technische universität dortmund

Faculty of Mechanical Engineering
Department of Materials Test Engineering (WPT)

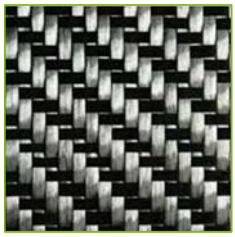
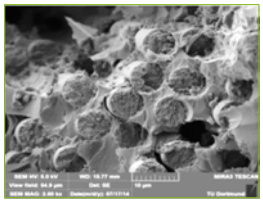
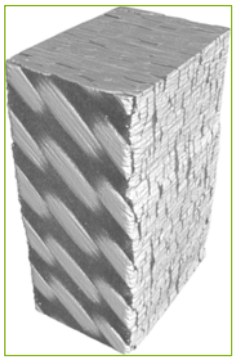
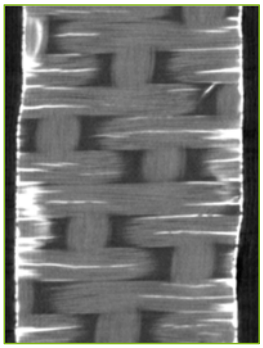
Prof. Dr.-Ing. Frank Walther

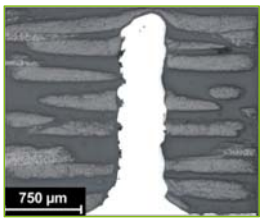
Charakterisierung und Bewertung des Verformungs- und Schädigungsverhaltens von faserverstärktem Polyurethan und Epoxidharz der Luftfahrtindustrie

D. Huelsbusch, F. Walther
Department of Materials Test Engineering (WPT), TU Dortmund University

Outline

1. Introduction
2. Experimental setup
3. Load increase method
4. Results
   - 4.1 Carbon fiber-reinforced polymers
   - 4.2 Glass fiber-reinforced polymers
   - 4.3 Strain rate adjusted testing
5. Conclusions

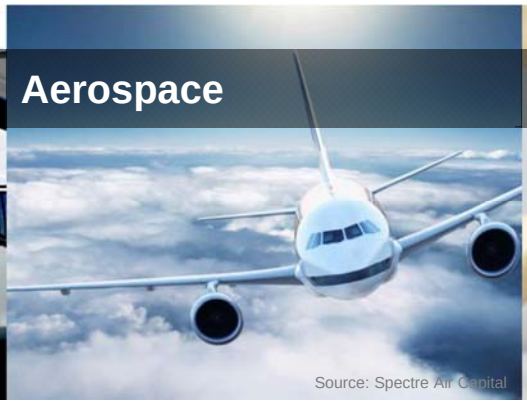


WPT Staff and Research Areas

Staff Members	1 Professor | 1 Secretary | 20 Scientific Assistants | 3 Technicians | 2 Apprentices 20 Student Assistants and Workers
Research Groups	Steels | Light Metals | Additive Manufacturing | Composites

Research Groups

Research Fields



- Casting
- Welding
- Brazing
- Screw Joints
- Recycling

- Lightweight Design
- Impact Resistance
- Graded Structures
- Cellular Structures
- Additive Manufacturing

- Functional Structures
- Degradable Structures
- Additive Manufacturing

Key Qualifications

Materials and Components Testing	Fatigue	Corrosion and Corrosion Prevention
Metallography	Low- and High-Cycle-Fatigue (LCF / HCF)	Electrochemical Corrosion Tests
Microscopy	Very-High-Cycle-Fatigue (VHCF)	Immersion Tests
DT and NDT	Thermo-Mechanical Fatigue (TMF)	Salt Spray Tests

Deformation-Induced Phase Transformations

Corrosion Fatigue

Calculation of Damage Propagation and (Remaining-) Fatigue Life

Structure-Property-Relations of Construction Materials

Influence of Manufacturing and Service Loading on Product Properties

Laboratories

Universal Testing

Servohydraulic Testing

Resonance Testing

Electromagnetic / Ultrasonic Testing

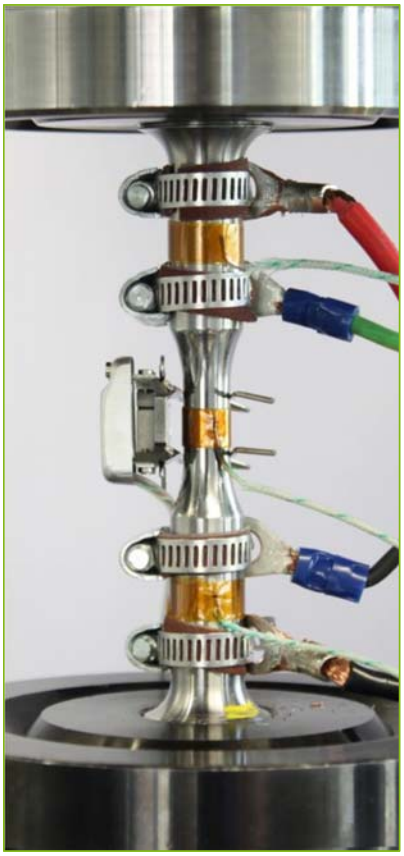
Corrosion Testing

Metallography

Light Microscopy / Hardness

SEM / CT

Measurement Techniques



mechanical

Extensometer

thermal

Thermocouples

Thermocamera

electrical

Direct current

Alternating current

magnetical

Barkhausen noise

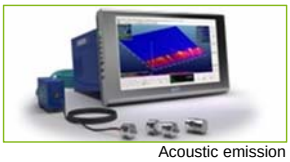
Feritscope

optical

Videoextensometer

Digital image correlation

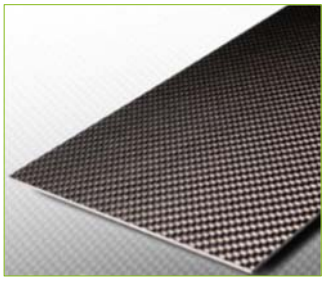
acoustical

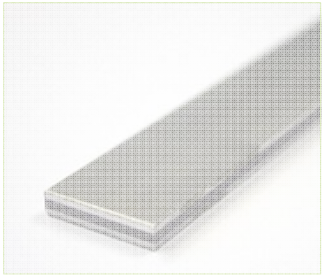


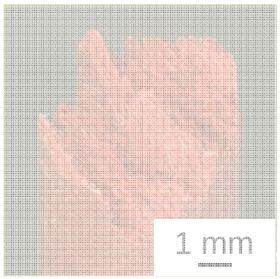
Acoustic emission

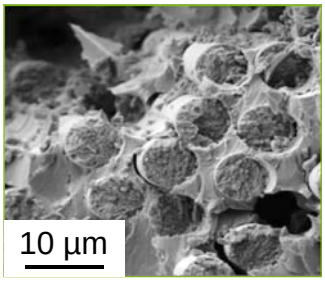
Composites

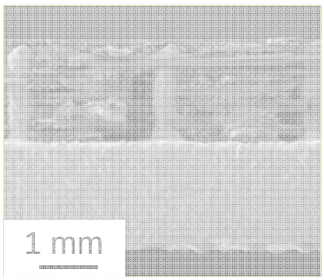
Fiber-reinforced polymers | **Hybrid structures** | **Renewable materials**

