Joining of CFRP-tubes to titanium-fittings by continous ultrasonic welding

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02.08 CMS - Hybrid & metacomposites | ICCM23, Belfast

Ultrasonic welding of hybrid material systems – Motivation

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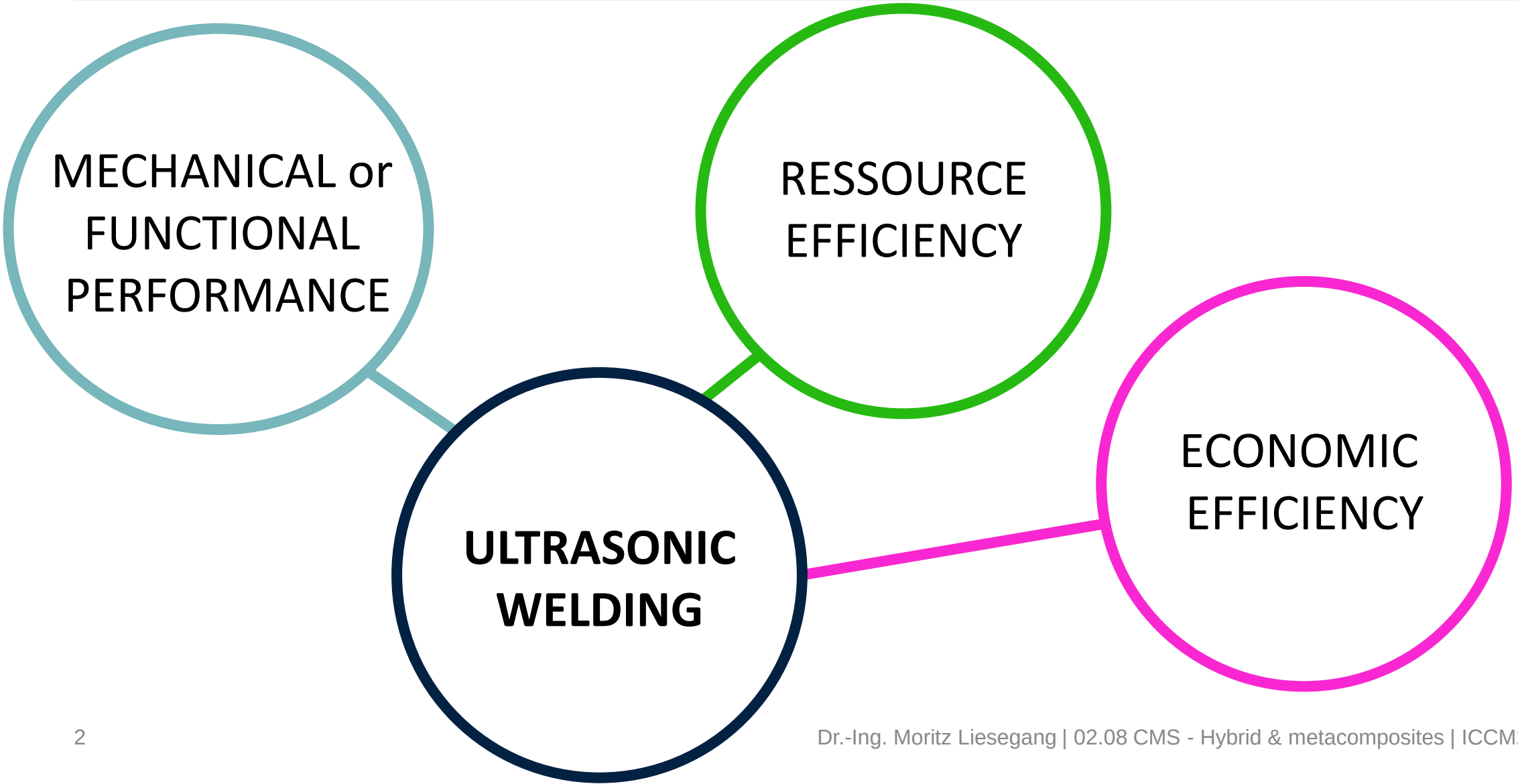

Ultrasonic welding of hybrid material systems – Current reseach

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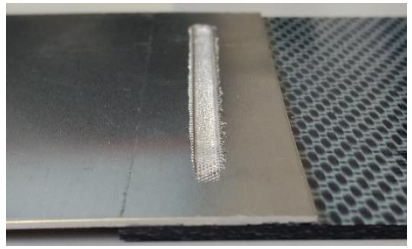
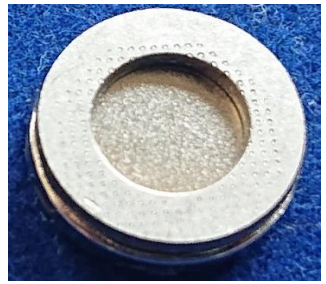
- Process developement using all conventionally available ultrasonic weldig (USW) types
- Unique orbital USW proccess to join tubular hybrids
- Sonotrode developement for considering the requirements of the particular process and material combination

https://doi.org/10.3390/jmmp5020061

metal+FRP

https://doi.org/10.3390/jmmp5020030

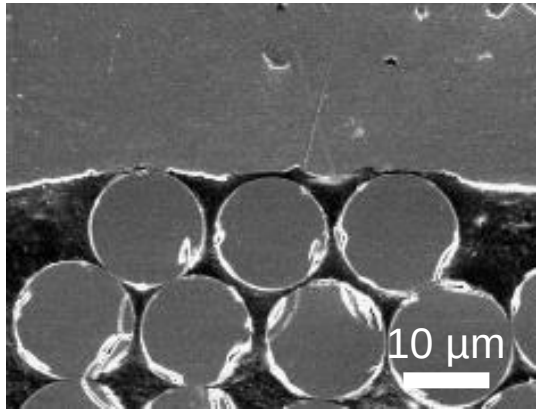


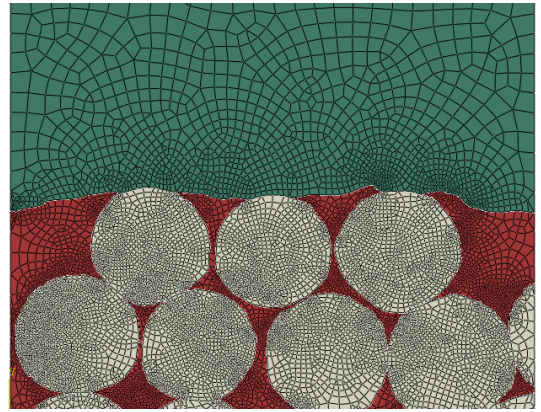


metal+RE-magnet

https://doi.org/10.1186/s42252-021-00017-1

metal+glass





https://doi.org/10.1007/s11665-023-08325-2 (accepted but not yet published)

