NewSkin: Test bed for corrosion and mechanical performance of large sized bolted connections

Value Propositions: On bolts for Wind Energy and Structural Engineering

Peter Schaumann, Leibniz University Hannover (LUH)
Jan Kulikowski, Leibniz University Hannover (LUH)

Leibniz Universität Hannover

Institute for Steel Construction
Prof. Dr.-Ing. Peter Schaumann

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Leibniz Universität Hannover

ForWind Center for Wind Energy Research Bremen Hannover Oldenburg

Leibniz University Hannover
Institut for Steel Construction
www.stahlbau.uni-hannover.de
schaumann@stahl.uni-hannover.de

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Research focuses

Load-bearing behaviour and stability

Durability

Support Structures for Wind Turbines

Structural fire safety in buildings

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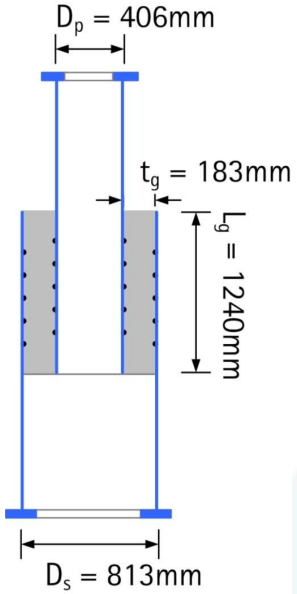
Large-scale Fatigue Tests

Experimental Fatigue Tests on Axially Loaded Grouted Joints

- 10 MN INSTRON *(coop. Institute of Building Materials Science)*
- Loading (Example):
  - f = 1 Hz
  - R = 1 up to 3 MN
  - R = ∞ up to -8 MN
- Large-scale Tests (1:2, 1:4)
- Ambient conditions: wet and dry
- Fully submerged grout section



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Experimental Fatigue Tests on Bolts

Fatigue Assessment of High-Strength Bolts with Very Large Diameters

- 10 MN INSTRON *(coop. Institute of Building Materials Science)*
- Adapters for bolts up to M72 (10.9)
- Testing frequency: 2-4 Hz
- Nominal preload: $F_{p,C}^*$ $= 0.7 \cdot R_{p0,2}$ $= 2180$ kN

- Resonance Pulsator 1 MN *(coop. Test Center for Wind Energy Support Structures)*
- Bolts up to M48 (10.9)
- Testing frequency: ~50 Hz
- Nominal preload: $F_{p,C}^*$ $= 0.7 \cdot R_{p0,2}$ $= 930$ kN

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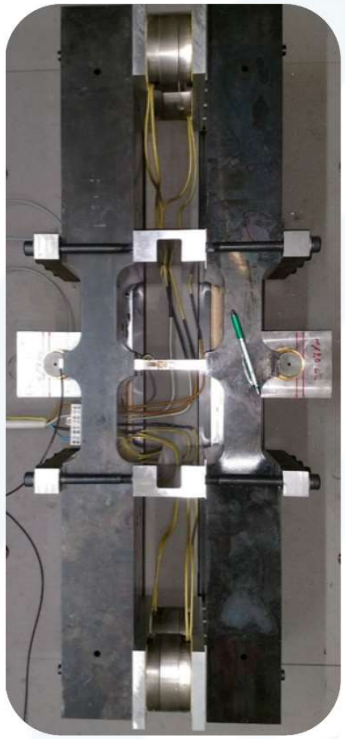
Experimental Fatigue Tests on Welded Joints

Servo-hydraulic Testing Machine

- Plates up to 40 mm
- Cylinders Ø 15 mm to 47 mm
- Testing frequency: up to 10 Hz
- $F_{max,dyn}$ = 500 kN

High Frequency Testing Device

- Nominal cross section test specimens:
  - Plates up to 20 mm x 30 mm
- Testing frequency: ~200 Hz
- σ_a = 280 MPa, σ_o = 560 MPa, $0.1 \leq R \leq 0.5$



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Servo-hydraulic Testing Actuators

Servo-hydraulic System I

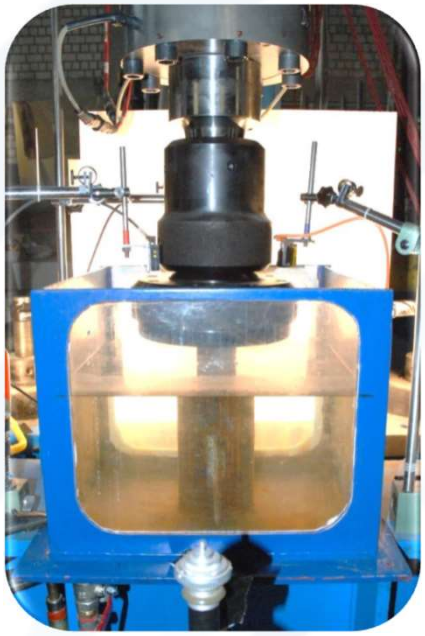
- Plates: 22 mm to 65 mm
- Testing frequency: up to 10 Hz
- $F_{max,dyn}$ = 900 kN

