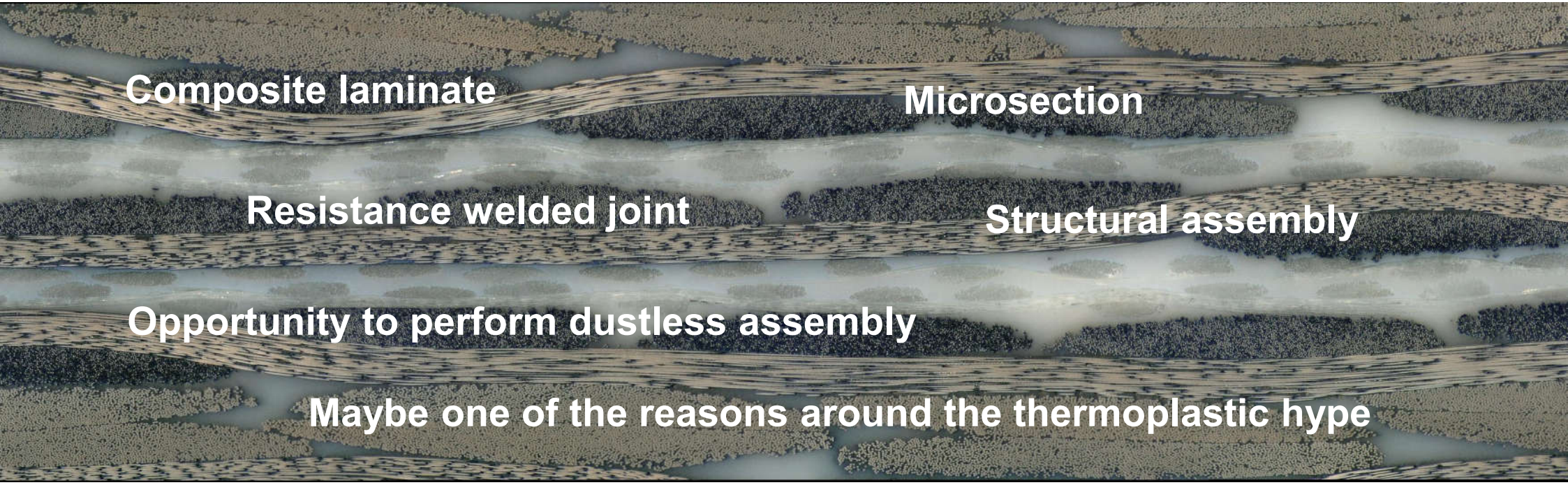
Towards the industrial welding of thermoplastic composites for full-scale applications

Portfolio of welding technologies @ the Institute of Structures and Design

DLR

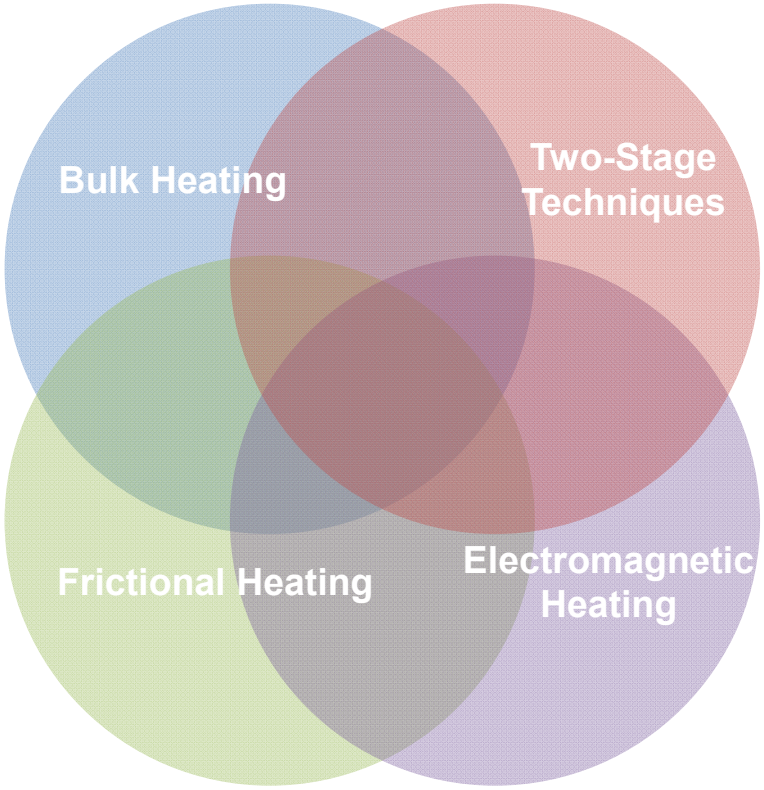
What do we see in this Picture?