Basics of ultrasonic welding – Oscillation system

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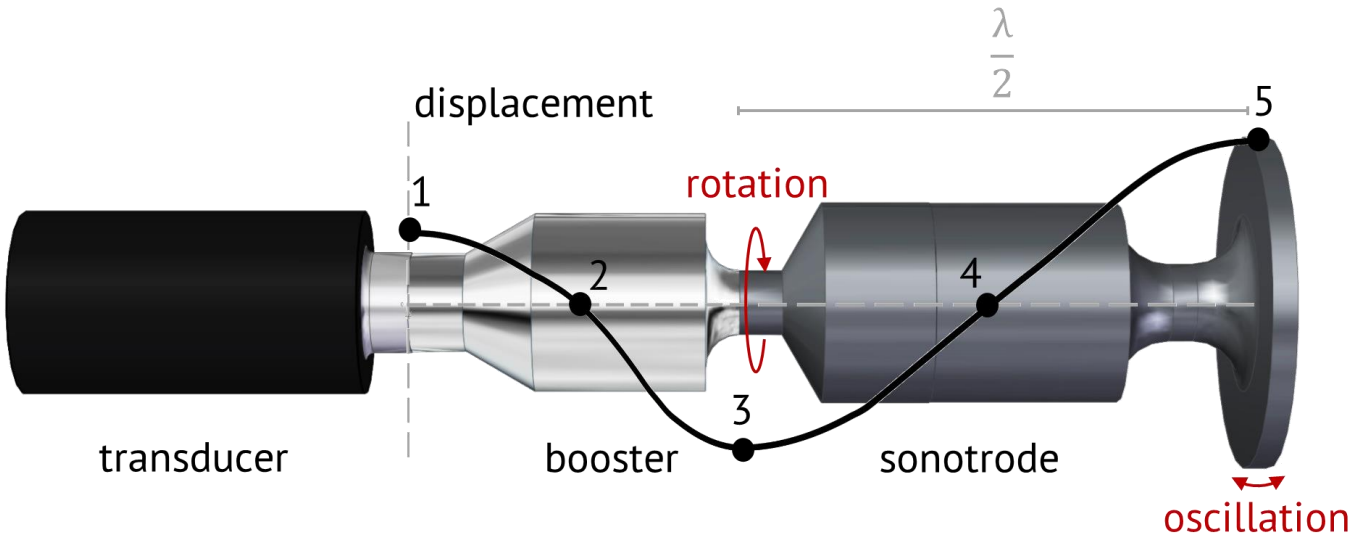

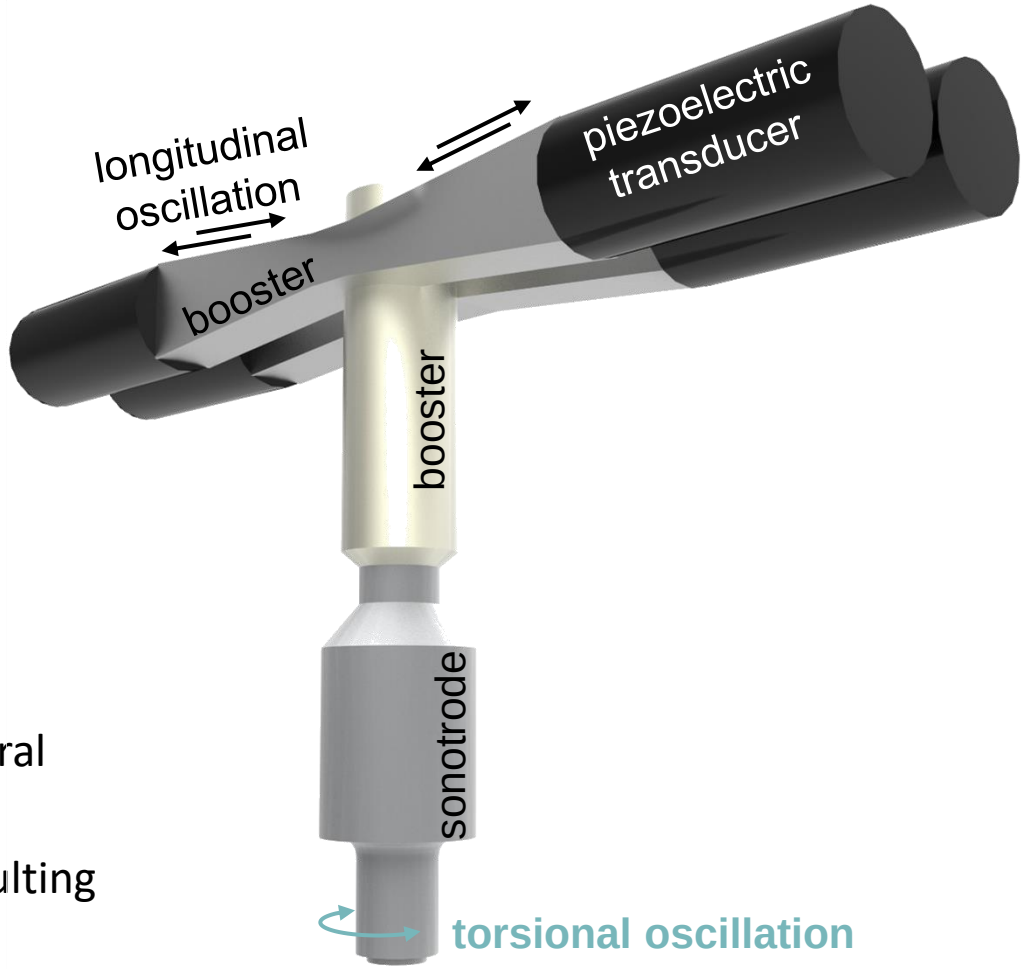

- Initiate an oscillation by inverse piezo electric effect close to the natural frequency of the system
- Acoustic translation of the boosters and the sonotrode affect the resulting amplitude at the sonotrode tip

Basics of ultrasonic welding – Process control

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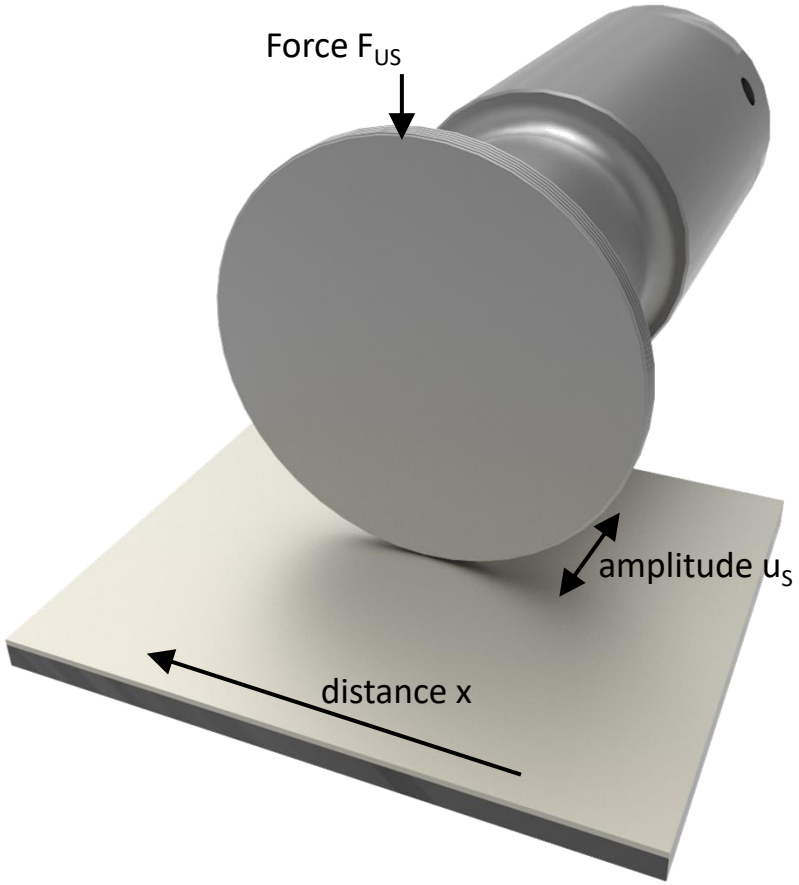

