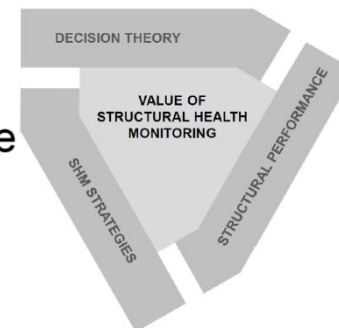# Subspace-based detection of fatigue damage on a steel frame laboratory structure for offshore applications

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COST Action TU1402: Quantifying the Value of Structural Health Monitoring

Vibration based damage diagnosis methods - verification and validation

Statistical damage detection theory

$$\mathcal{H}_{p+1,q}^{(0)} \overset{def}{=} \begin{bmatrix} R_1 & R_2 & \cdots & R_q \\ R_2 & R_3 & \cdots & R_{q+1} \\ \vdots & \vdots & \ddots & \vdots \\ R_{p+1} & R_{p+2} & \cdots & R_{p+q} \end{bmatrix}$$

$$\zeta_N = \sqrt{N}\, \mathrm{vec}\left(S^T \mathcal{H}^{(new)}\right)$$

$$\chi^2 = \zeta_N^T\, \Sigma^{-1}\, \zeta_N$$

$$\mathcal{H}^{(0)} = \begin{pmatrix} U_1 & U_0 \end{pmatrix} \begin{pmatrix} \Delta_1 & 0 \\ 0 & \Delta_0 \end{pmatrix} V^T$$

$$\mathcal{S}^T \mathcal{H}^{(0)} = 0$$

$$\Sigma = E\left[\zeta_N\, \zeta_N^T\right]$$

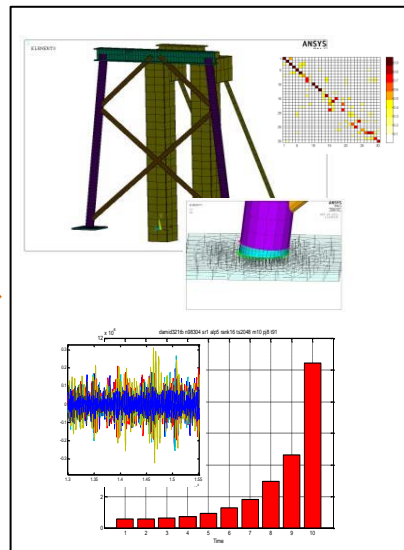**Robust and reliable performance monitoring**

Experimental analysis:

Numerical test verification:

Numerical simulation OWT:

Sensor-Setup

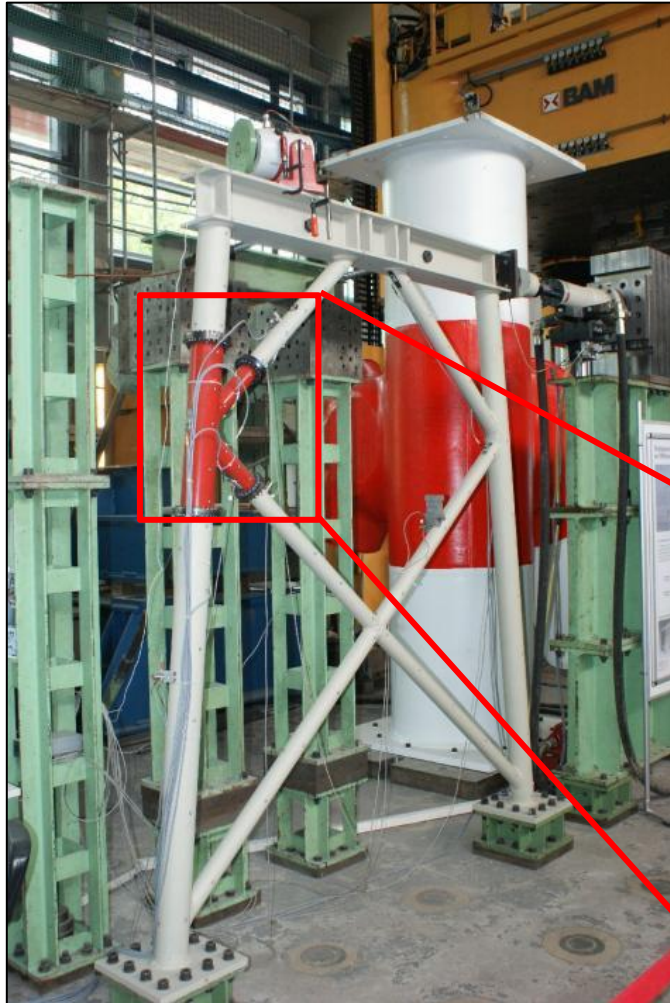**To consider beside others:**

- Dynamic properties
- Realistic Loading
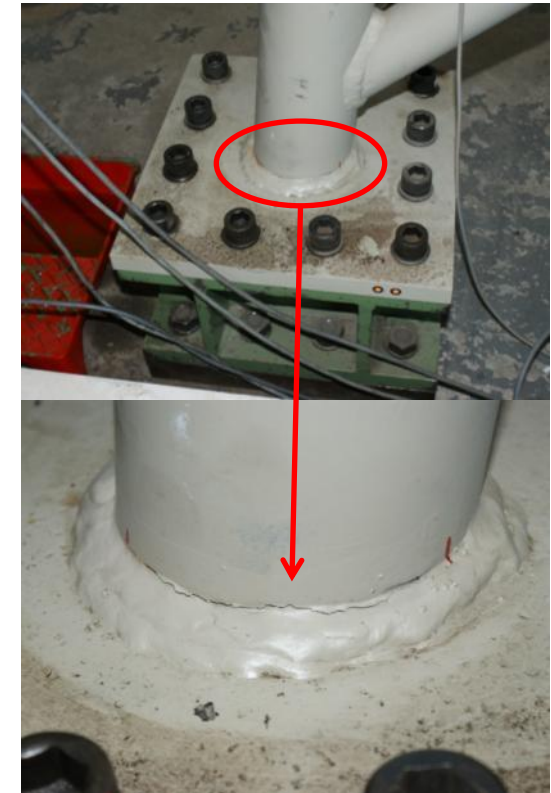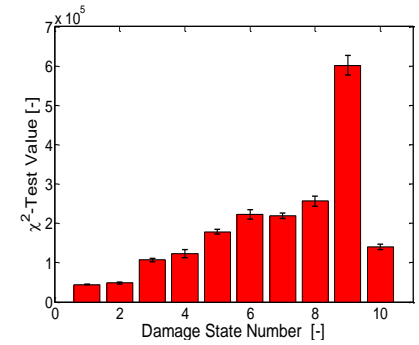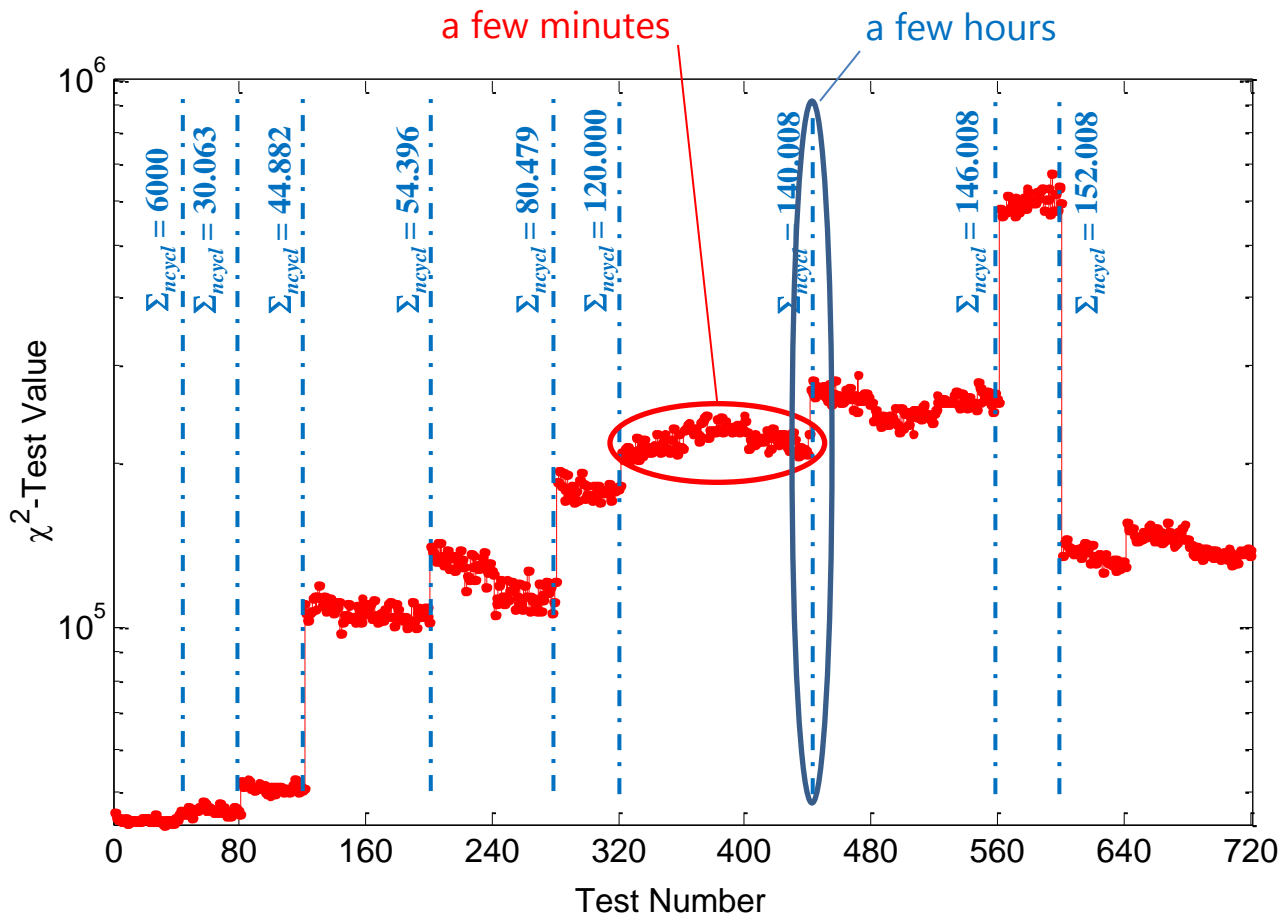- Environmental nuisance
- Operational influences

