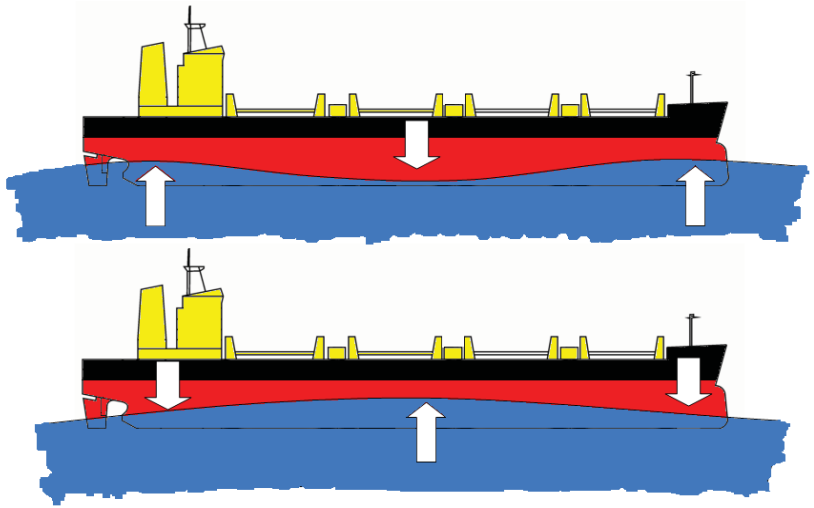
Wave-induced overload

Unexpected loads from major damage/water ingress

… Quite rare events







Fiber Optic Sensor Systems

Direct strain measurement

Low noise: No EMI/EMC

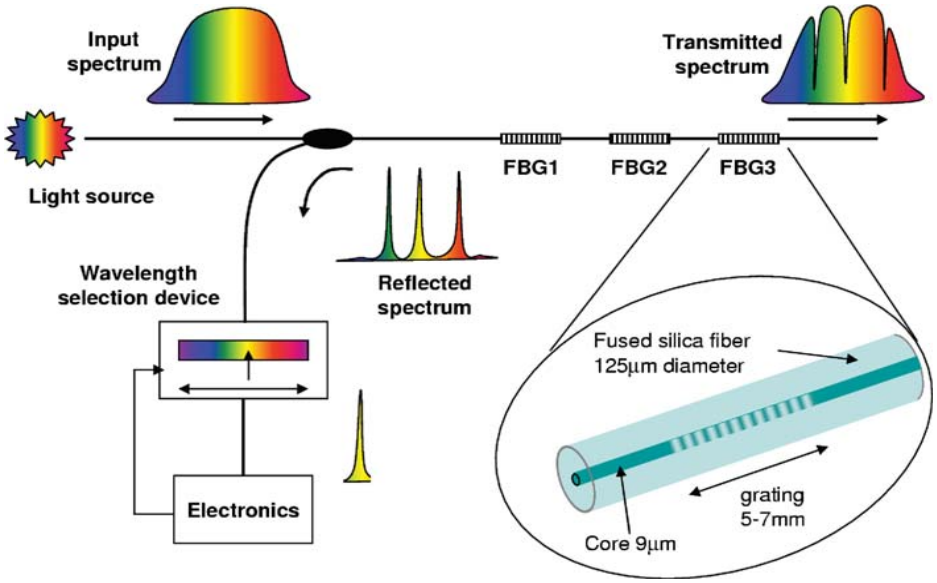
Intrinsically EX safe

Multiplex

Long life

Cold environments

Flexible placement (WBTs / Containment systems etc)



Fatigue management

HSMS follows every hull load cycle

Processed to calculate:

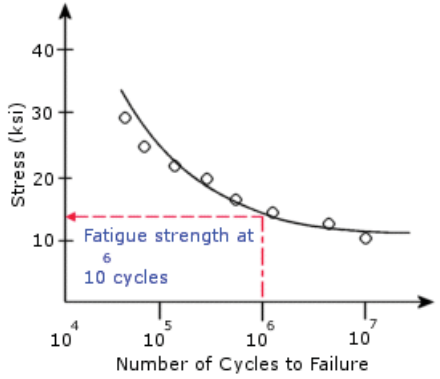
- fatigue accumulation rate

- total accumulation so far

Pinpoint causes

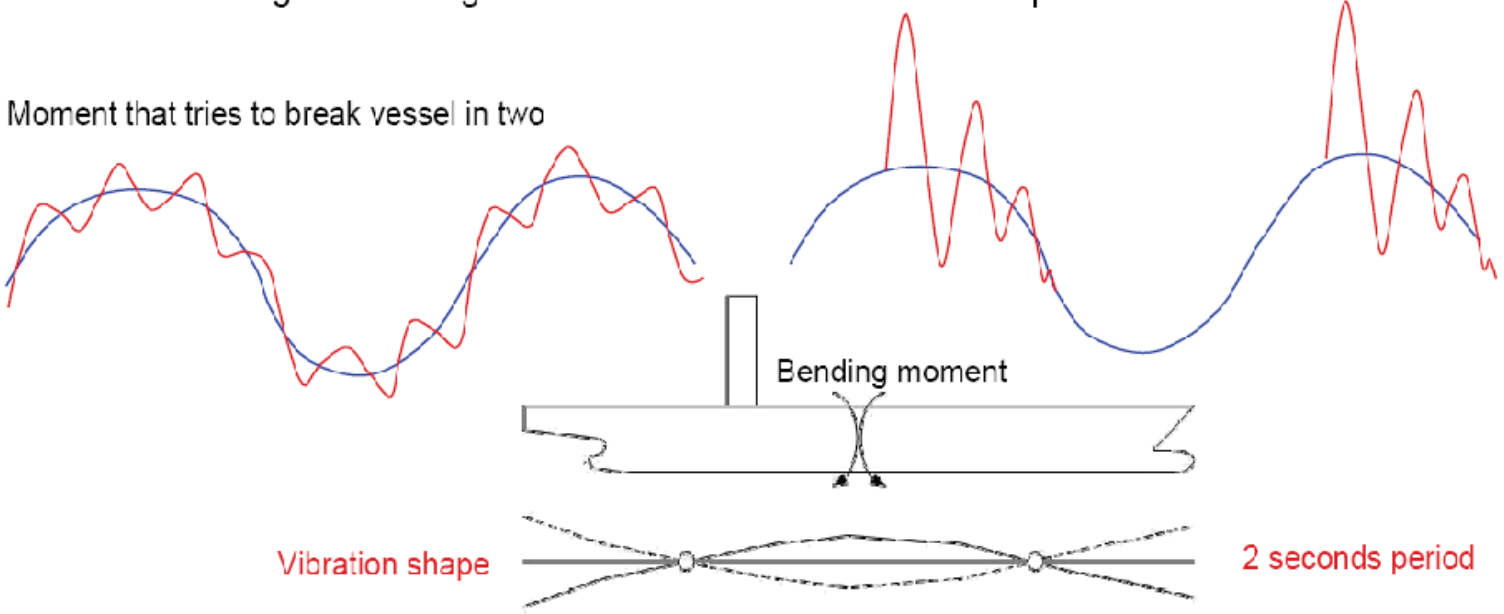
Promote operational awareness

Minor adjustment – major gain



Vibration phenomena

- Springing
  - Resonance
  - Oscillating loads along the hull
- Whipping
  - Transient response
  - Wave impacts in bow and stern



Springing and whipping increases fatigue and extreme loading

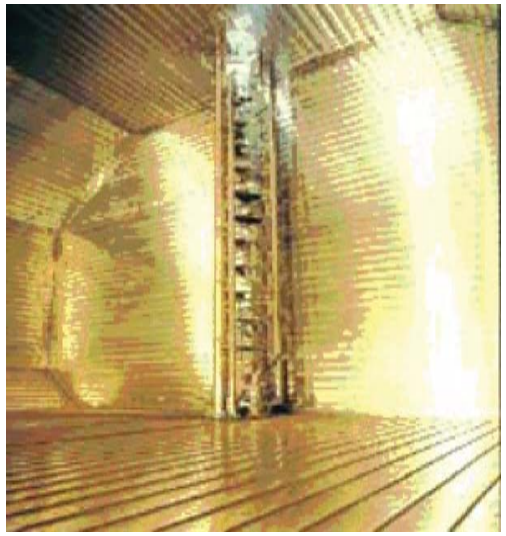
Springing and whipping is not accounted for in design of ships!

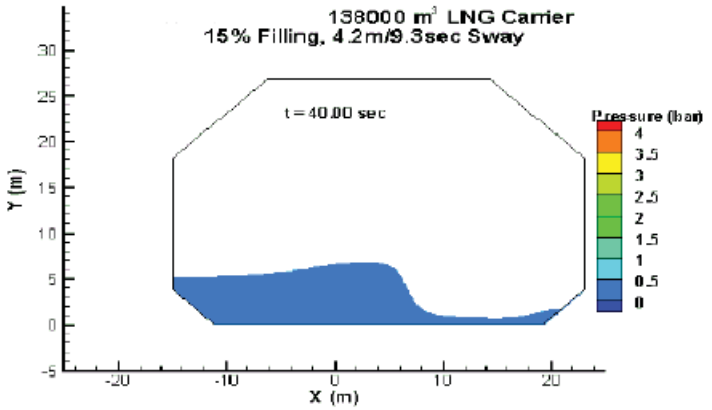
LNG tank sloshing monitoring

Monitors the pressure and force exerted by liquid cargo sloshing inside cargo tank

Qualified for very low temperatures

Provides information about condition of hard-to-inspect parts of the containment system