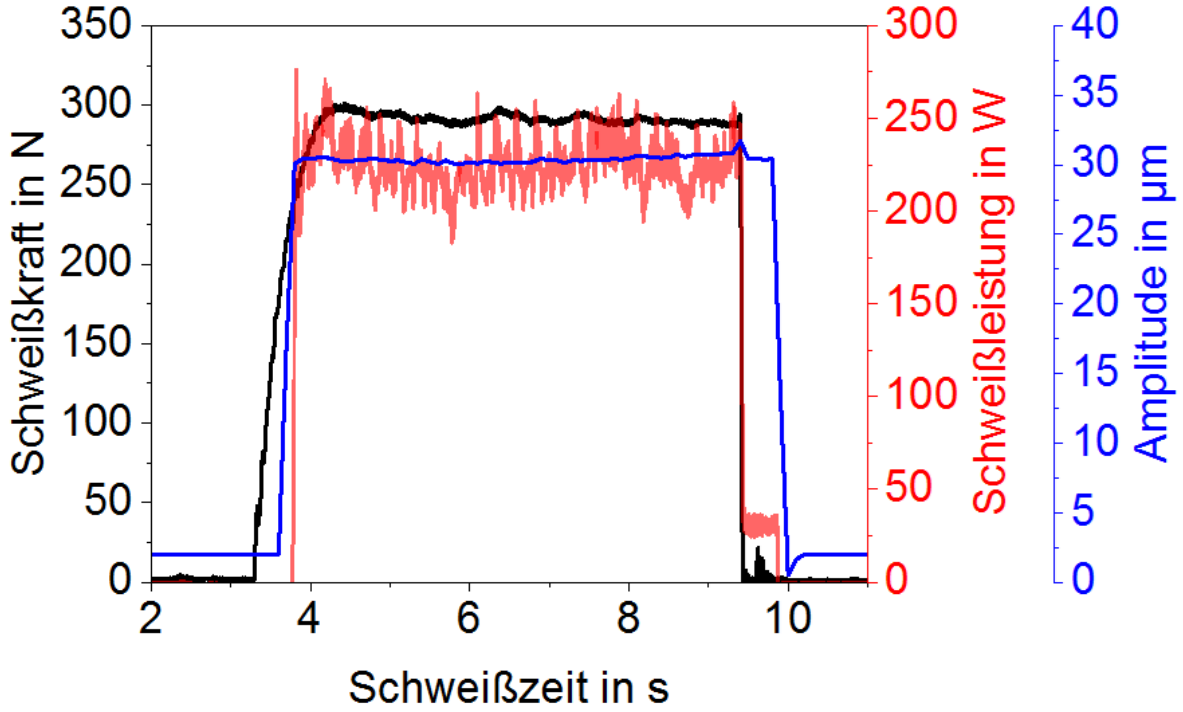

Basics of ultrasonic welding – Joint formation

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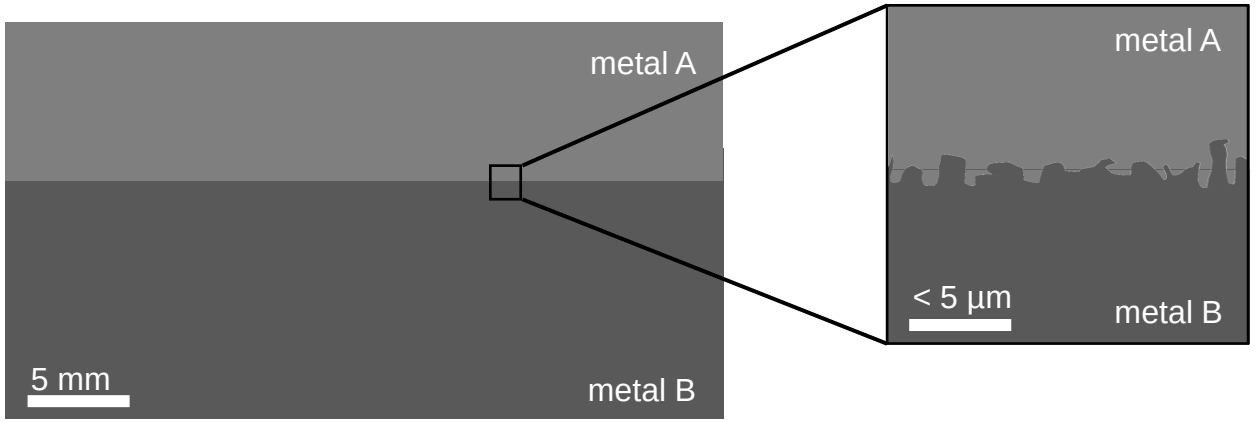
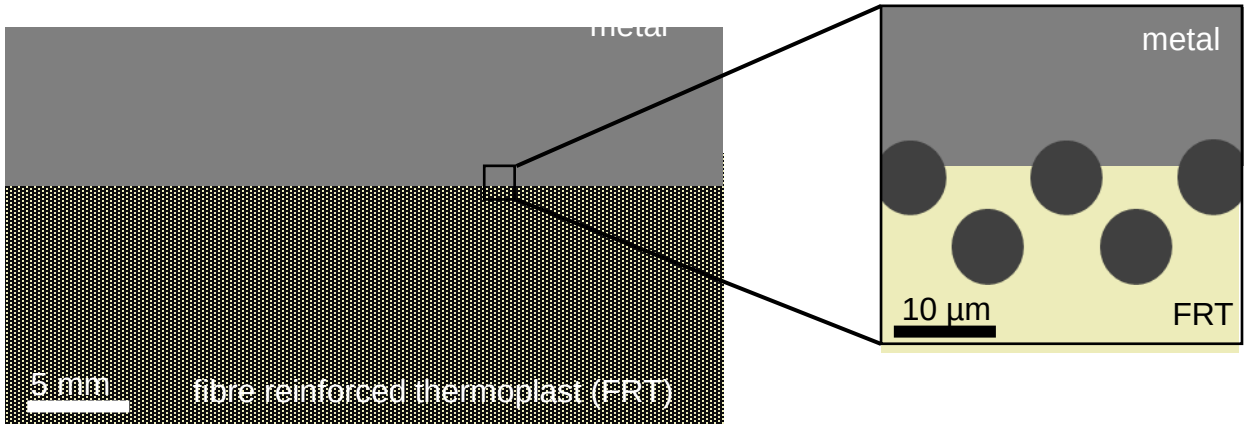


1. Shearing off topographie peaks
2. Breaking up oxide layers
3. Pure metal/metal contact
4. Interlocking by plastic deformation