What do we see in this Picture?



Fusion Bonding Processes for Thermoplastic Composites

An Overview



Fusion Bonding Processes for Thermoplastic Composites

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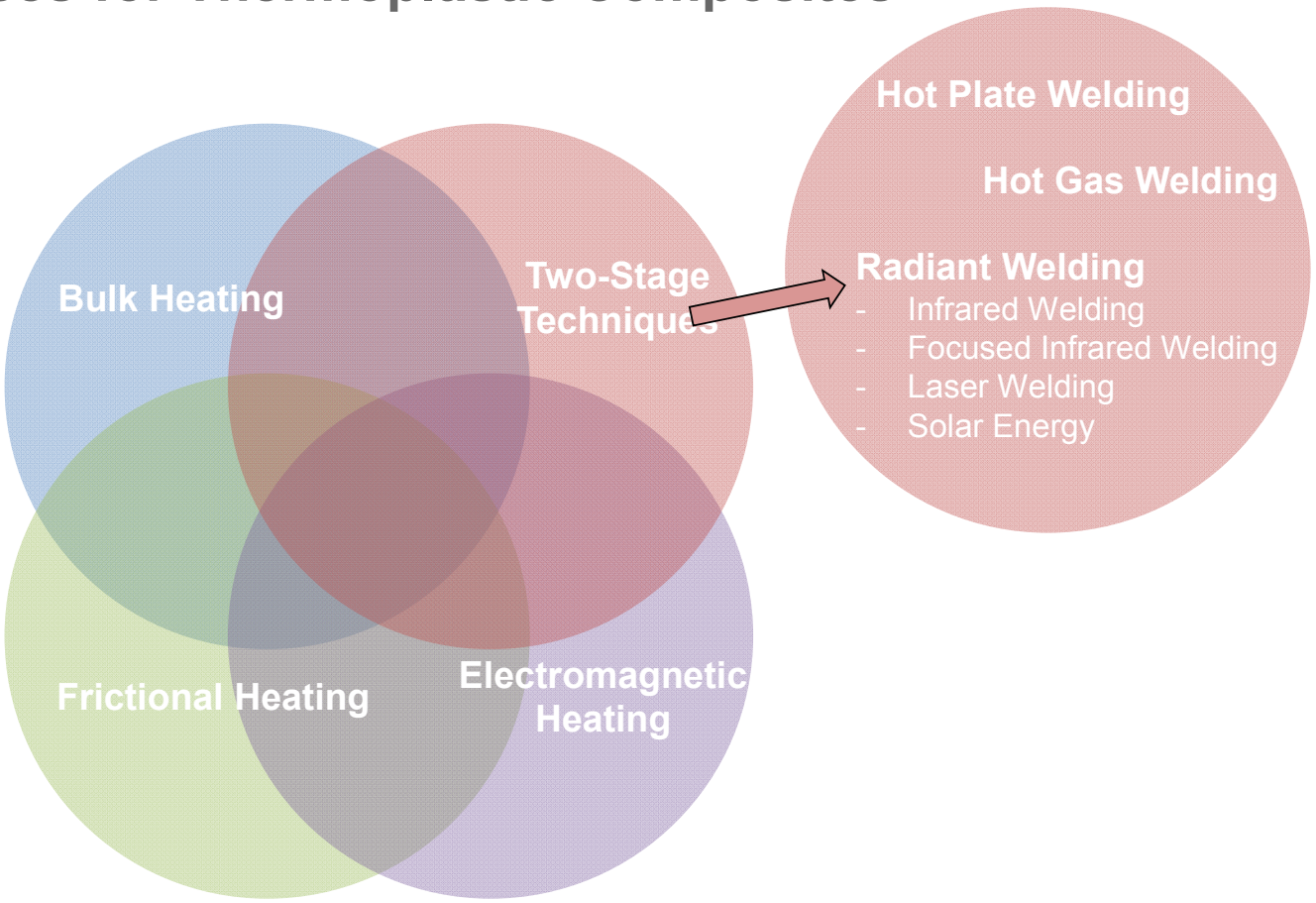