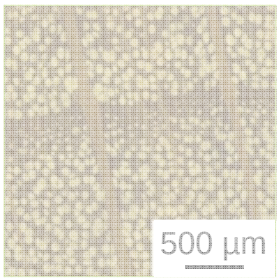






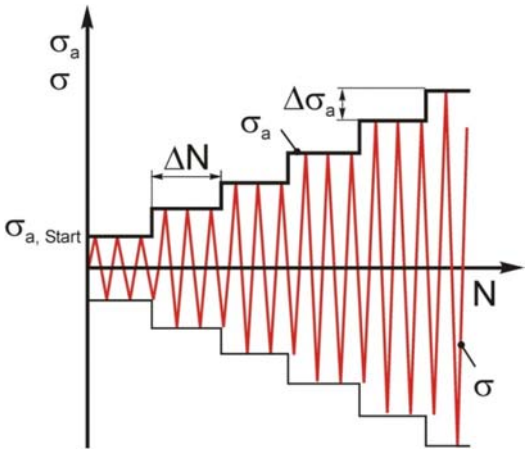


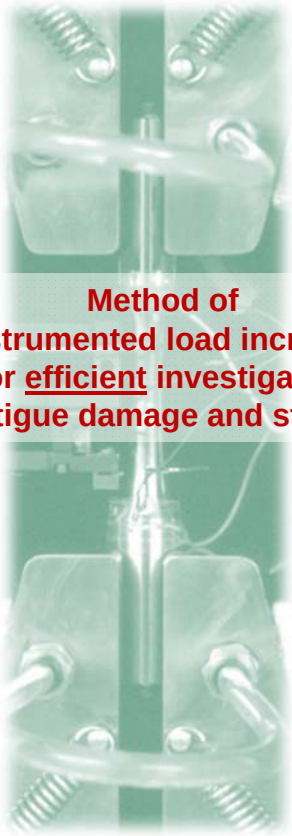




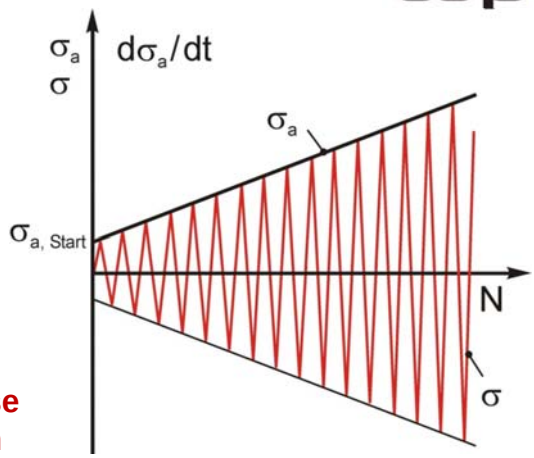
3. Load increase method

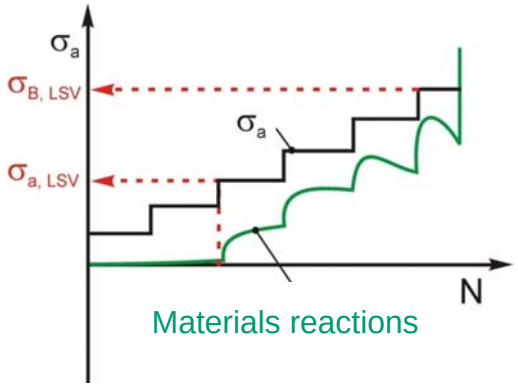
Schematic Procedure – Stepwise vs. Continuous Load Increase Method

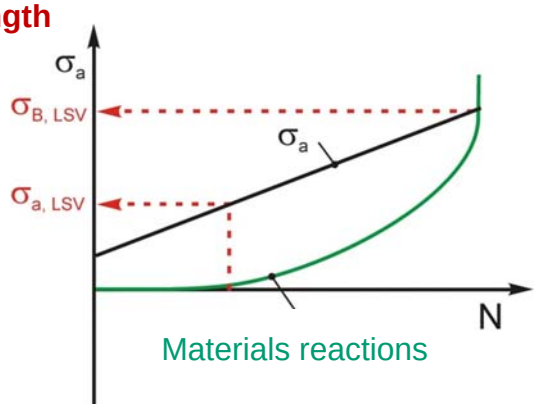




Method of instrumented load increase for <u>efficient</u> investigation of fatigue damage and strength



