SHM strategies for fatigue assessment of infrastructure components

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What is Structural Health Monitoring (SHM)?

The process of determining and tracking the integrity of a structure, assessing the existence and nature of *damage* and estimating its remaining life (*by analysing data from sensors*) is referred as *Structural Health Monitoring* (Chang et al. 2003)

KEY ISSUES:

1) What is the expected life of a monitored asset?

2) Is the asset behaving as expected? Need for quantitative tools to assess and predict actual structural performance

3) Limitation of visual inspection

4) Increased "know-how" for later use

5) Long-span bridges incorporate advanced SHM systems and increasing use in Offshore Wind Turbine industry

6) Detection of extreme events, Reduced closure time at maintaince or idling time for wind turbines

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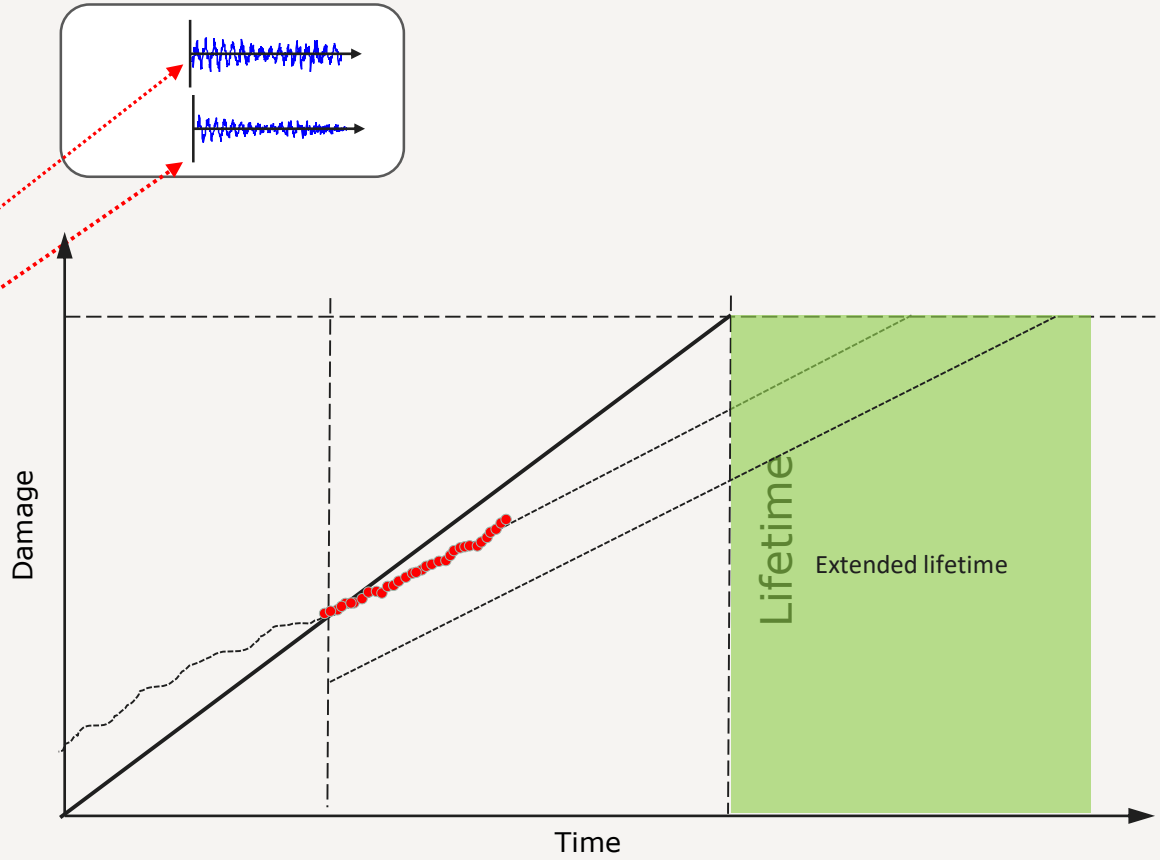
Fatigue Monitoring