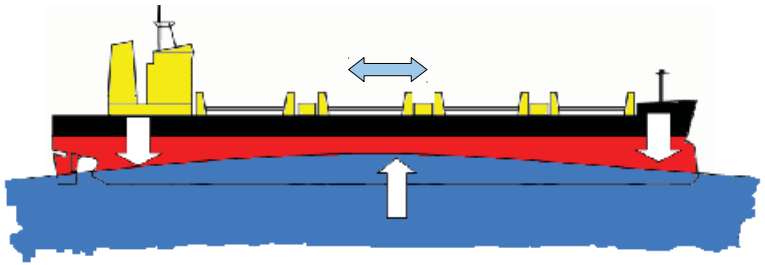
Linear Structural Response Models

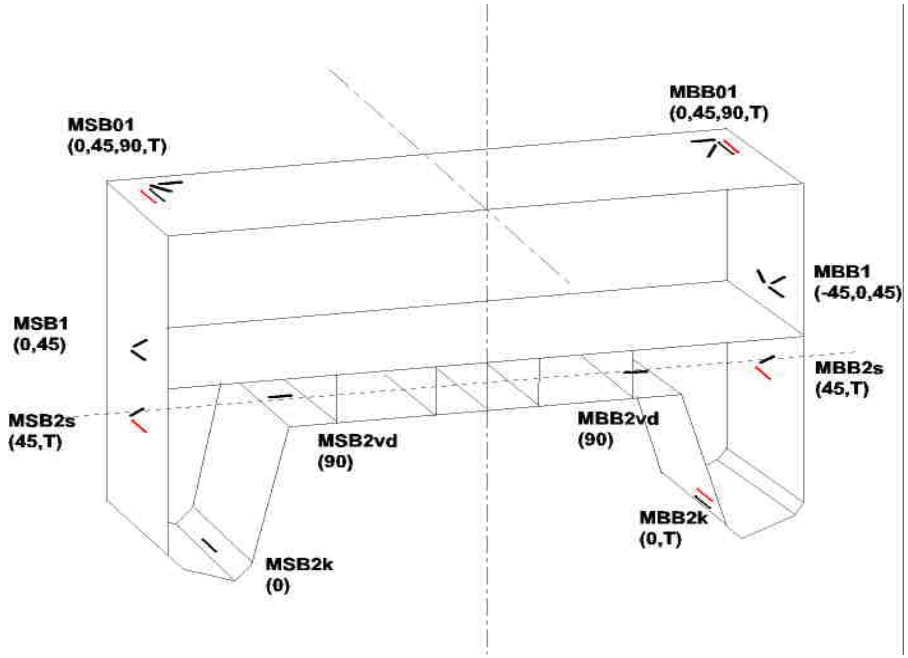
Calc Loads

Meas Strains

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

Response factors from FE models or Calibration





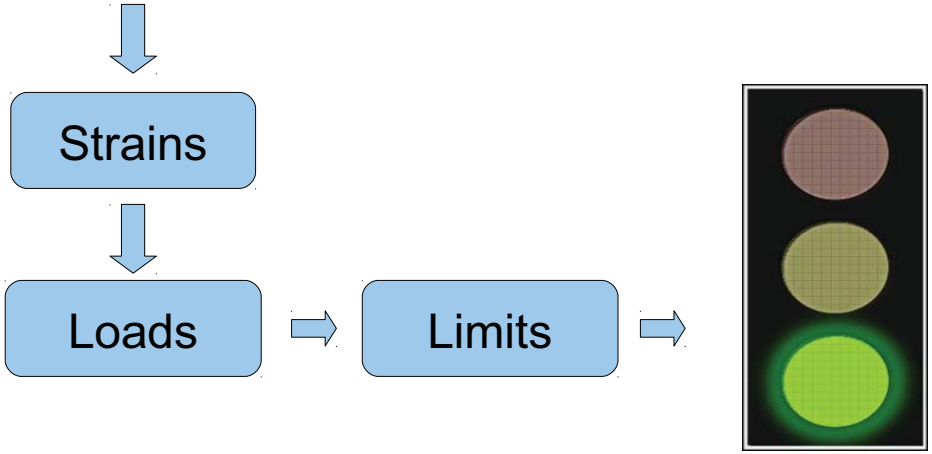
Realtime Load Measurements

Royal Norwegian Navy Skjold class

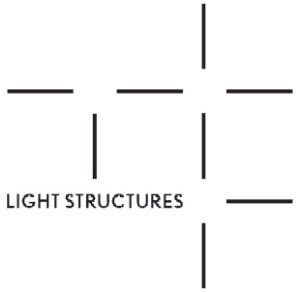
60 kn +, Norwegian North Sea Coast

Operational limits based on Loads (not seastate)

Optimal utilization of strength in any condition



Ice Load Monitoring project



Project partners:

StatoilHydro

Motivation for the ILM study

Commercial shipping in Arctic is rapidly increasing

New oil & gas projects

New shipping routes as the icecap recedes (alas!)