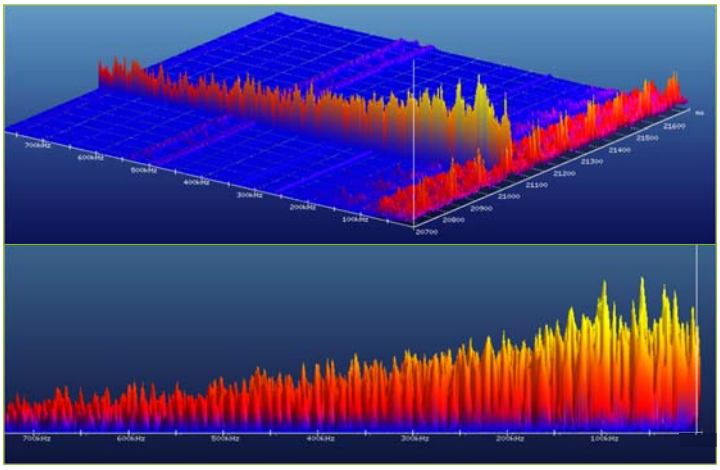


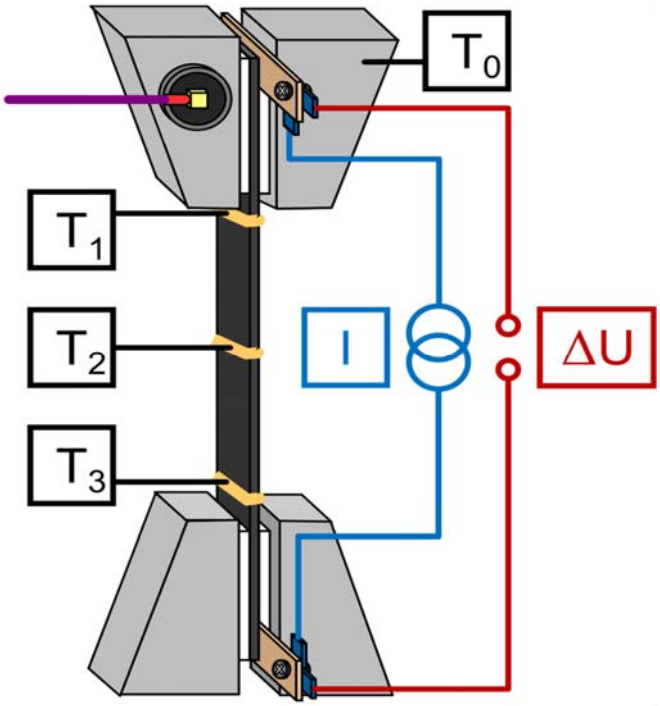


Walther, F.: Materials Testing 56, 7-8 (**2014**) 519-527.

Carbon Fiber-Reinforced Polymer – Fatigue Test Setup

- Acoustic emission analysis
- Signal acquisition rate 100 MHz
- Real-time process scenario

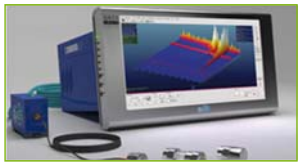


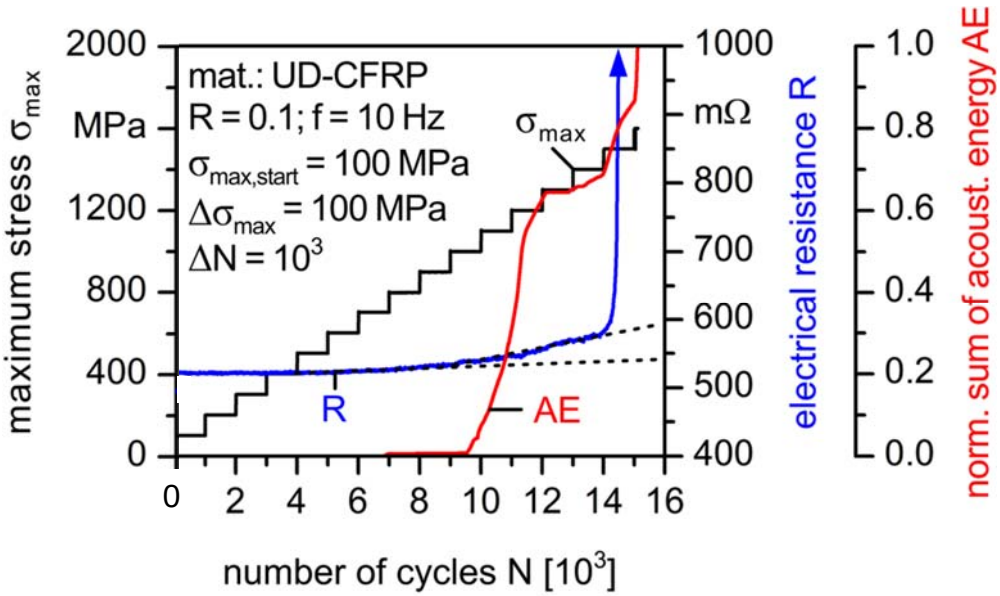


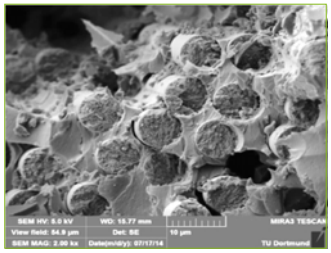
Structural-Health-Monitoring (SHM) …?

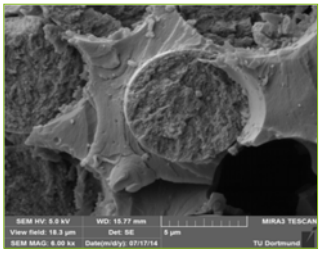
Huelsbusch, D.; Walther, F.: **The e-Journal of Nondestructive Testing 20** (**2015**) 1-9.

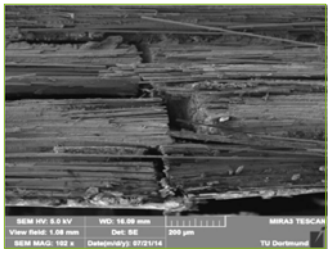
Carbon Fiber-Reinforced Polymer – Load increase method