1. Fusing of theroplastic matrix
2. Approximation of metal and fibres
3. Interlocking of metal and fibres

https://doi.org/10.3390/jmmp5020030

Ultrasonic welding of metal and frp – Ti6Al4V and CF-PEEK

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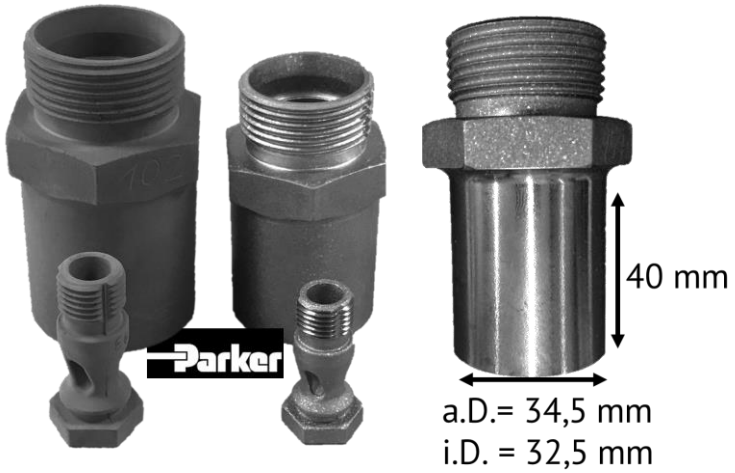
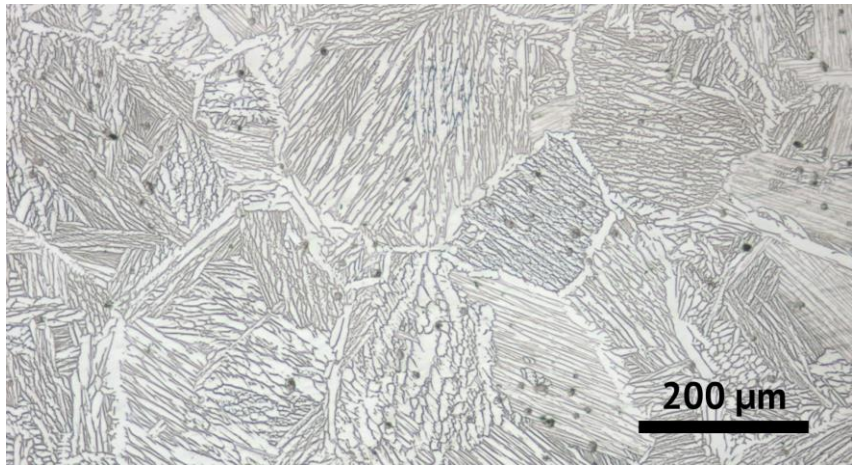
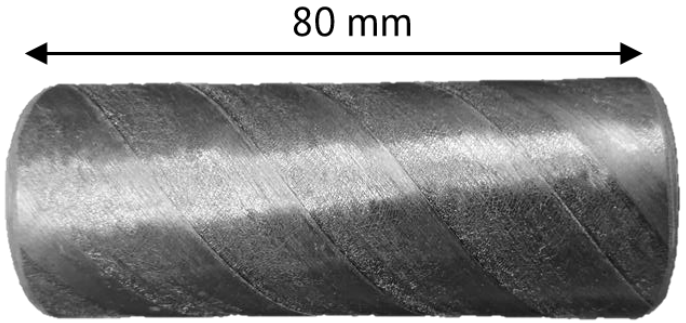
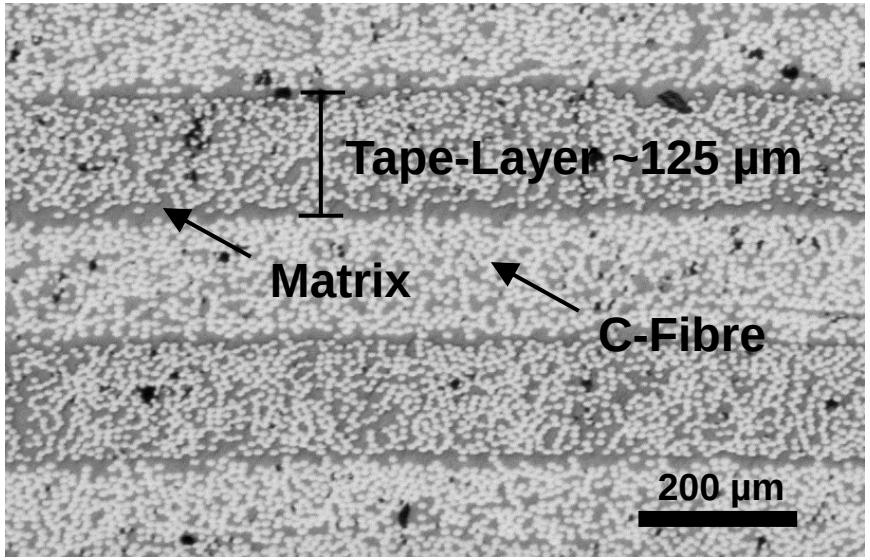
Metal injection molded Ti6Al4V fitting





Tape layered CF-PEEK tubes





Ultrasonic welding of metal and frp – Sonotrodes

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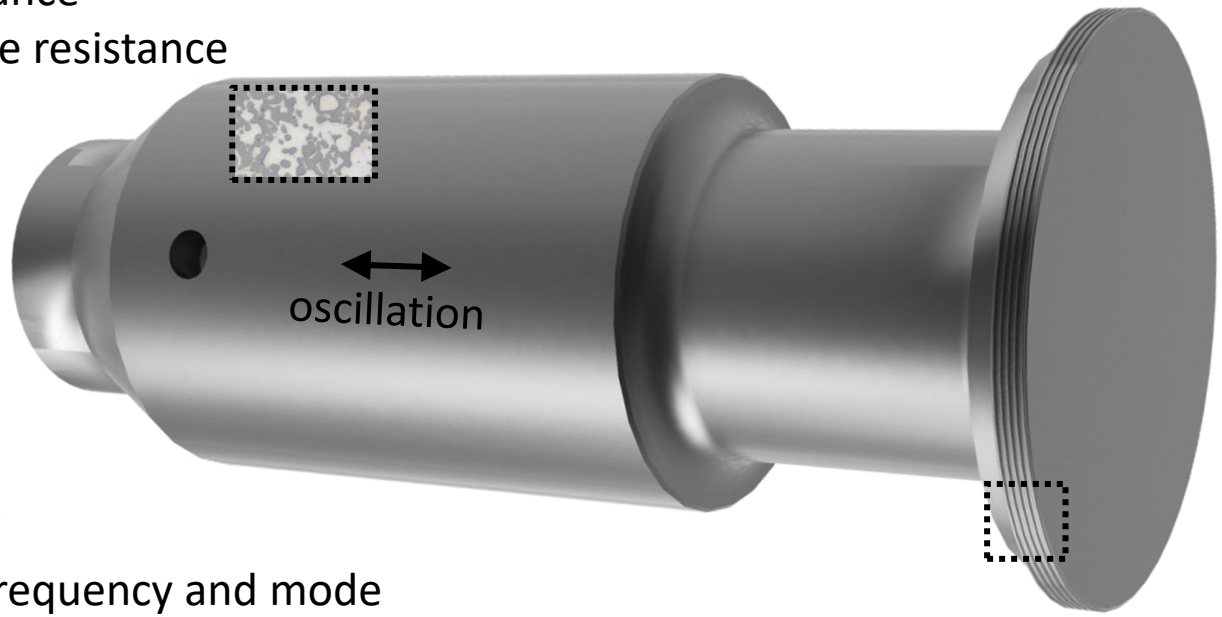
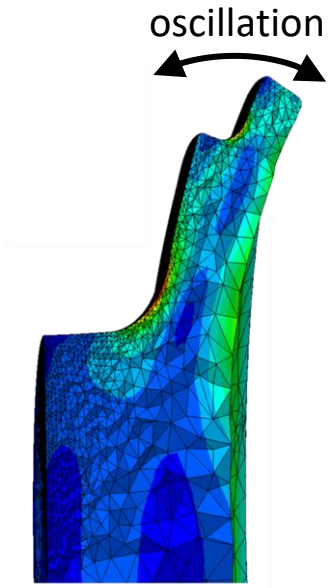
MATERIALS SELECTION
homogeneous properties
fatigue strength (VHCF)
wear resistance
temperature resistance