Evaluation of the ice conditions is mainly experience based, and even more difficult during nighttime transits

Satellite ice maps only show the ice cover, not type and thickness

Need for a SHM tool to assist the vessel operator, and uplink experience data to shore for routing forecasts

The «KV Svalbard»

Project Goals

Field test of a full scale ice load monitoring system

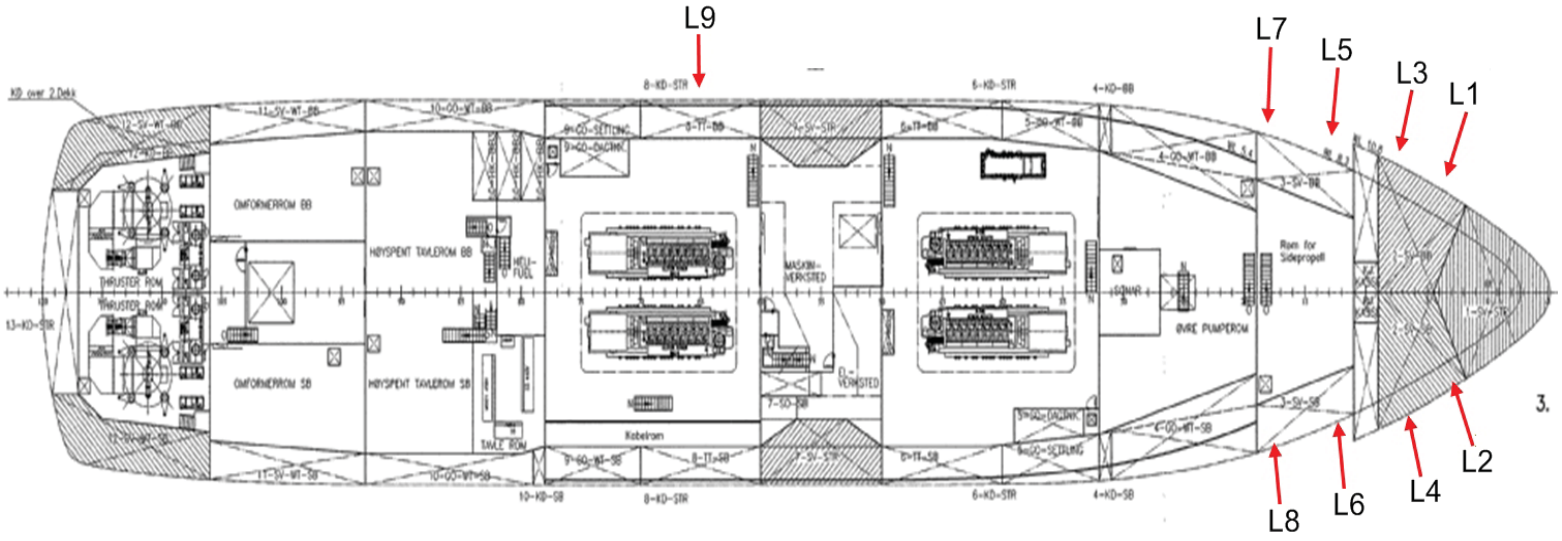
Permanent, autonomous system, real time analysis

Evaluate sensor configurations

Gain experience with data

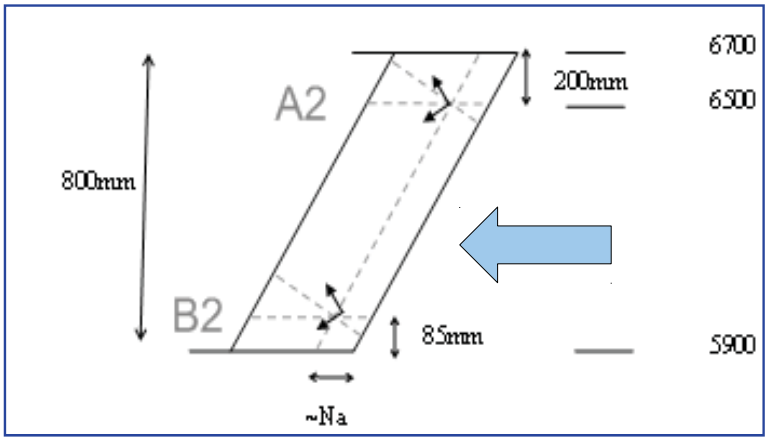
Test a method for local load evaluation and frame utilization