Fusion Bonding Processes for Thermoplastic Composites

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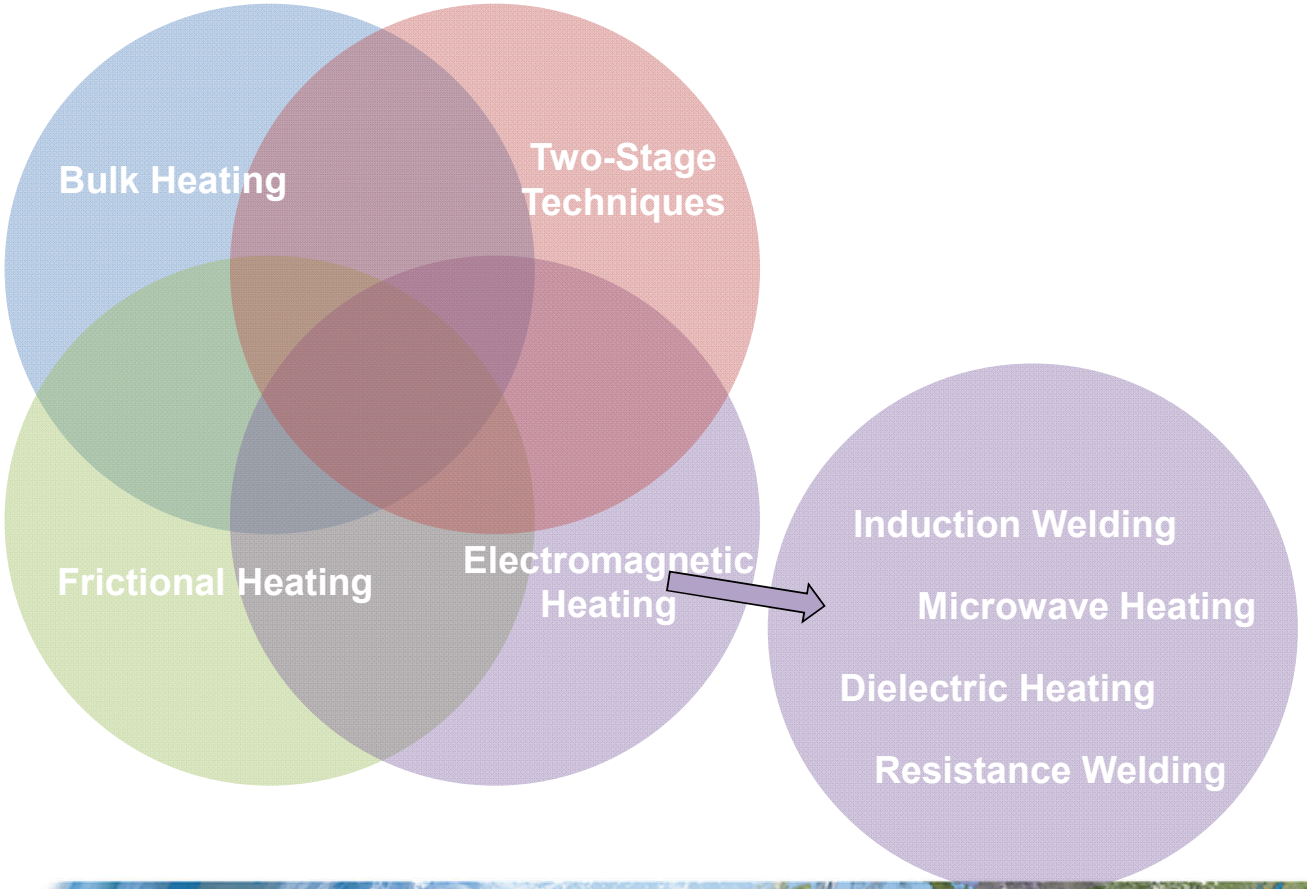
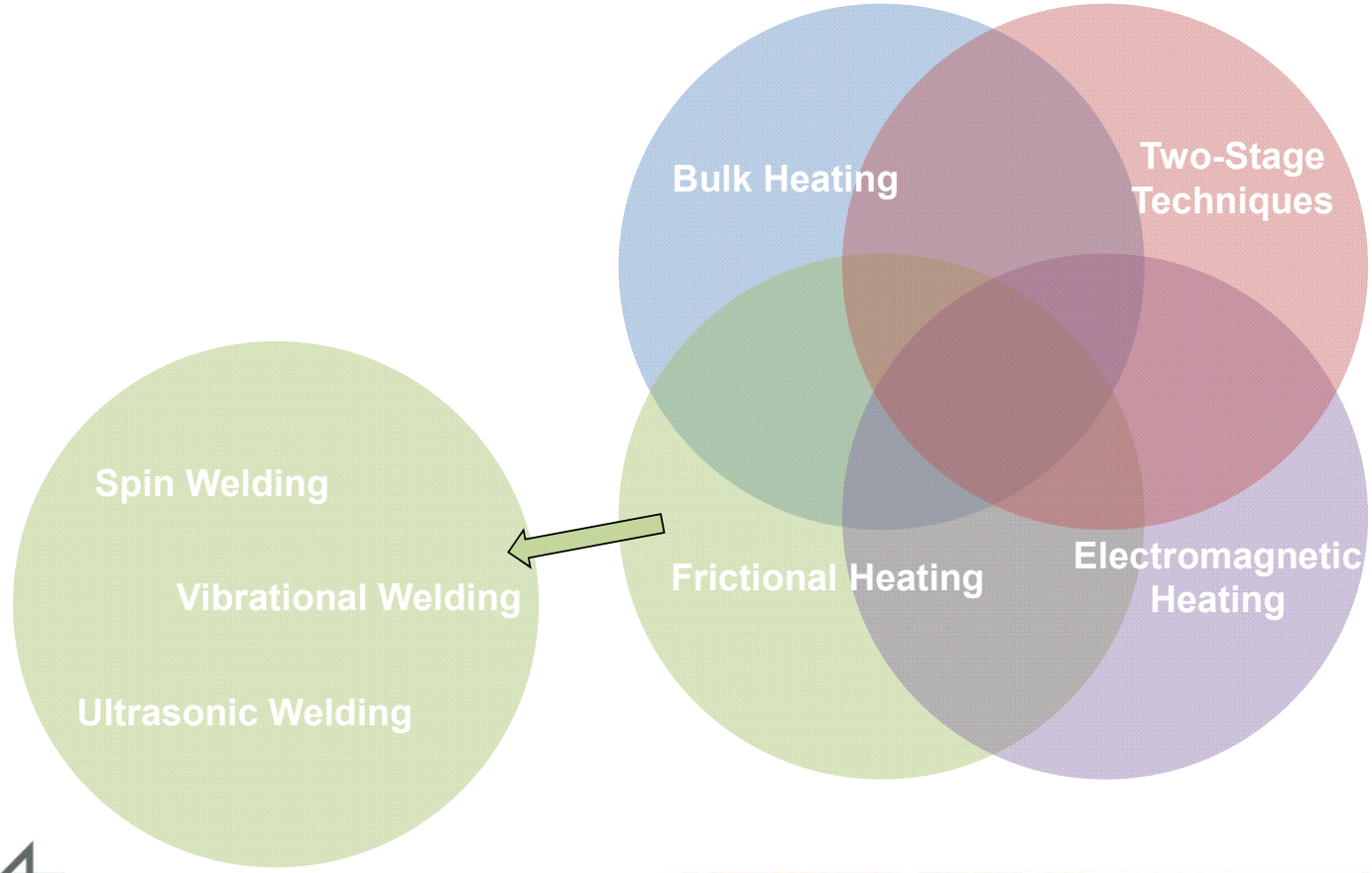