Laboratory test structure

- jacket-like steel frame
- defined artificial damaging
- different excitations
- acceleration sensor net
- cyclic loading unit
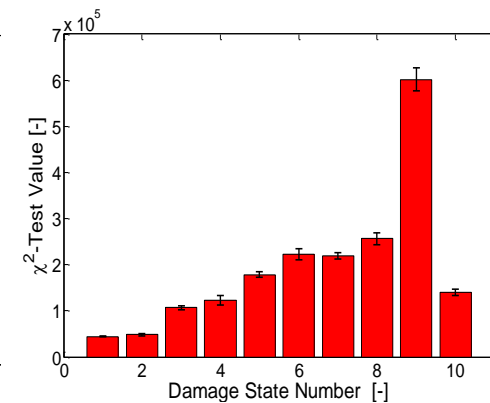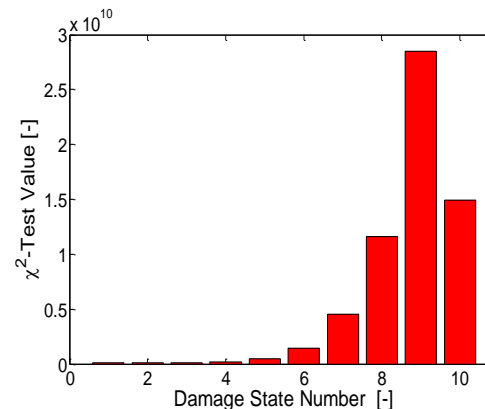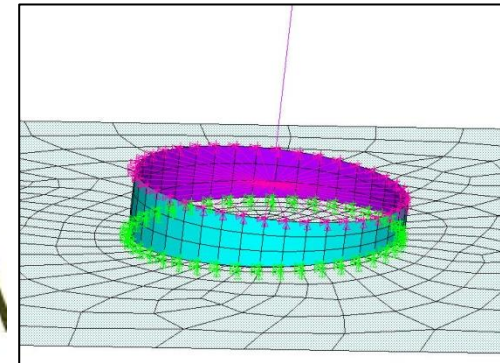
Laboratory fatigue test
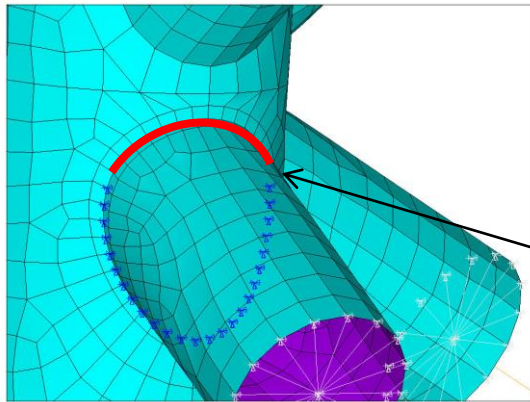
Fatigue test – numerical simulation