Ice load monitoring system



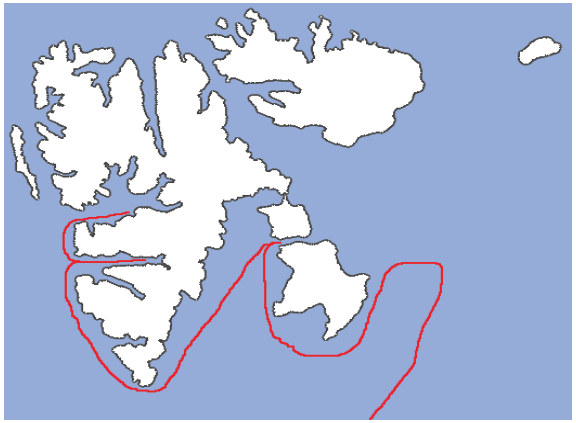
9 frames instrumented, mainly in the bow area

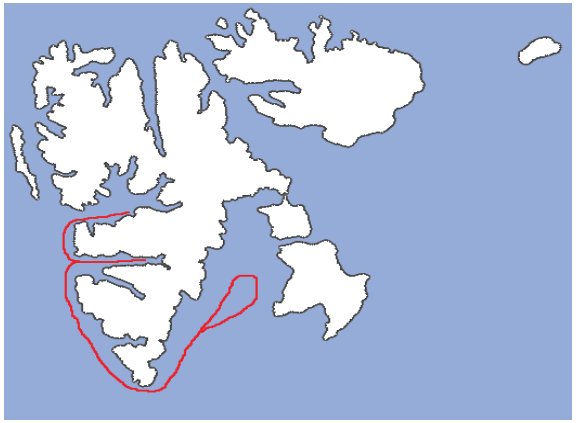
25 locations, 2 and 3 filament rosettes, 54 FBGs total



Hull pressure sensitive areas

Field test





Detailed analysis of two measurement voyages

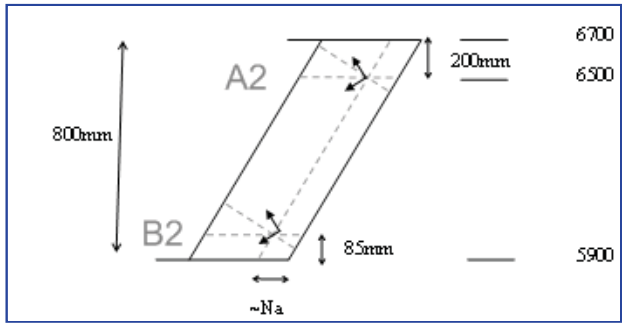
System operated satisfactorily throughout the project period in Arctic conditions

A large number of loads detected

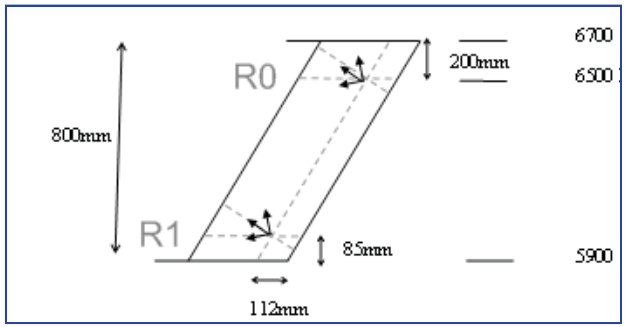
Load magnitudes and durations within expected range

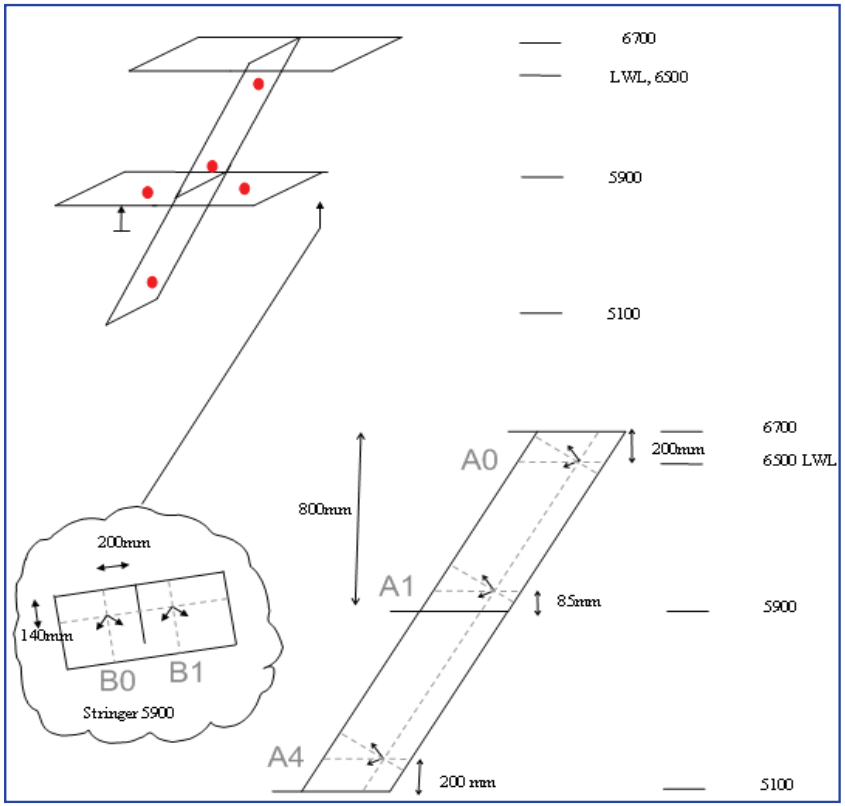
Loads follow statistical models reasonably well