Servo-hydraulic System II

- Compression tests
- Testing frequency: up to 10 Hz
- $F_{max,dyn}$ = 350 kN

Source: Project GROW

Source: Project OPTIWELD



Source: Project GROWup
IWEC 2013, Schaumann

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Further measuring equipment

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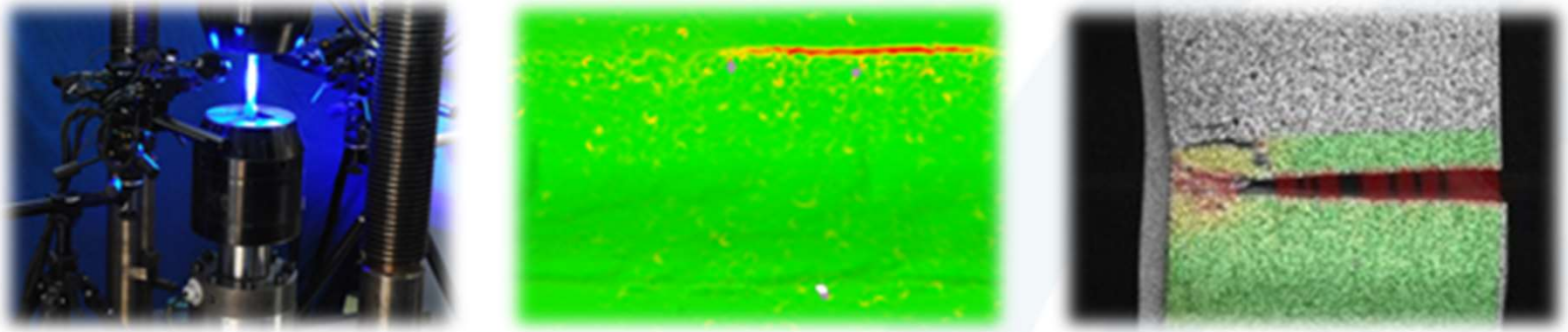
- Roughness measuring device
- Surface measurement by laser
- KEYENCE digital microscope
- ARAMIS 3D surface monitoring system
- ARAMIS 3D DIC System
- …

University internal

- Micrographs
- Material testing (destructive / non-destructive)
- X-ray nanography
- KEYENCE 3D profilometer
- ...



Monitoring of progressive fatigue damage with ARAMIS 3D DIC

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Test Center for Support Structures (joint facility)

Resonance testing machine

- Axial force: +/- 1 MN
- Frequency: 50 – 80 Hz

Climate chamber

- 4.2 x 2.8 m (L x W
- Salt spray test according to ISO 9227

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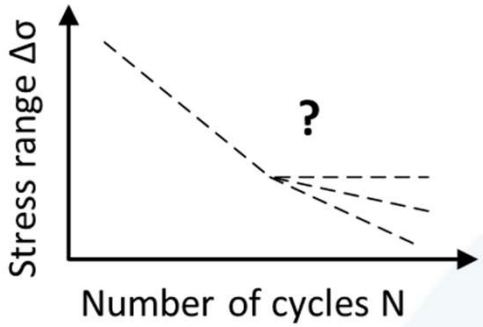
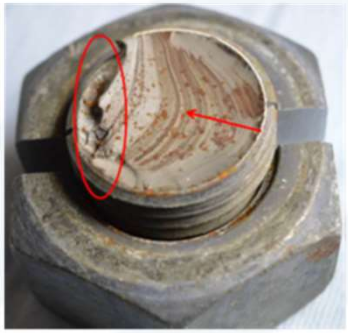
Description

- Systematic investigation of the interaction of influences

  of:
  - Nano-coatings
  - Pretension of the bolts
  - Corrosion of the bolts

  on:
  - Service Life / Fatigue





- Identification of influences on service life under extreme environmental conditions
- High frequency accelerated fatigue tests
- Development of standards and design of coatings/materials system for bolted joints

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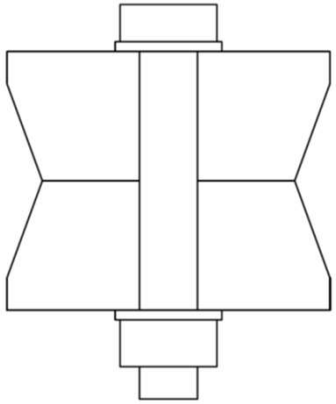
Climatic chamber:

- Salt spray test according to ISO 9227
  - With and without preload (up to M36)
  - Without preload (up to M72)
  - Preloading under corrosion with monitoring system

Preload Construction



Climate chamber

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Fatigue test

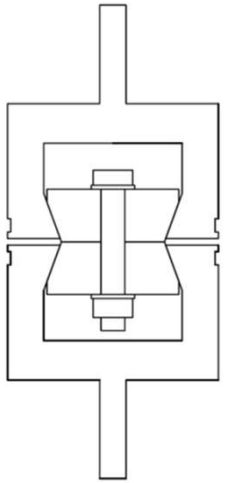
- Up to M72
  - Under corrosion
  - Monitoring system

- Up to M36
  - With and without preload under corrosion
  - Preloading monitoring system
  - High frequent

Up to M72

Photo: Matthias Döring

Up to M36



Test Adaption for pretension construction

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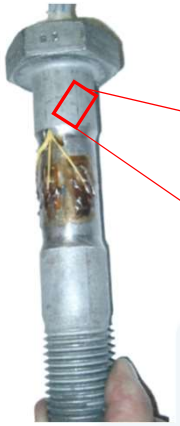
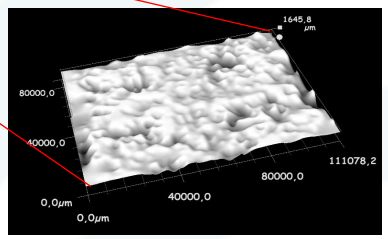
Monitoring system

- Stresses, strains and corrosion monitoring
  - Climate chamber
  - Fatigue tests
- Categorization and evaluation of corroded surfaces

Monitoring



Evaluation



Test Procedure

1. Surface scan, roughness measurement, coating thickness measurement
2. Climatic chamber: Salt spray test according to ISO 9227 with and without preload.
3. Fatigue tests incl. evaluation
4. Surface scan and roughness measurement, layer thickness measurement, fracture surface analysis

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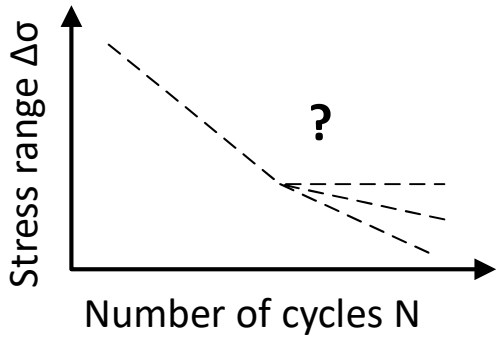
Objectives

- Determination of corrosion fatigue performance
- Evaluation of new corrosion protection systems
- Determination of optimal coatings

Approach

- Experimental simulation of long-term product lifetime with short-term test period
- Basic information for approval procedures
- Suitable for series testing



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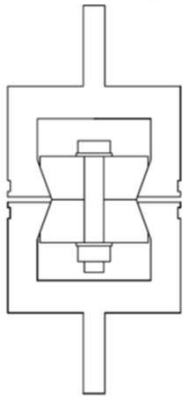
Tests to be performed in NewSkin

- Validation and benchmarking tests
  - M36
  - With and without preload under corrosion (Salt spray test)
  - Preloading monitoring system
  - Black and galvanised bolts

- Open for collaborations
  - Newly developed coatings for bolts
  - Cycling ageing or other corrosions tests methods

Photo: Matthias Döring



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- Influence of corrosive media on the fatigue strength of offshore wind energy support structures, AiF (2020-2023)
- Yield-controlled tightening of bolted connections M12 to M72 for steel construction, AiF (2020-2022)
- Intelligent integrative systems for the monitoring of surface protection systems for offshore wind energy structures, BMWi (2019-2021)
- German Research Platform for Wind Energy (2016-2022)
- Collaborative research to increase the efficiency of wind turbines in the energy system, MWK (2015-2019)
- Experimental and numerical evaluation of the fatigue strength of bolts of large dimensions in steel construction under consideration of surface layer influences, AiF (2013 – 2015)
- Increasing the nominal pretensioning forces of axially stressed bolted connections in wind turbines by using DISC (2007-2008)
- Fatigue strength of high-strength bolts of large dimensions, AiF (2006-2008)
- Experimental determination of S/N curves of large bolts, DIBt (2006-2007)
- Measurement of achieved prestressing forces under real assembly conditions, DIBt (2002-2005)