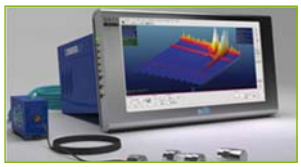


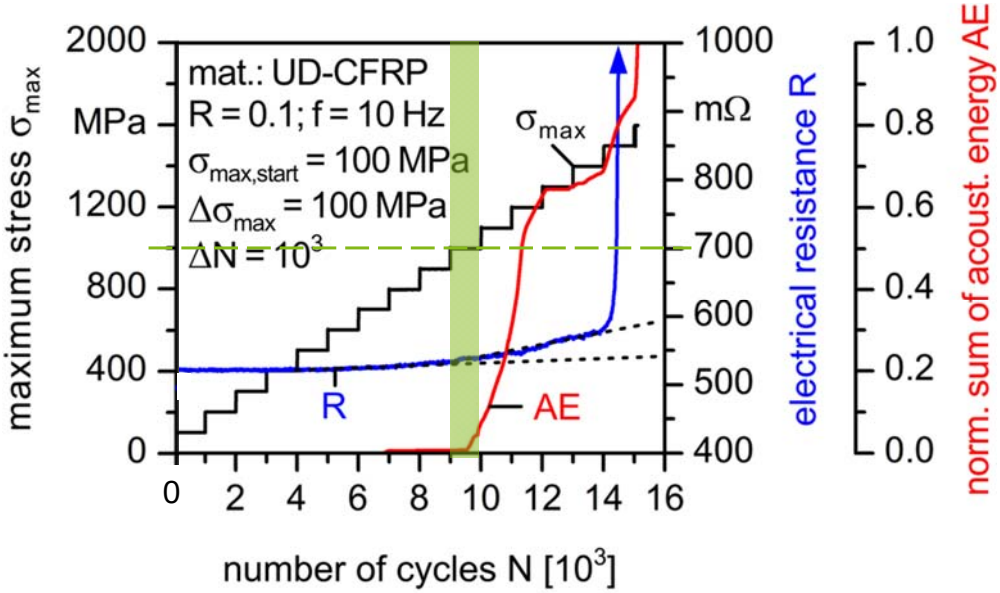


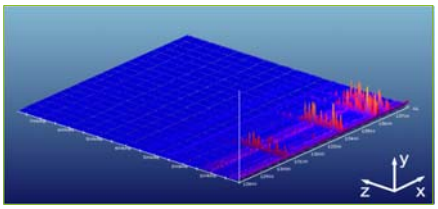


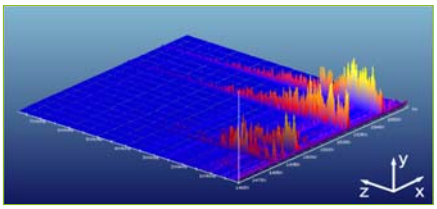
Huelsbusch, D.; Walther, F.: **The e-Journal of Nondestructive Testing 20** (**2015**) 1-9.

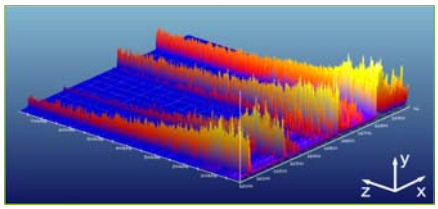
Carbon Fiber-Reinforced Polymer – Load increase method





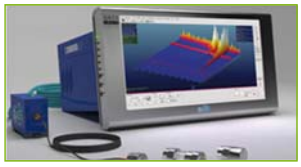


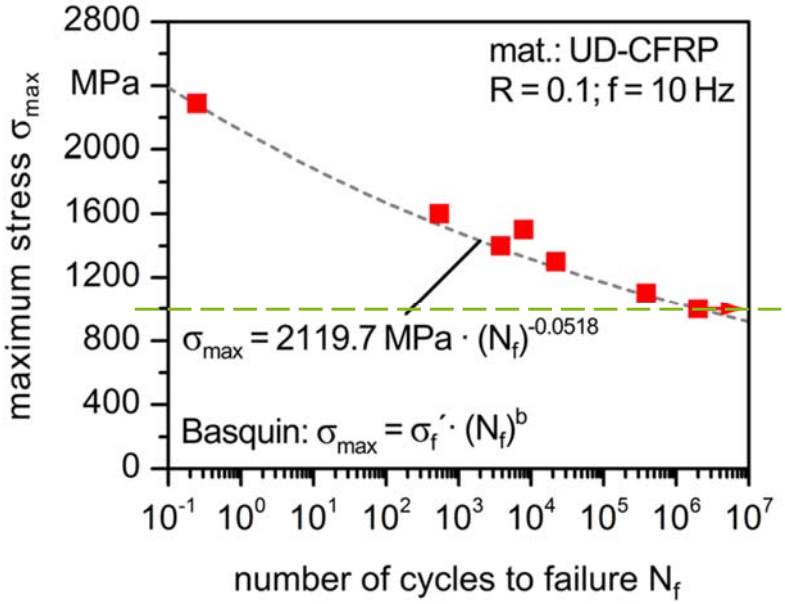


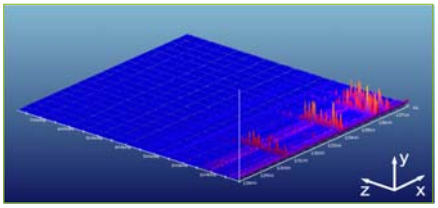


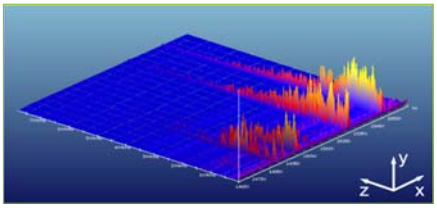
Huelsbusch, D.; Walther, F.: **The e-Journal of Nondestructive Testing 20** (**2015**) 1-9.

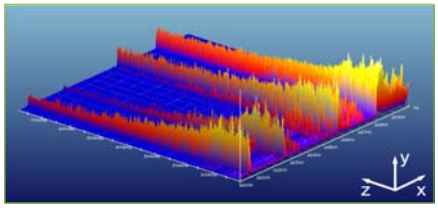
Carbon Fiber-Reinforced Polymer – Woehler Curve











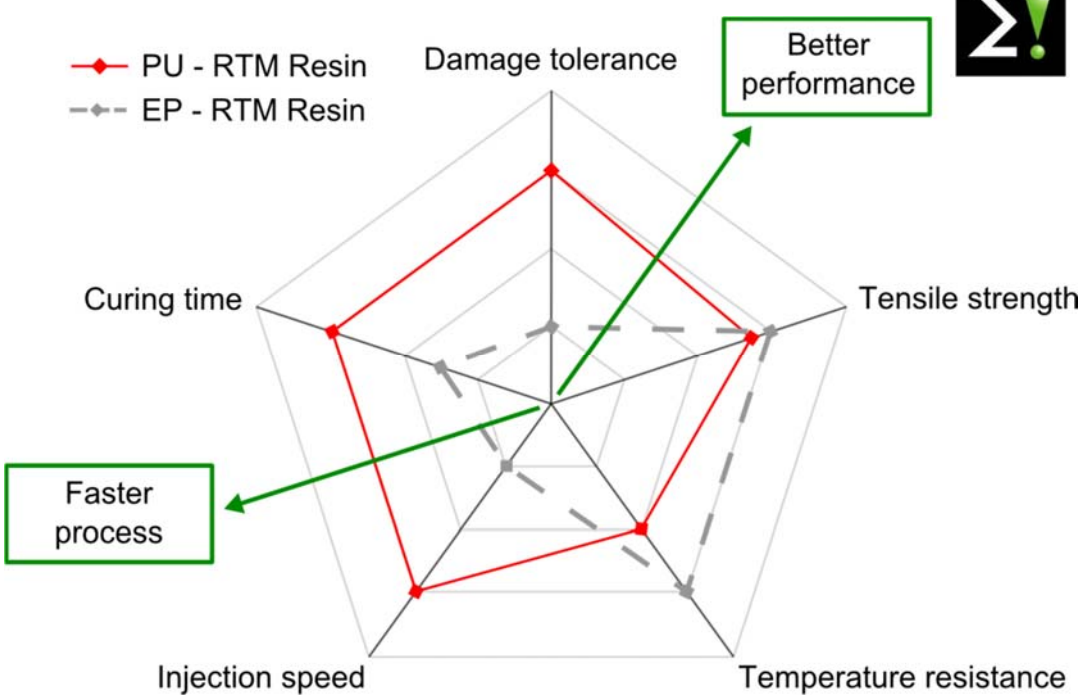
Huelsbusch, D.; Walther, F.: **The e-Journal of Nondestructive Testing 20** (**2015**) 1-9.