To which extend the numerical simulation is able to reproduce the effects of the real fatigue test.

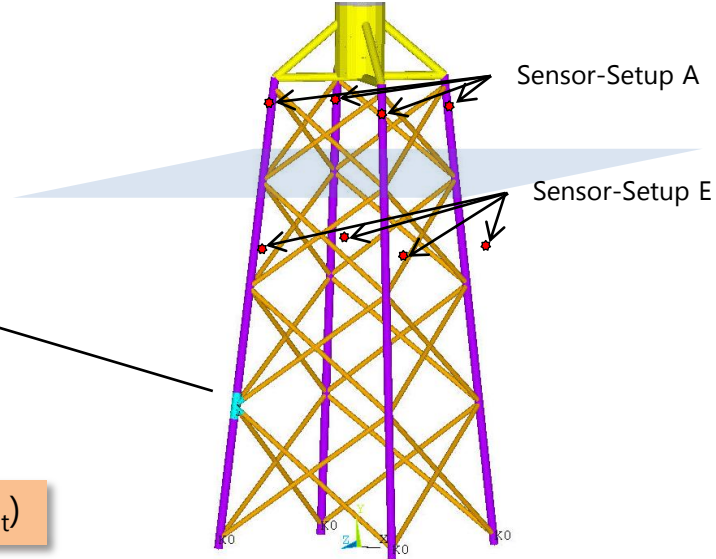## Modelling and transient analysis:

- beam and shell elements
- damage by deleting couplings
- validation by exp. modal analysis
- stochastic input
- 98.000 load steps each response
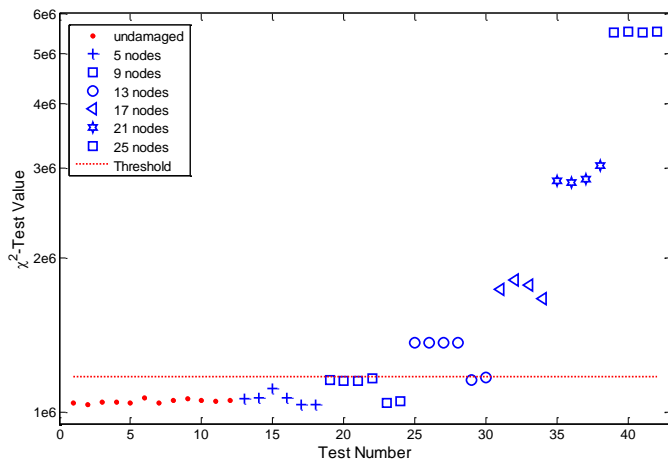- 50 responses
- SSDD on each response

Numerical analysis of fatigue damage on OWT-Jacket

Sensor-Setup A

Sensor-Setup E

13 nodes (a_r=606 mm; I_{dam}=78% I_{tot})

Increasing damage – setup A

Legend:
- undamaged
- 5 nodes
- 9 nodes
- 13 nodes
- 17 nodes
- 21 nodes
- 25 nodes
- Threshold

y-axis: χ^2-Test Value
x-axis: Test Number

Increasing turbulence intensity – setup E

Legend:
- undamaged
- t_i=3
- t_i=4
- t_i=5
- t_i=6
- t_i=7
- t_i=10
- t_i=13
- Threshold

y-axis: χ^2-Testwert
x-axis: Test Number