Physical structure



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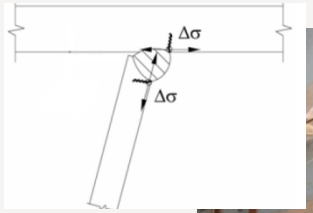
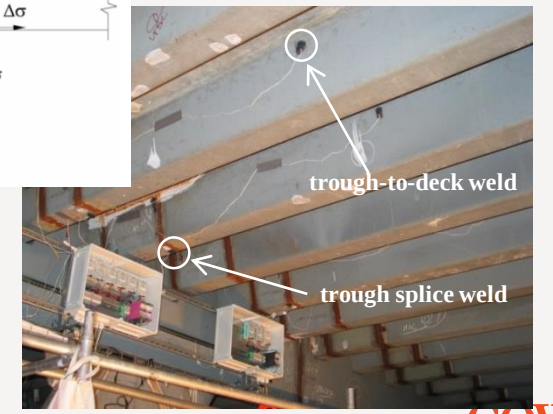
Application in long-span bridges: SHM of welded joints at Great Belt Bridge

The Great Belt Bridge:

- Inaugurated in 1998 in Denmark
- 1624m main span
- Orthotropic steel deck





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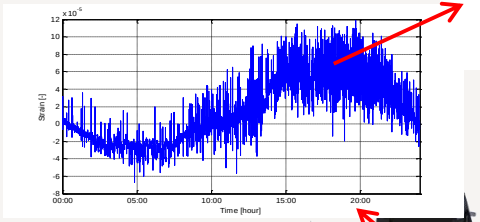
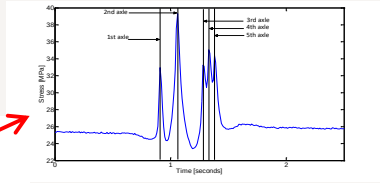
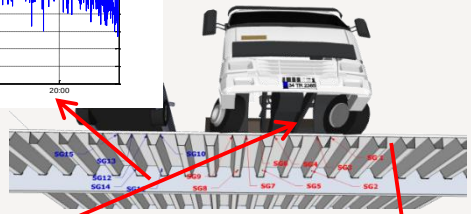
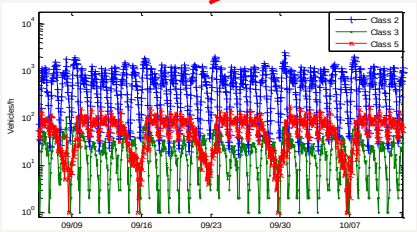
Data driven fatigue model for steel bridge



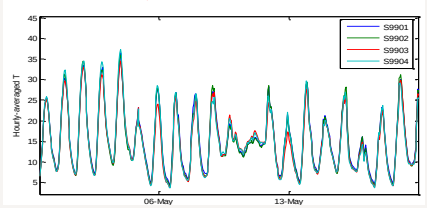
Strains





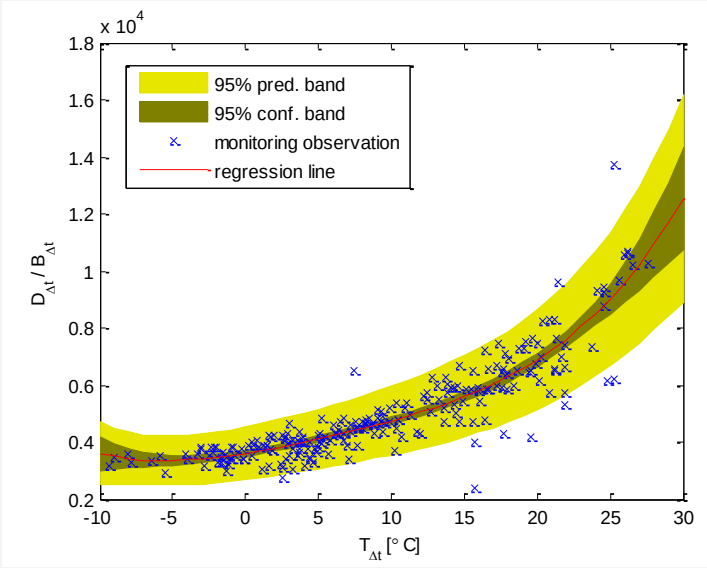


Vehicle classification



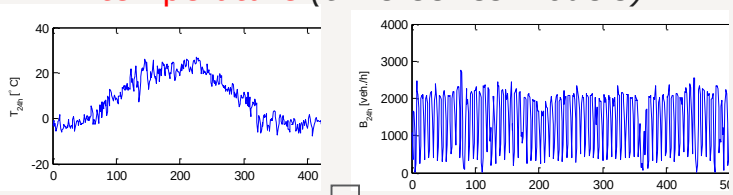
Pavement temperatures

Regression model for fatigue damage prediction as a function of environmental and operational loads