PRISCA – Motivation

Source: faz.net

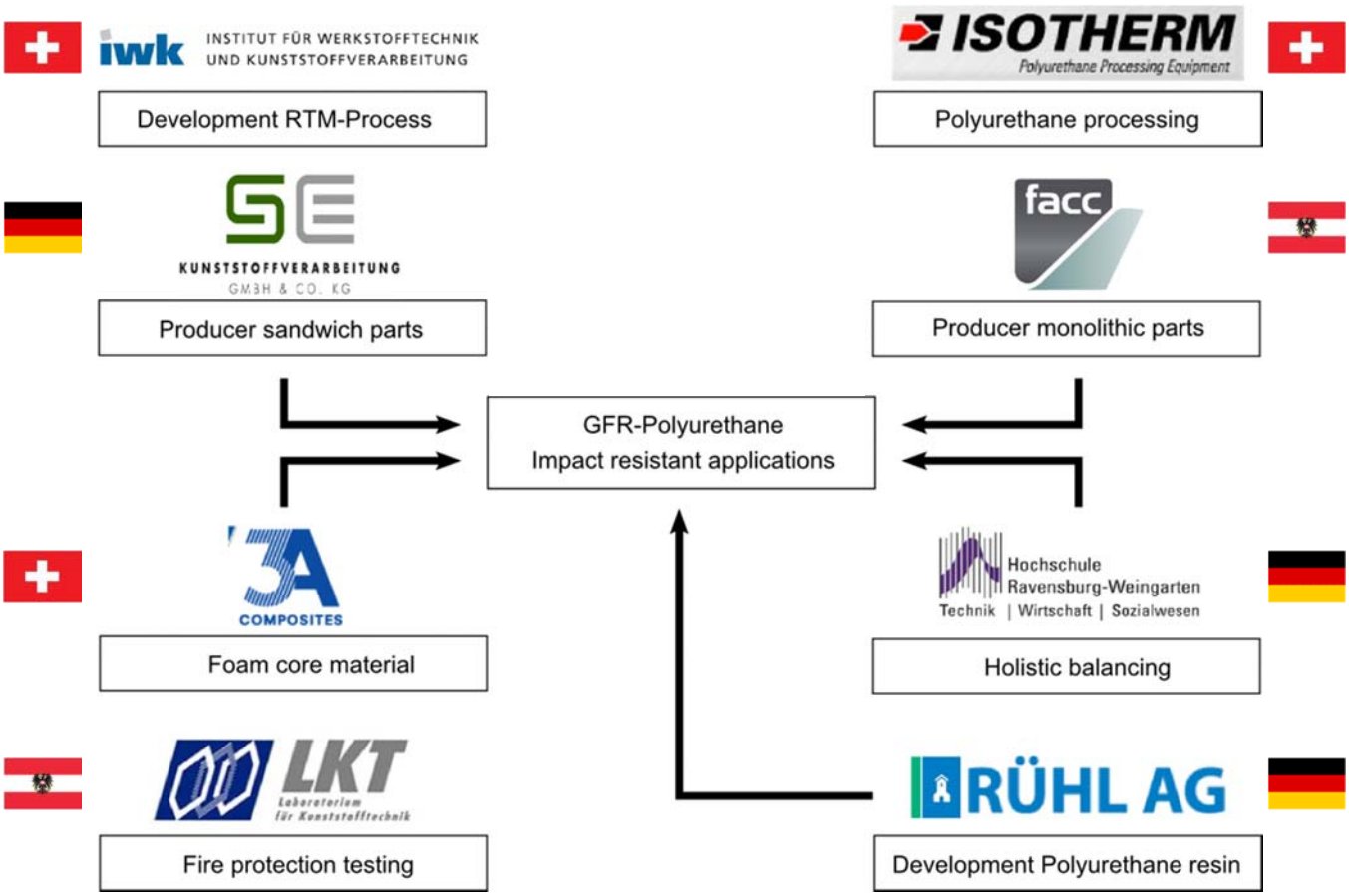
Source: aerospace-technology.com

Source: FACC

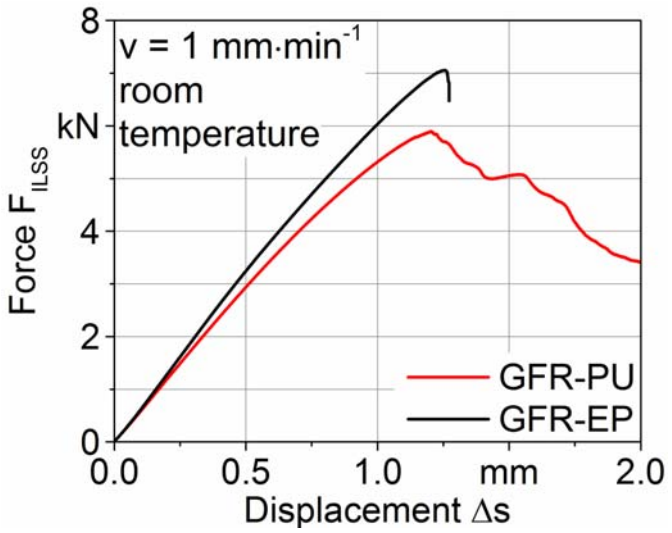


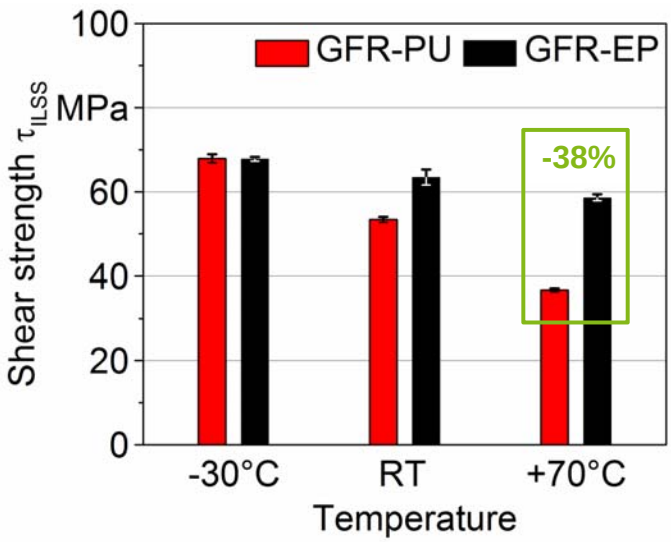
Source: Henkel

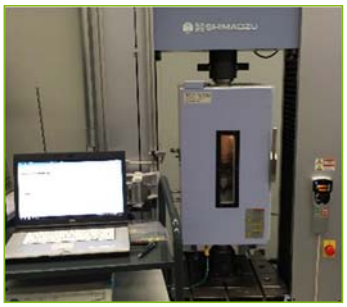
PRISCA – Structure www.prisca-eureka.eu

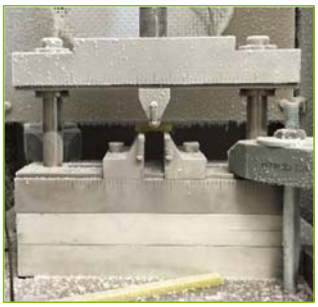


Glass Fiber-Reinforced Polymers – Interlaminar Shear Test (ILSS)





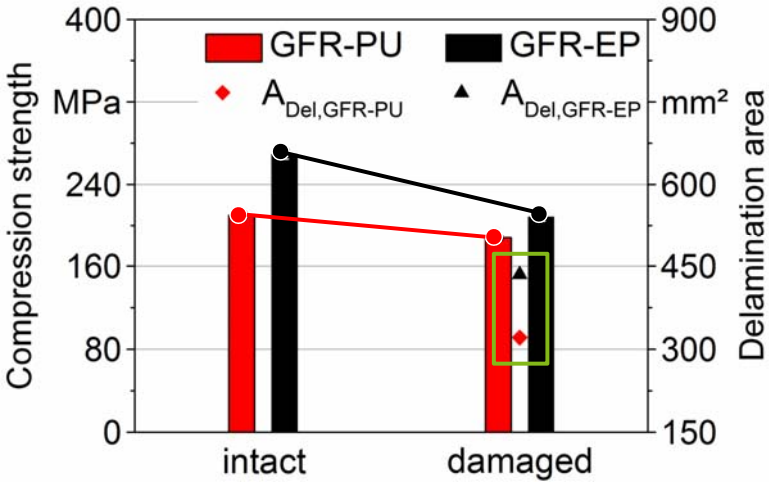


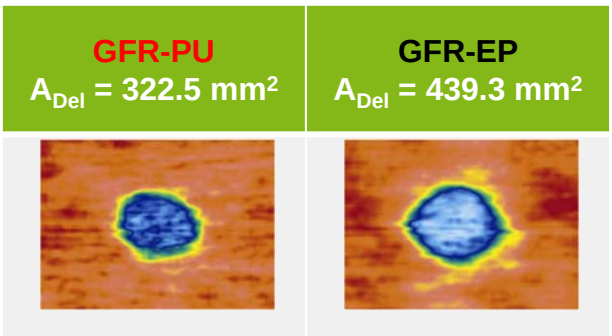


- Interlaminar shear test based on DIN 14130-1
- Determination of interlaminar shear strength of GFR-PU and GFR-EP
- Investigation of the influence of temperature -30°C, RT, +70°C