Evaluation of sensor arrangement



Basic instrumentation

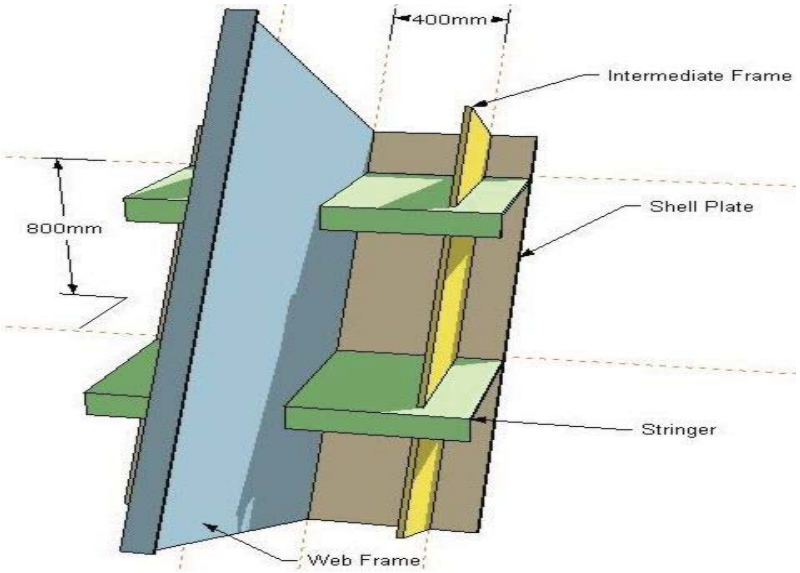


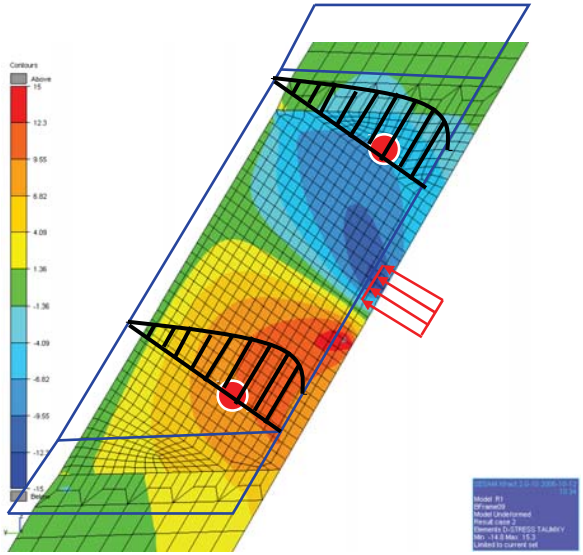


Comparison confirms: Basic instrumentation suffice for the ILM application

Allows a larger instrumented area / lower system cost

Load Models





Find load position and magnitude from sensor shear stress measurement

Several unknowns: Position of contact, number of contact points

Load models, ensemble average

$$F \propto \Delta\gamma$$

Average force acting on a frame is proportional to the shear stress difference measured by the 4 sensor filaments

Proportionality factor depends on an ensemble average of all likely load cases, as well as the material parameters and geometric details of the structure

Proportionality factors and structural capacity was found using non-linear finite element models

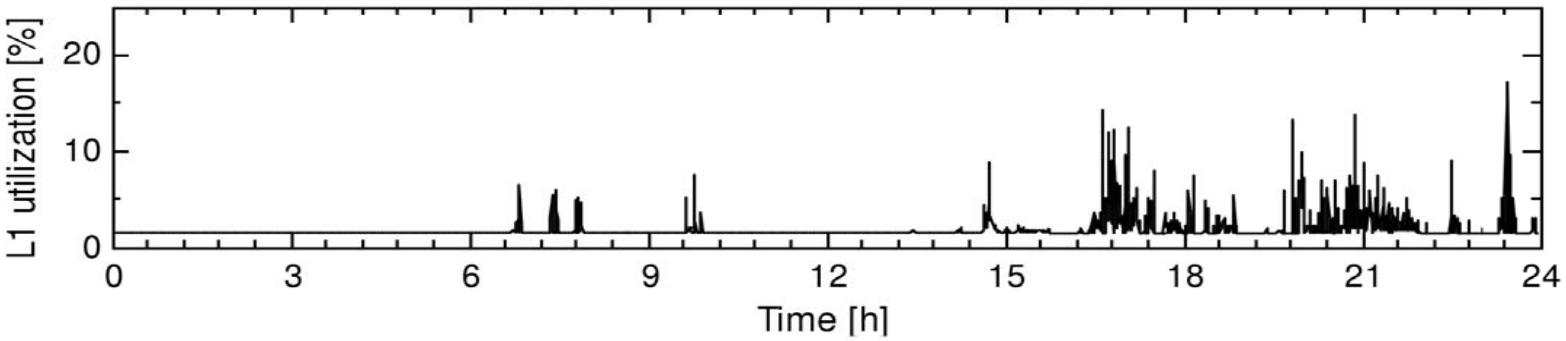
The true load in an individual load case may deviate significantly from the ensemble average