STRESS ANALYSIS
fatigue strength (VHCF)
longevity

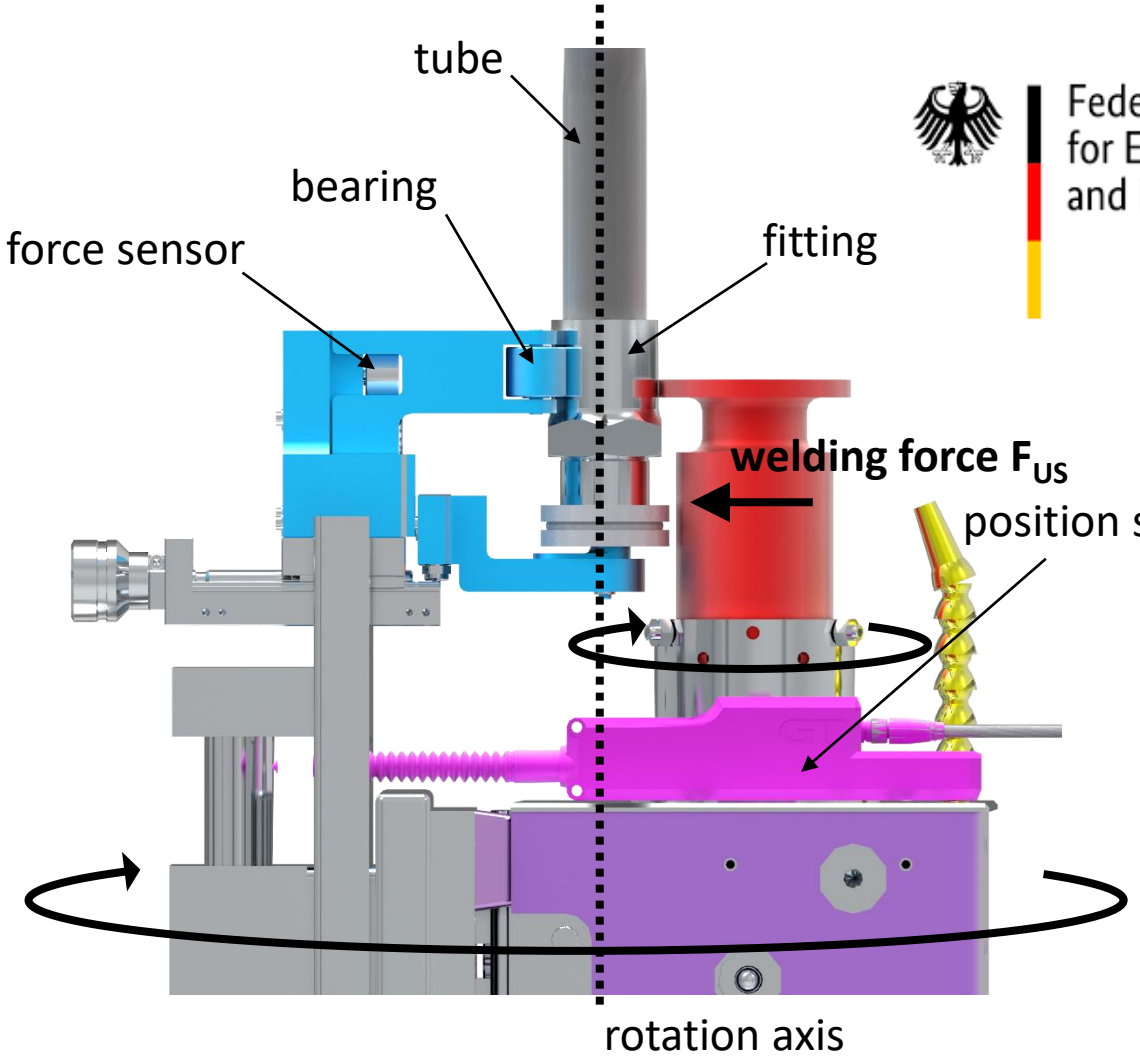




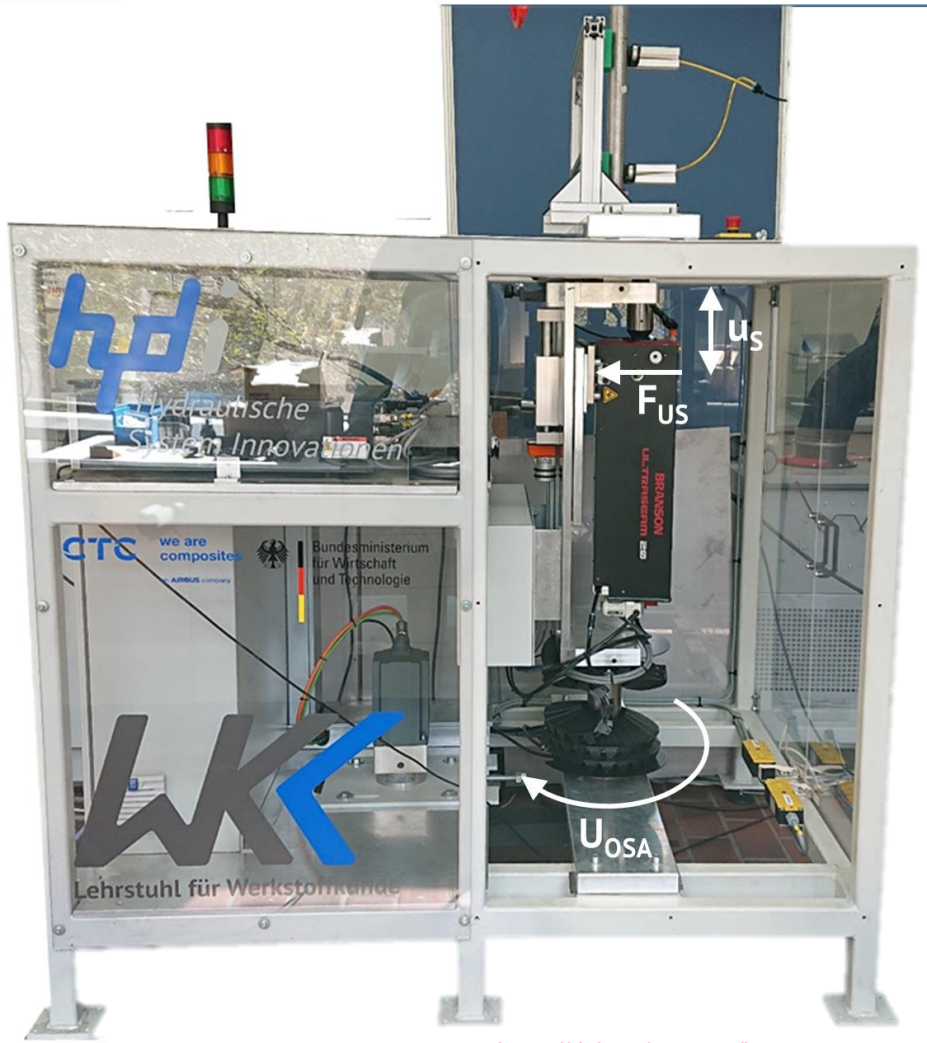
GEOMETRY
operation frequency and mode
isolation of modes
translation of amplitude
state of stress