Huelsbusch, D.; Mueller, Y.; Barandun, G.-A.; Niedermeier, M.; Walther, F.: **European Conference on Composite Materials 17**, ECCM17 (**2016**).

Glass Fiber-Reinforced Polymers – Compression after Impact Test (CAI)



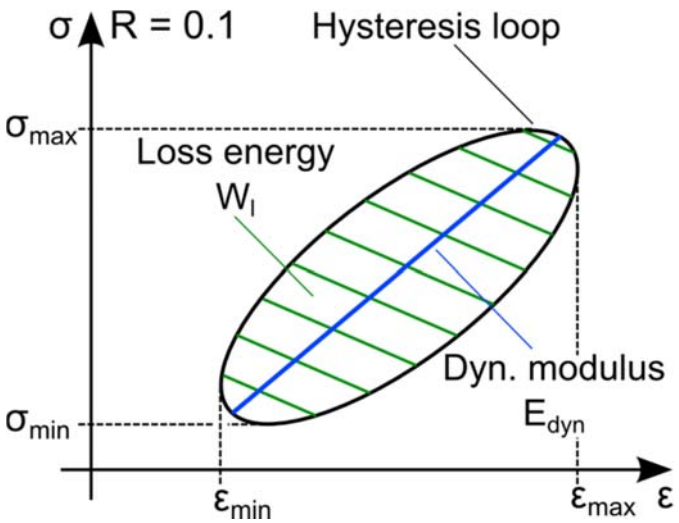


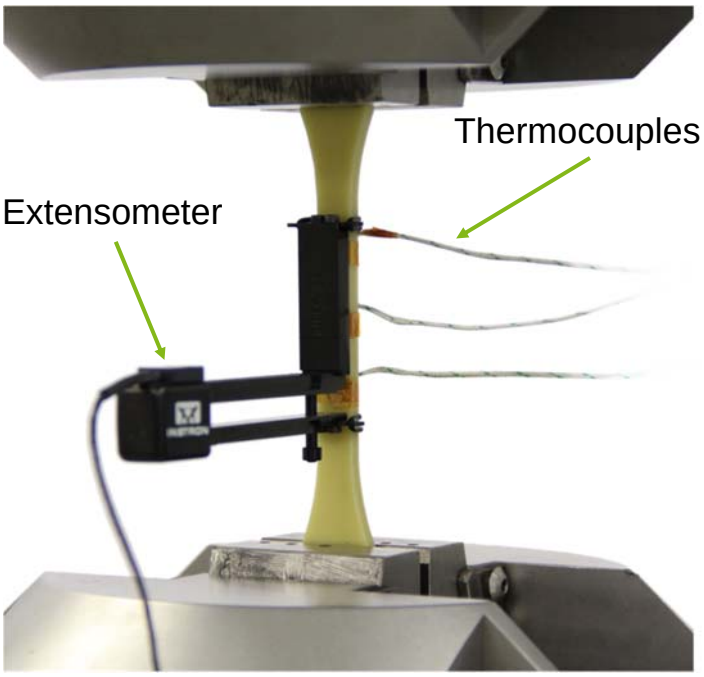
- Compression after impact test based on ASTM D7136
- Impact energy 30J
- Determination of compression strength of GFR-PU and GFR-EP
- Investigation of the influence of temperature -30°C, RT, +70°C

Huelsbusch, D.; Mueller, Y.; Barandun, G.-A.; Niedermeier, M.; Walther, F.: **European Conference on Composite Materials 17**, ECCM17 (**2016**).