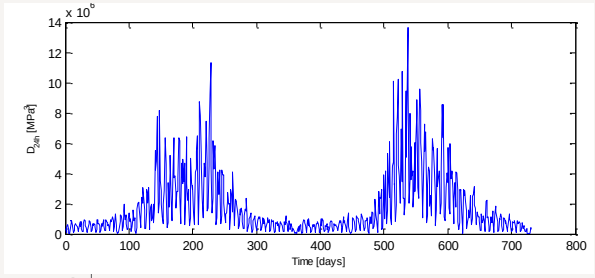


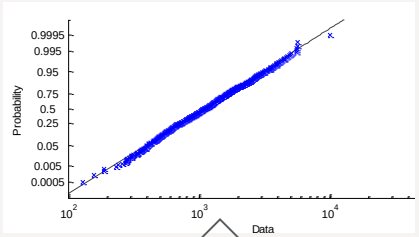
Application 1: Fatigue life prediction

Simulation of actions, i.e. traffic and temperature *(time-series models)*

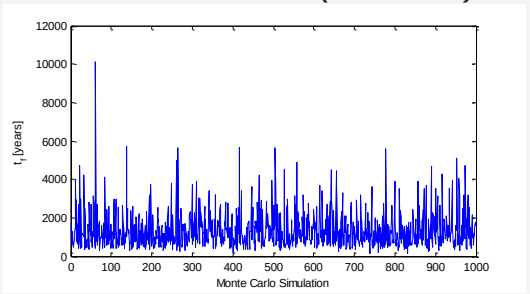


Simulation of fatigue loading *(regression models)*

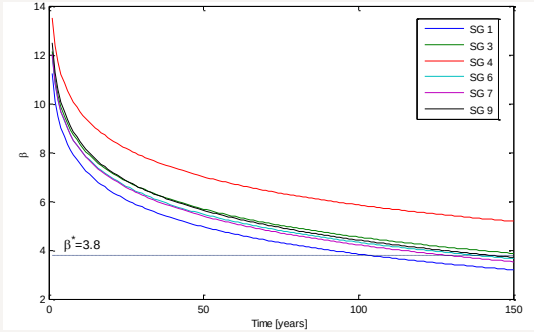


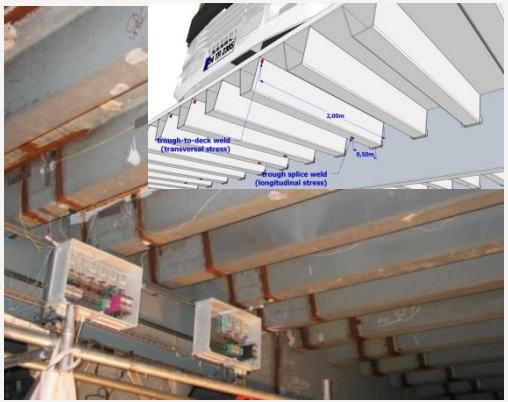


Monte Carlo simulation: time to failure realizations *(S-N LSF)*



Fatigue life calculation *(reliability profile)*



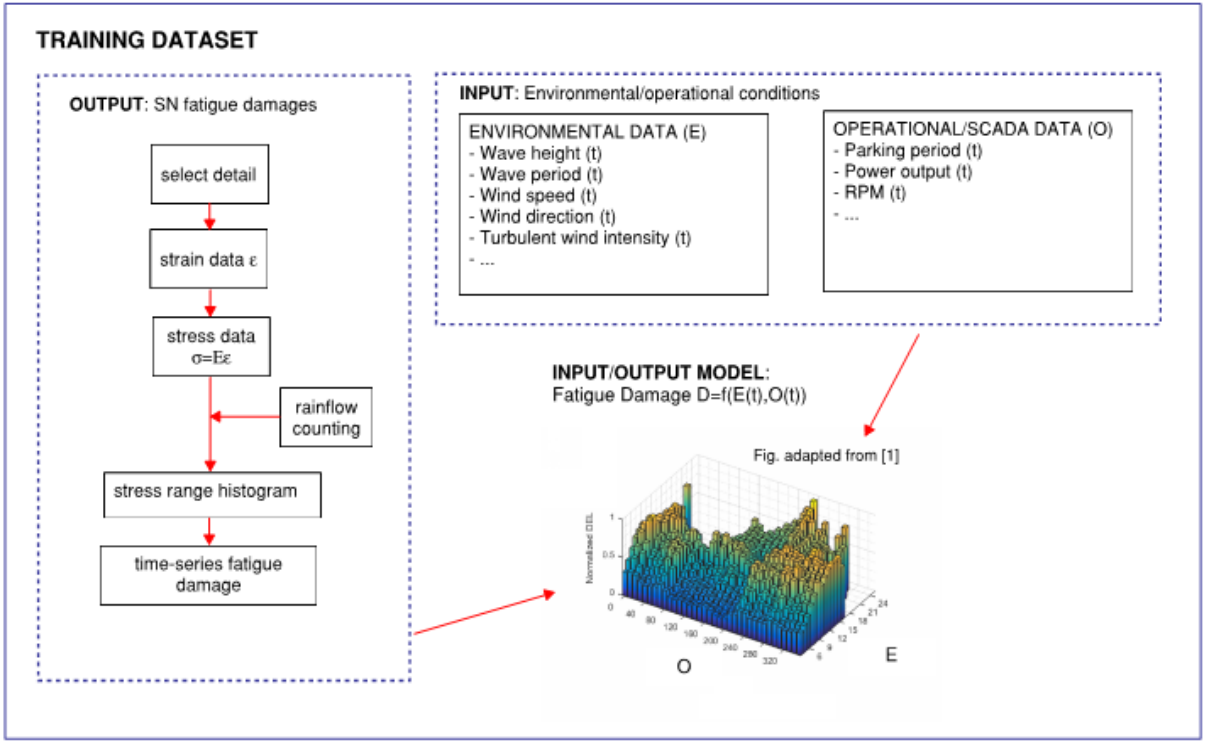


Data driven fatigue model for off shore wind farm

- Environmental and operational conditions have a big impact on measured S-N fatigue consumptions.
- Operational conditions can be characterized with SCADA data.
- Environmental conditions can be characterized with SCADA and weather station data.
- Wind speed impacts the magnitude of bending moments and hence of fatigue consumptions.
- Operational conditions impact fatigue consumptions. For instance, parking conditions lead to higher stress ranges, probably due to the fact that damping for parked conditions is lower than for operating conditions.
- Low-frequent variations in thrust during operation lead to a low number of high stress ranges.
- Air turbulence has a very significant effect on measured stress ranges, and hence fatigue life consumptions. This has important implications. For instance, wind turbines located in the middle of wind farms are always subject to turbulent air, this not being the case for OWT located at the edges of a wind farm.