SONOTRODE TIP
induction of energy
wear resistance

Orbital ultrasonic welding – Machine construction



Federal Ministry
for Economic Affairs
and Energy



https://doi.org/10.3390/jmmp5020030

Orbital ultrasonic welding – Process overview

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we are composites

Orbital ultrasonic welding – Process detail

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Orbital ultrasonic welding – Influence of weld seam design on mechanical behaviour

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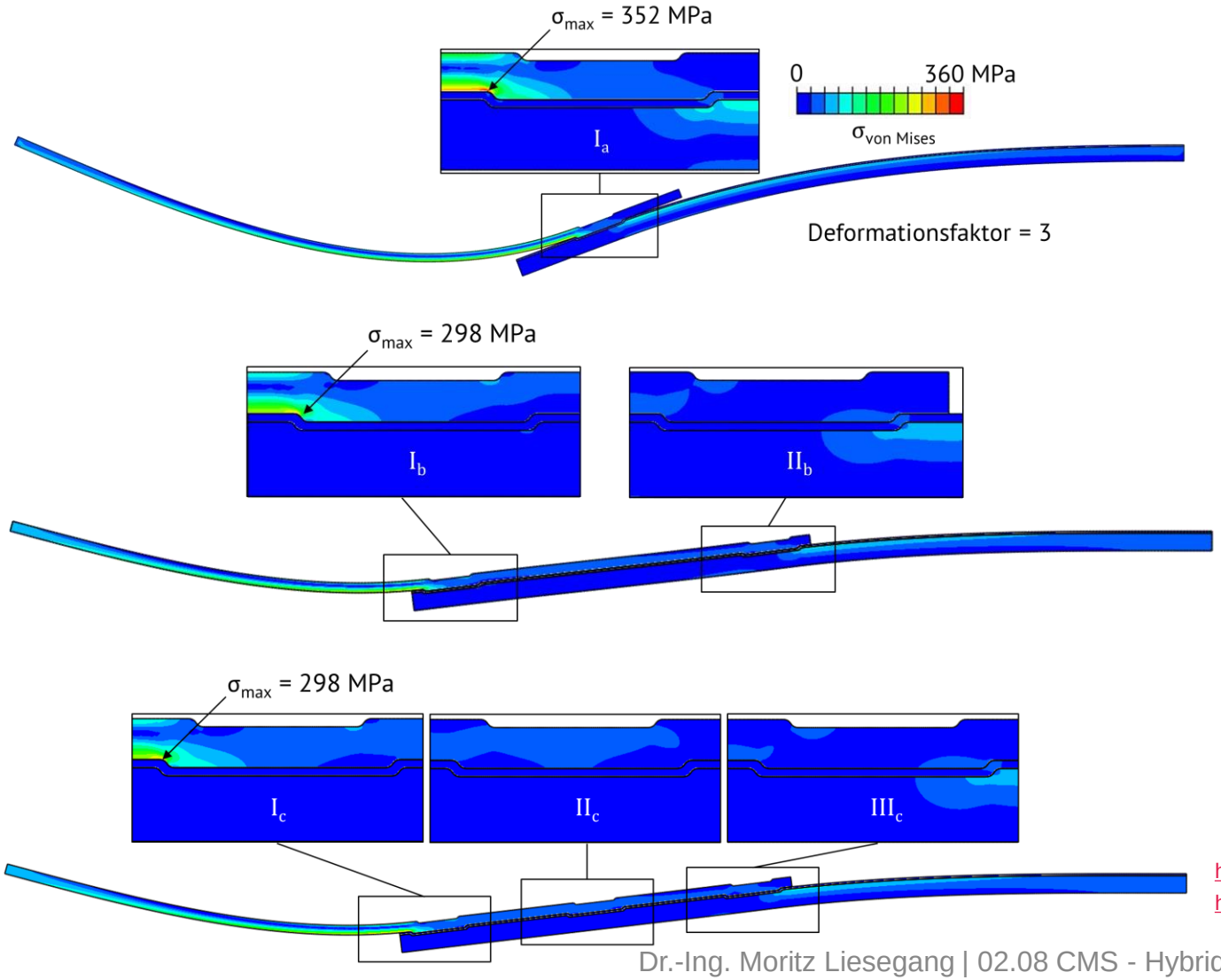

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https://doi.org/10.26204/KLUEDO/6290