Structural utilization

Proportionality assumption allows calculating the structural utilization in percent of total capacity

Key parameter for vessel operator, easily understandable

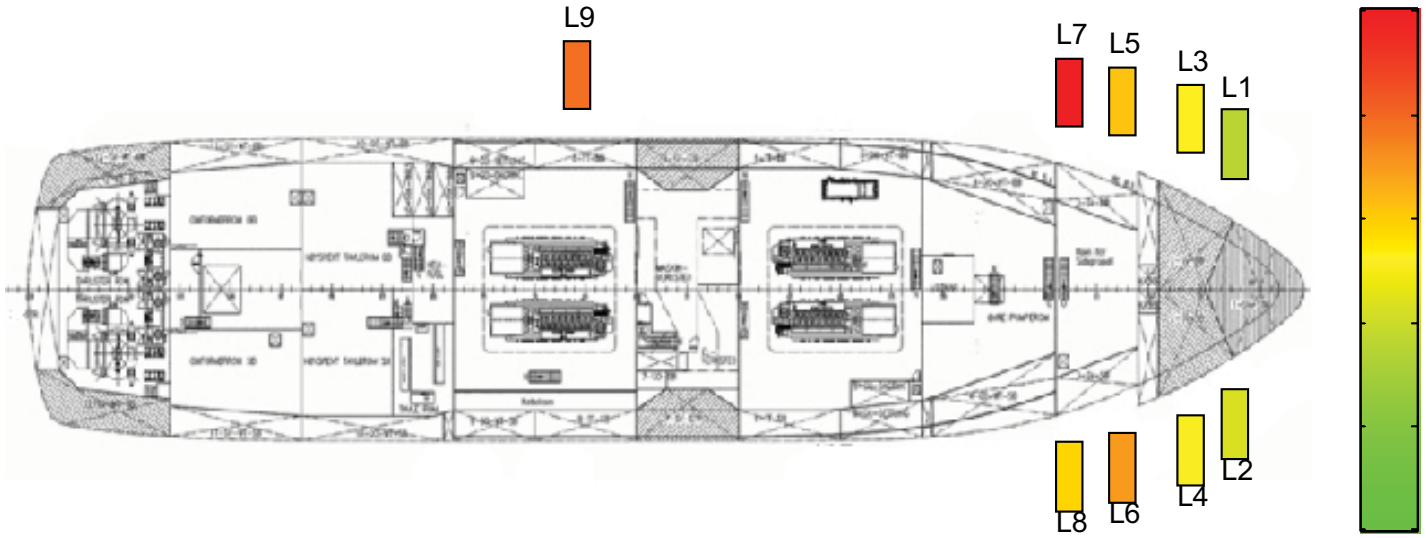
Results agree well with expectations; with regard to ice type and thickness, range of levels observed, and statistical distribution of the loads



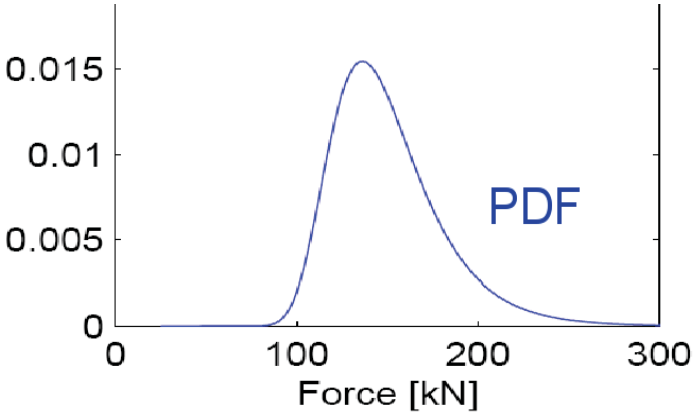
Distribution of Loads

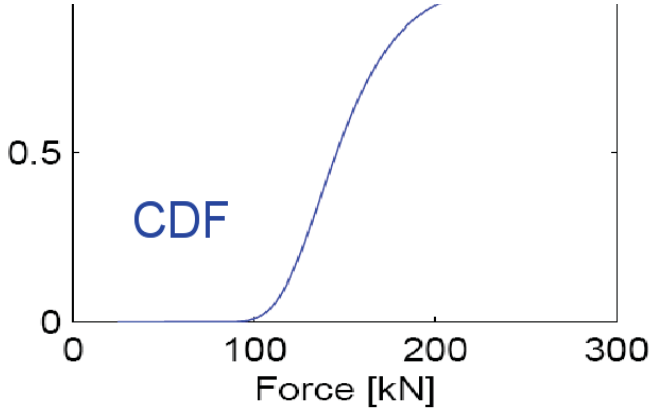
Maximum loads registered during the test voyages:

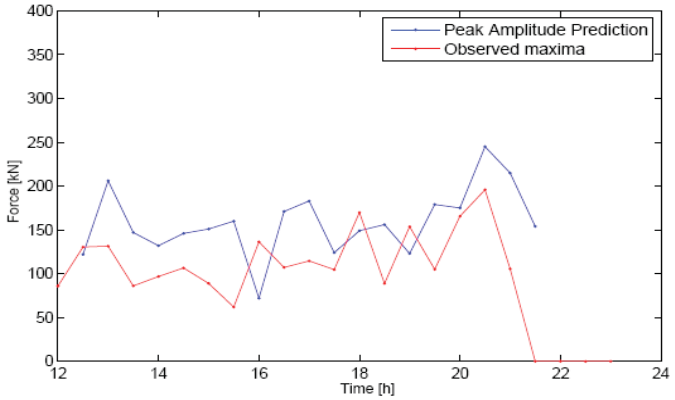
- **Higher loads close to shoulder area.**
- **Midship section sensitive for course changes.**
- **Comparable loads between port and starboard sides**



Load magnitude predictions

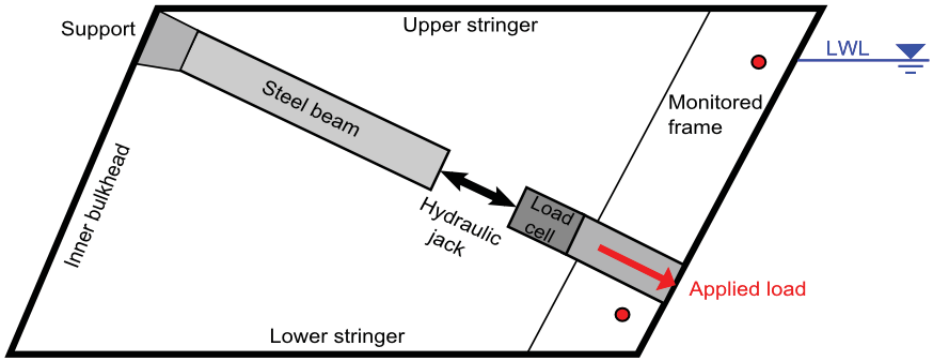






PDF/CDF from distribution of mangnitudes and inter-event times

Calibration and verification



Applied controlled static load at several positions of monitored frames

Measured response agree well with theoretical expectations

Summary

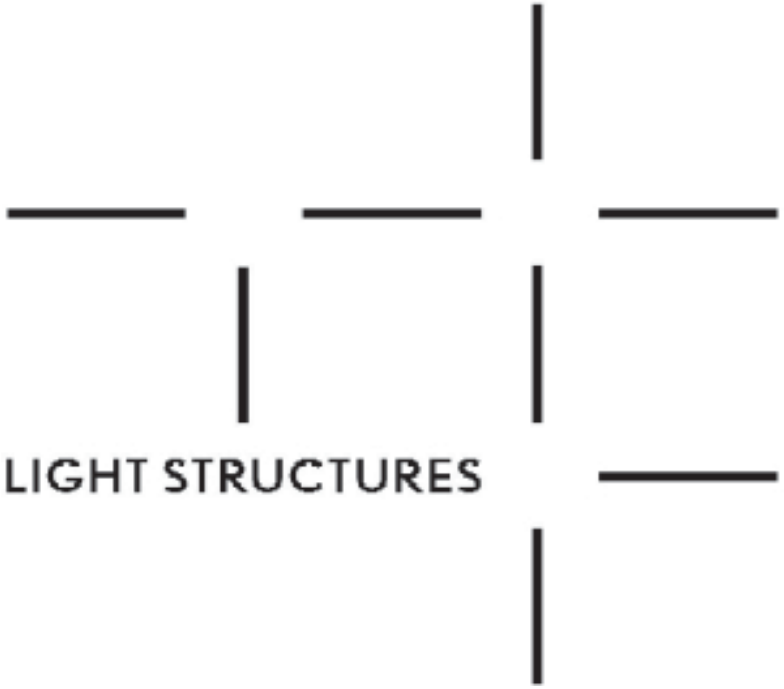
Structural monitoring systems have progressed far from the early hull girder overload alarm systems

Systems can be tailored to provide information on fatigue development, loads and deformations on the hull or on any detail of interest

Examples shown from ice load monitoring, one of many application examples in our portifolio

Potential of providing control parameters of interest to DP systems

Thank you



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