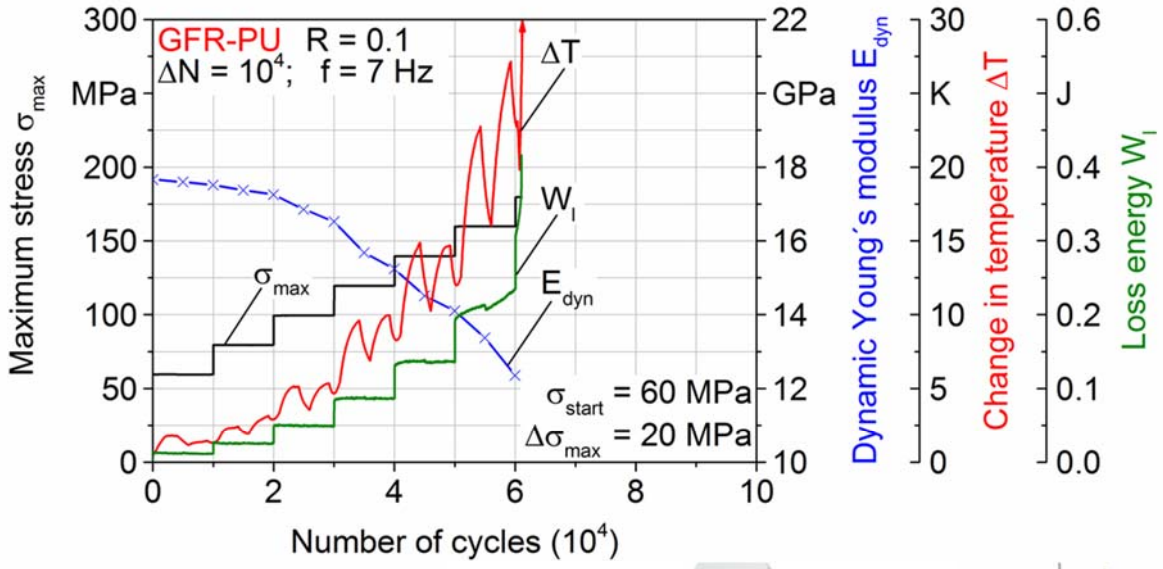
Glass Fiber-Reinforced Polymers – Fatigue Test Setup

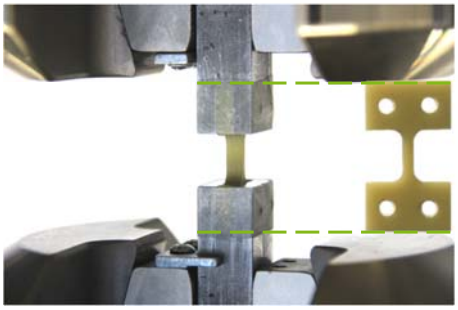
- Hysteresis analysis
- Loss energy
- Dyn. Young‘s modulus → Stiffness degradation





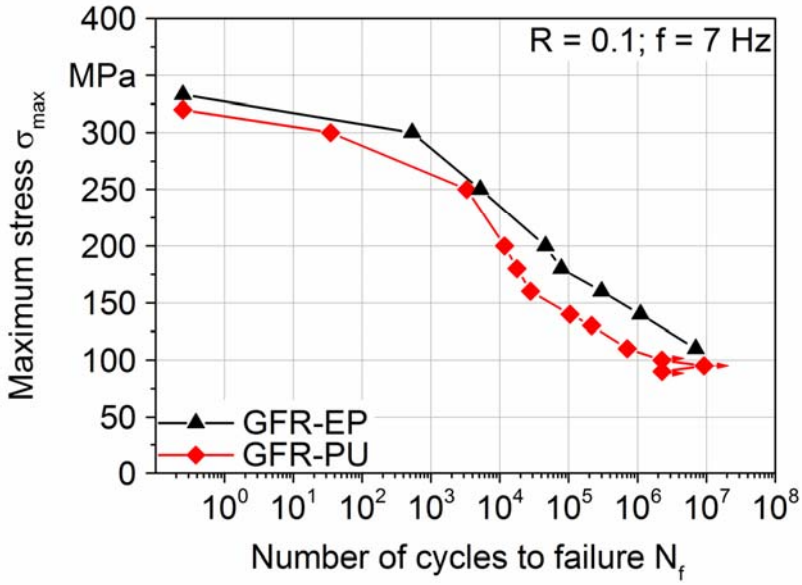
Glass Fiber-Reinforced Polyurethane – Load increase Method

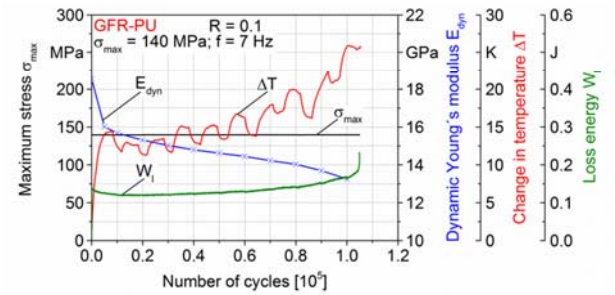


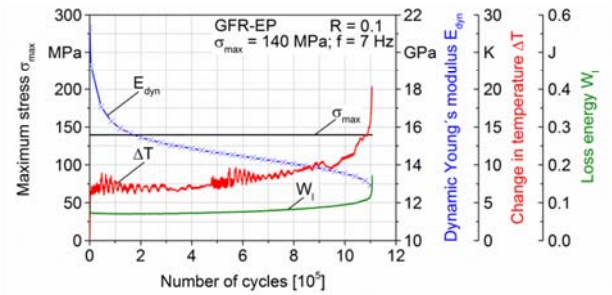


Huelsbusch, D.; Jamrozy, M.; Frieling, G.; Mueller, Y.; Barandun, G.-A.; Niedermeier, M.; Walther, F.: **Materials Testing 59**, 2 (**2017**) 109-117.