Orbital ultrasonic welding – Influence of load type on mechanical behaviour

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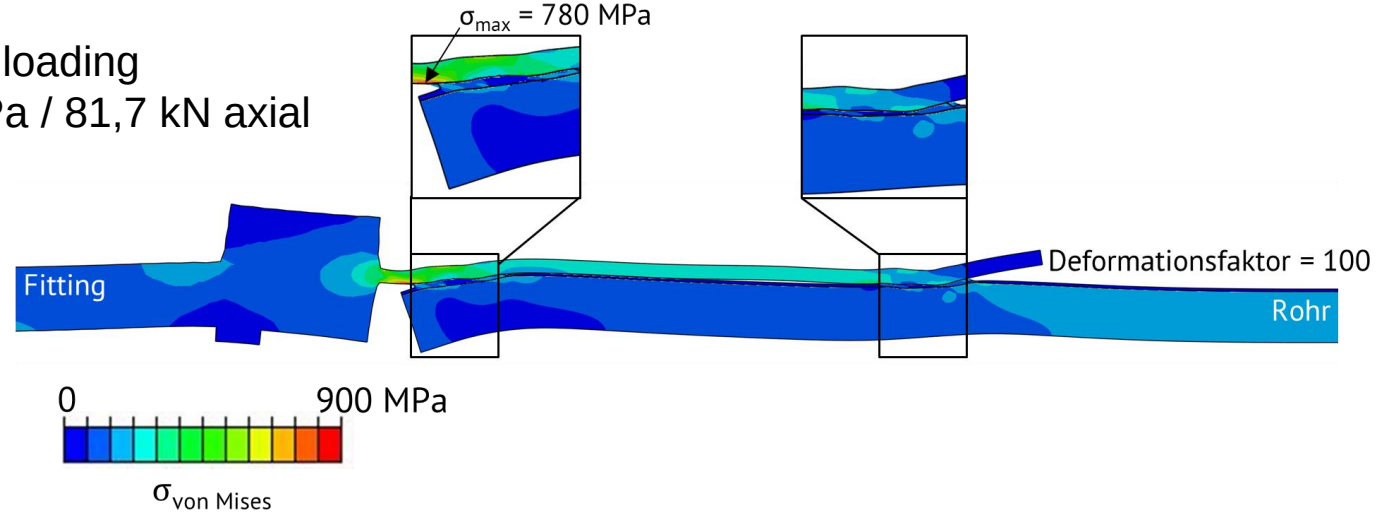
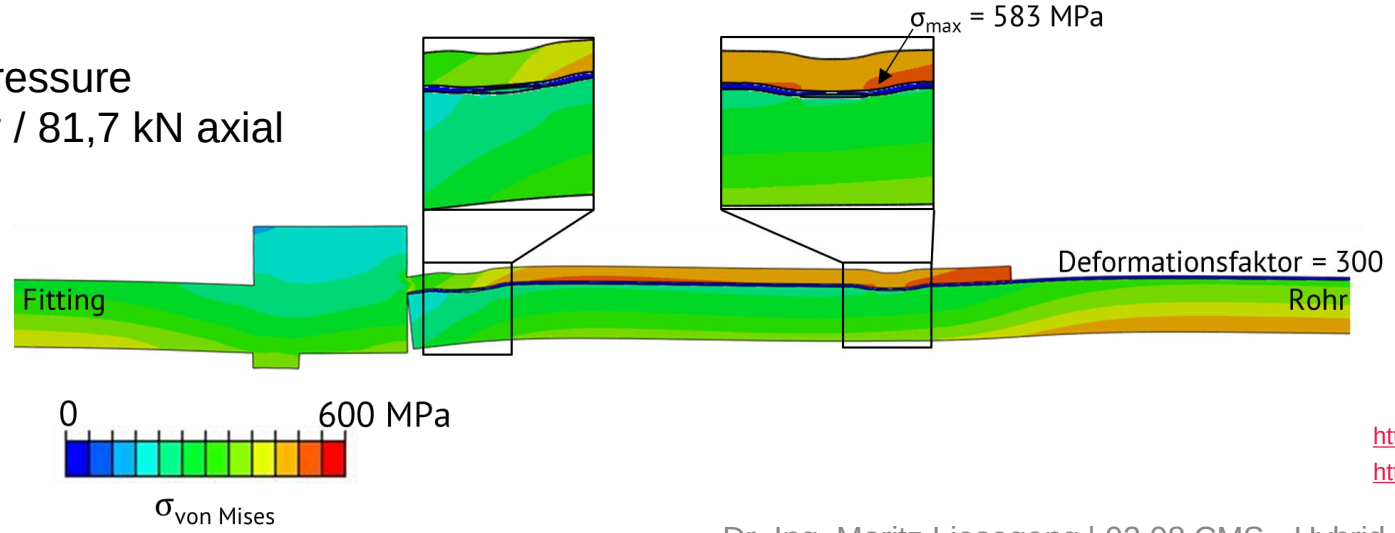
Tensile loading
400 MPa / 81,7 kN axial



Inner pressure
960 bar / 81,7 kN axial



https://doi.org/10.3390/jmmp5020030
https://doi.org/10.26204/KLUEDO/6290

Orbital ultrasonic welding – Ti6Al4V/CF-PEEK-joints

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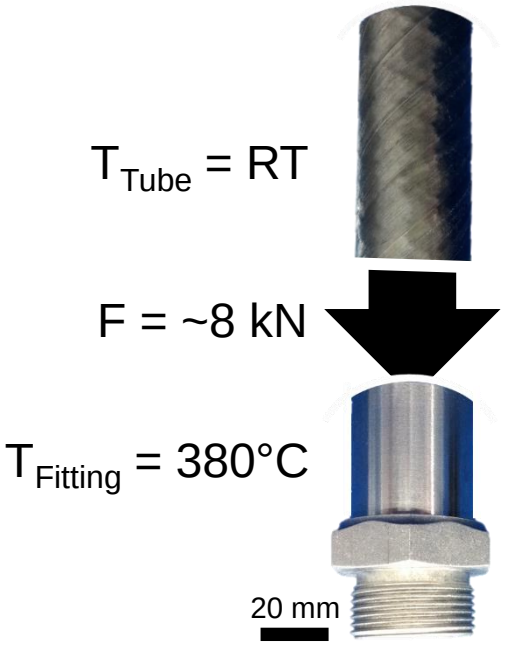
- Gap-free contact between the joining partners is required for energy transfer into the joining zone
- Interference fit of thermally expanded Ti-Fitting and CFRP-tube



https://doi.org/10.3390/jmmp5020030
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US welded Ti6Al4V/CF-PEEK-joints – Micro structure and strength

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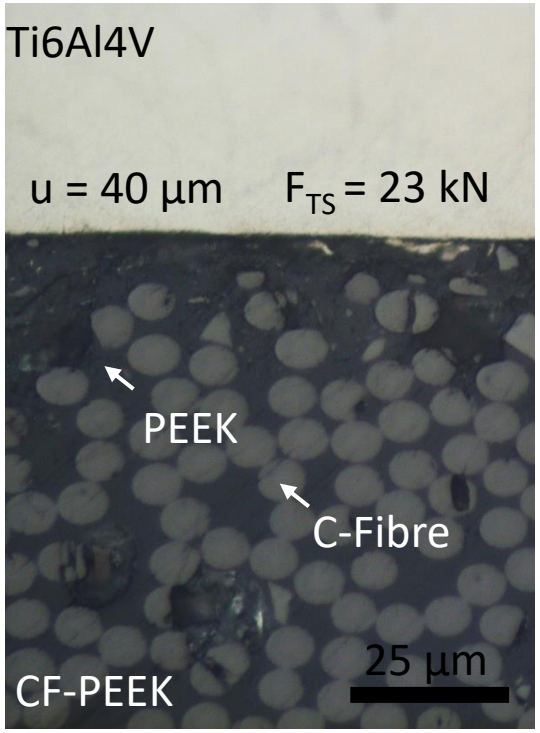
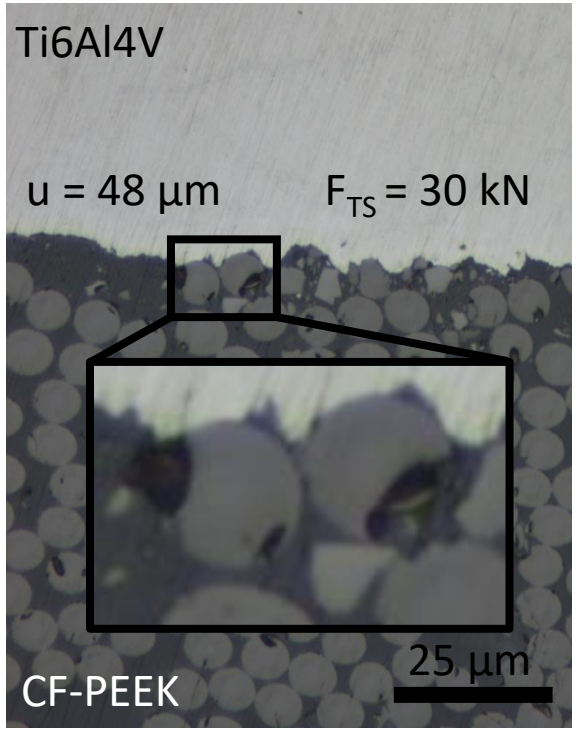
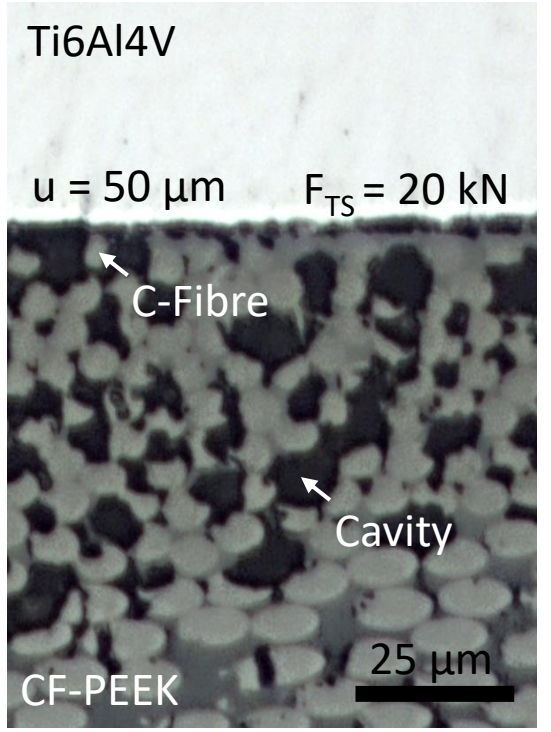
- No fibre-metal-contact
- Insufficient amount of welding energy to form high strength joint