Data driven fatigue model for off shore wind farm

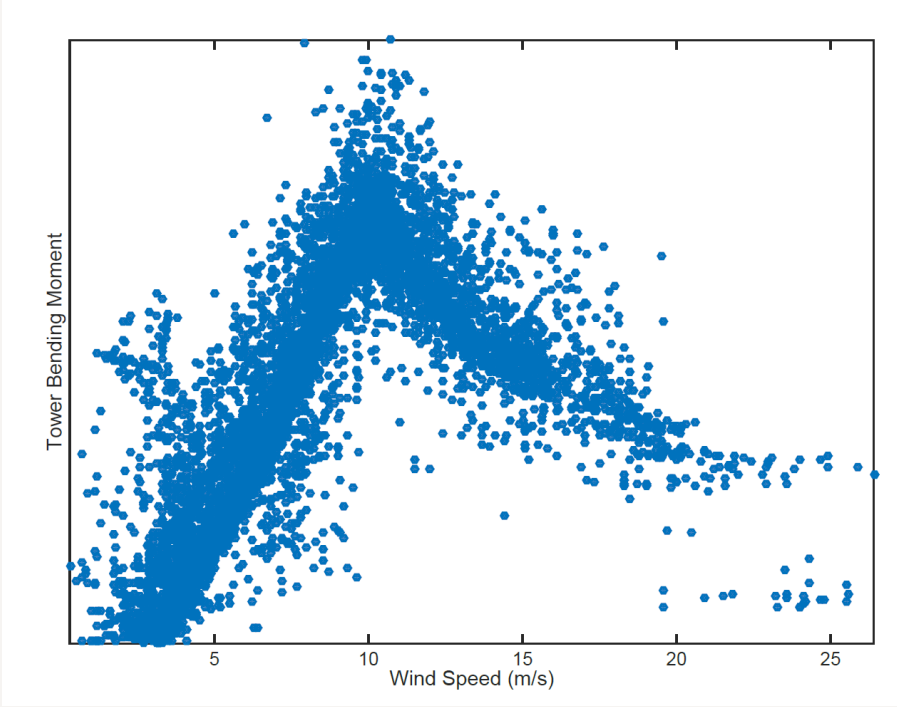
- It consists of developing a fully data-driven model D for predicting S-N fatigue damages by linking measured fatigue damages at pre-defined locations with measured environmental (E) and operational (O) conditions. The model relies on a sufficiently large training dataset encompassing enough variability in both E and O



Fatigue Life Consumption of WT on Monopile Foundation

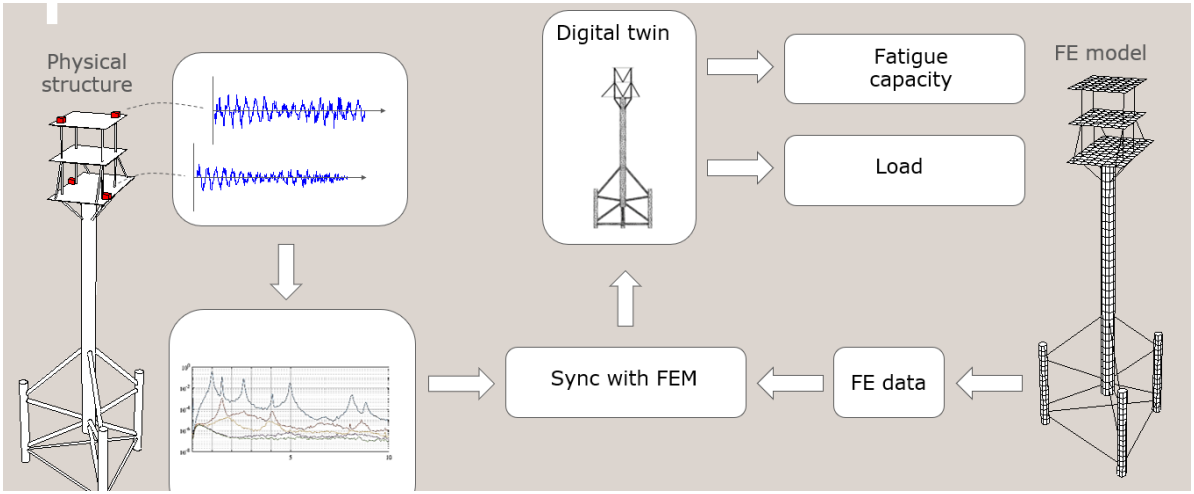
Results: environmental effects on measured sollicitations

- Effect of wind speed on tower bending moment



Fatigue Monitoring by use of digital twin

- Measured accelerations can be expressed as a function of a FE-based mode shape matrix at monitored locations and a vector of model coordinates
- Hereby defining the acceleration / strain relationship



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Fatigue Monitoring by use of digital twin

- It is noted that mode shapes are obtained numerically via a calibrated FE model and that the number of monitored locations should be higher than the number of participating mode shapes.
- The main advantage of this approach is that unmonitored locations can be assessed thereby reducing installation costs. Moreover, for calculating fatigue damages it is not necessary to determine the causes leading to acceleration time-histories.
- The disadvantages/challenges are that the accuracy of the results depends on the calibrated FE model, 1 or 2 acceleration channels might be insufficient for the approach, Another advantage is that you could reply only on accelerometers, hereby avoiding strain gauges and all the difficulties in getting these installed, calibrated, maintained etc. Accelerometers also have a much longer life time.

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Thank you for your attention

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