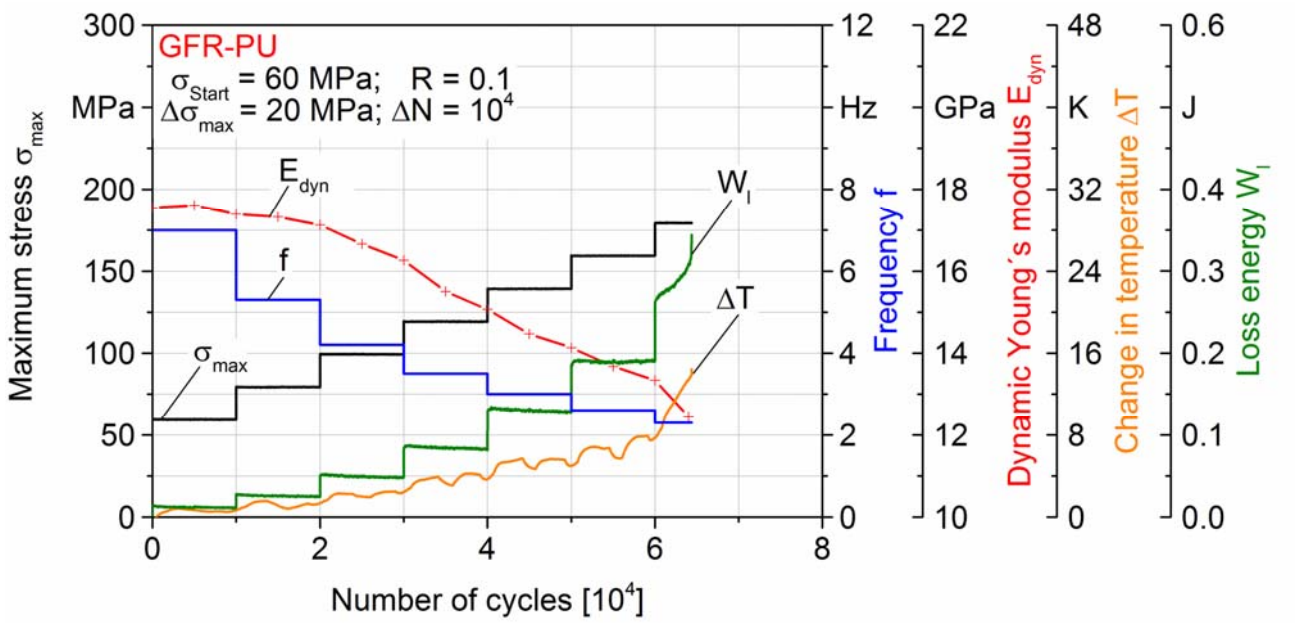
Glass Fiber-Reinforced Polymers – Woehler Curve



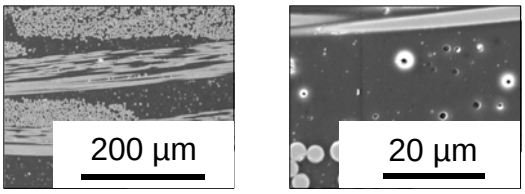




Strain Rate-Adjusted Testing – Variable Frequency



GFR-PU



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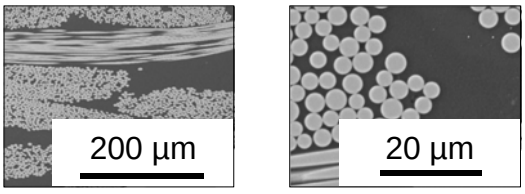
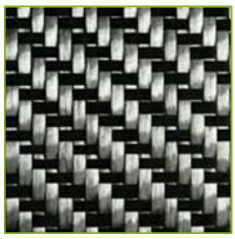
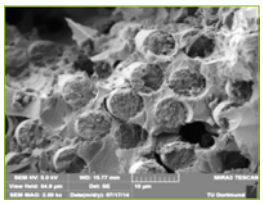
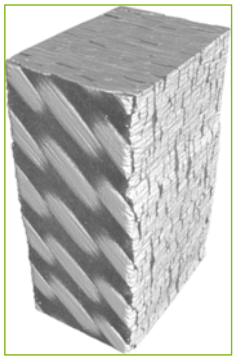
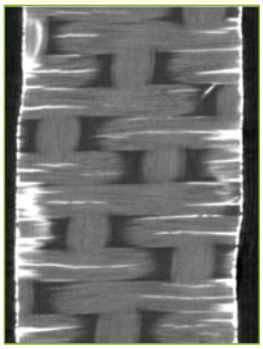
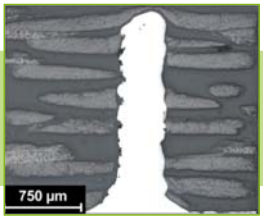


Huelsbusch, D.; Jamrozy, M.; Mrzljak, S.; Walther, F.: **International Conference on Composite Materials 21**, ICCM21 (**2017**)

Key Points

- **Research strategy**
  - Characterization of structure-property relations
  - Evaluation of deformation and damage mechanisms and processes with physical sensor systems
- Gain of **additional information** compared to lifetime-oriented tests (Woehler curve)
- **Applicability** of physical sensor systems
  - for structures and components
  - during service loading (condition-monitoring)
  - at very high frequencies (VHCF)
- **Reduction of experimental efforts and costs**
  - Combination of load increase and constant amplitude tests
- **Conclusions:**
  Basis for a secure and economic application of fatigue-loaded construction materials and joints



Daniel Huelsbusch

Publications

#1: Huelsbusch, D.; Jamrozy, M.; Frieling, G.; Mueller, Y.; Barandun, G.A.; Niedermeier, M.; Walther, F.: **Materials Testing 59**, 2 (**2017**) 109-117.

#2: Huelsbusch, D.; Mueller, Y.; Barandun, G.-A.; Niedermeier, M.; Walther, F.: ECCM17, Proc. of **17th European Conference on Composite Materials**, Publisher: European Society for Composite Materials (ESCM) ISBN 978-3-00-053387-7 (**2016**) 1-9.

#3: Huelsbusch, D.; Haack, M.; Solbach, A.; Emmelmann, C.; Walther, F.: ICCM20, Proc. of **20th International Conference on Composite Materials**, (**2015**) 1-12.

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Thank you for your attention!

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