- Fibre-metal-contact
- No cavities
- ➡ Suitable process parameters



- Large cavities
- PEEK decomposition



960 bar
97.5 MPa

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US welded Ti6Al4V/CF-PEEK-joints – Simulated mechanical behaviour

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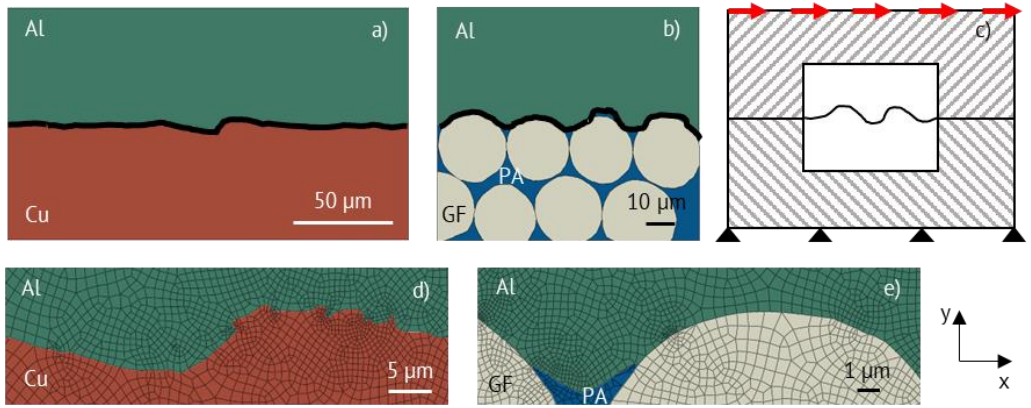
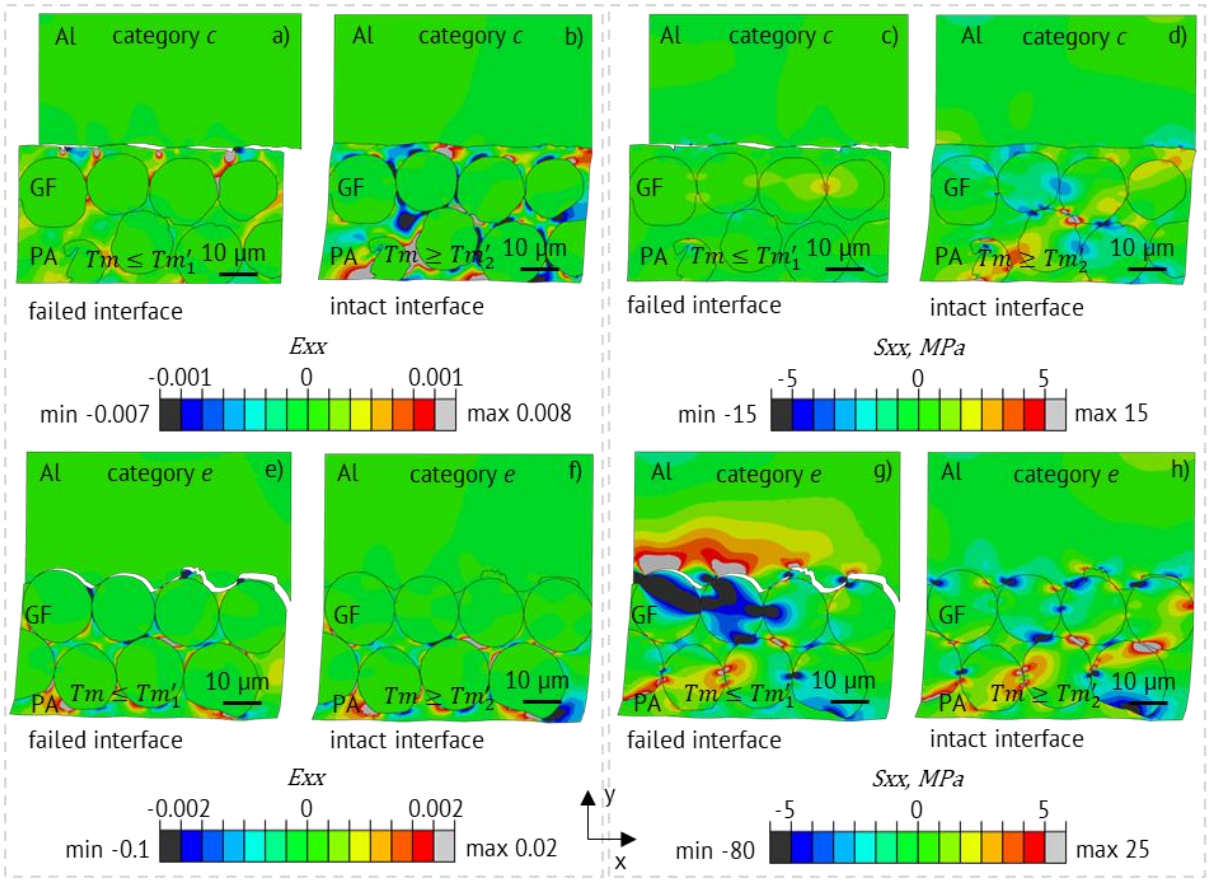
- Conversion of mikrostructural characteristics to FE-models to develop a contact model for ultrasonically welded joints
- Stress and strain calculations confirmed the observed correlation between fibre metal interlocking and joint strength





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Thank you!

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