Fusion Bonding Processes for Thermoplastic Composites

An Overview



Fusion Bonding Processes for Thermoplastic Composites

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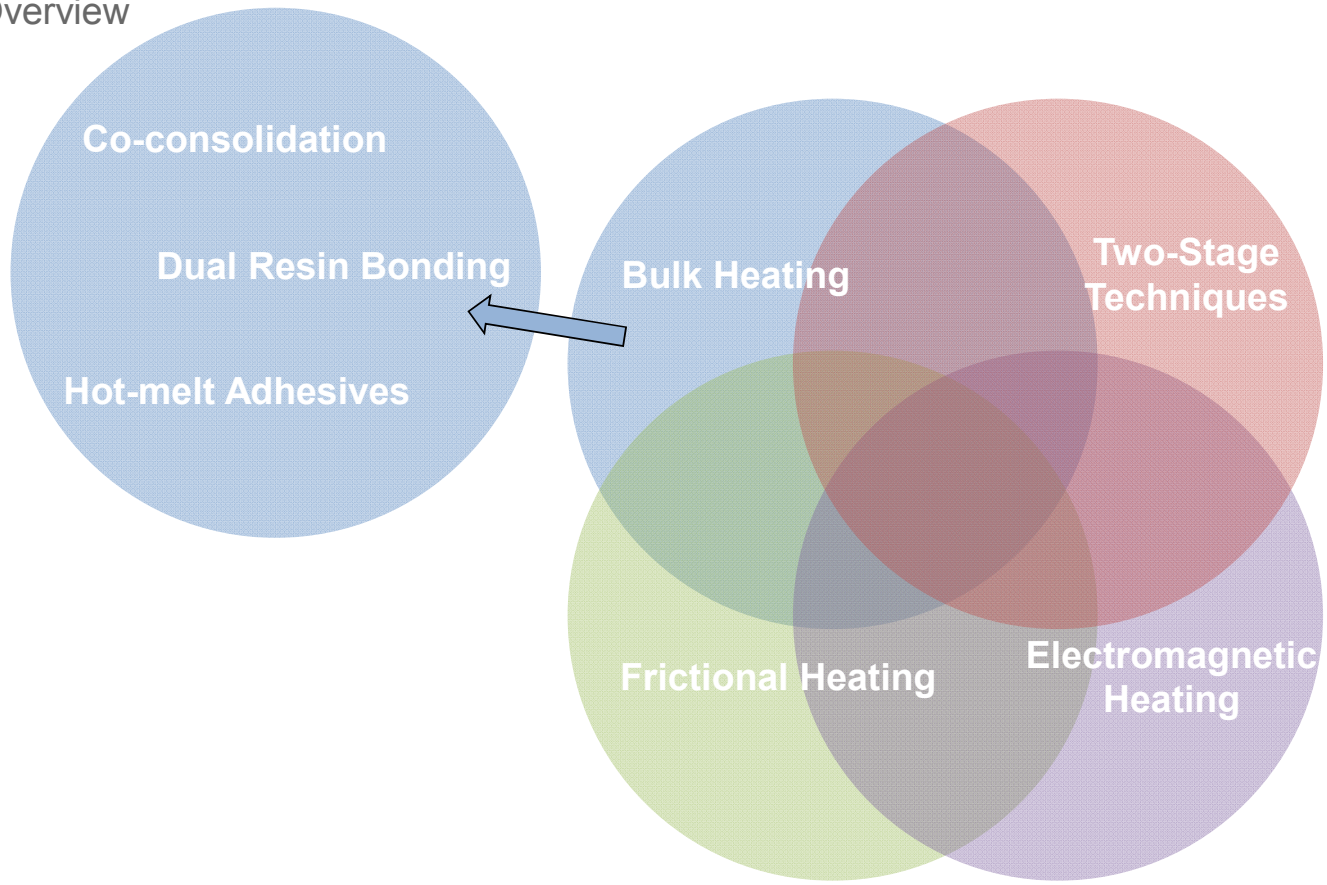


Fusion Bonding Processes for Thermoplastic Composites

Suitable Joining Technologies for Aerospace Components

Source: Premium AEROTEC GmbH

Which Joining Technology fits best?

Fusion Bonding Processes for Thermoplastic Composites

Suitable Joining Technologies for Aerospace Components

Co-consolidation

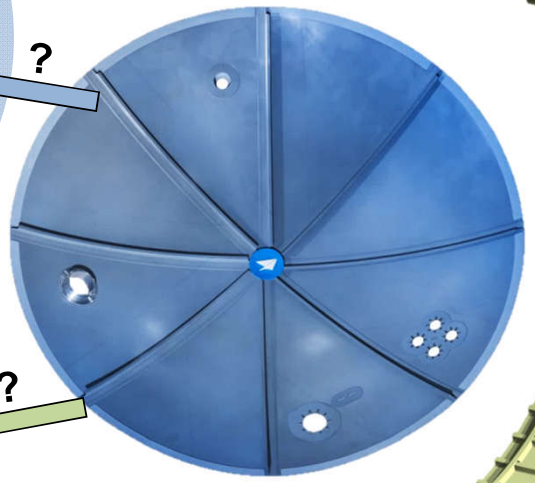
Dual Resin Bonding

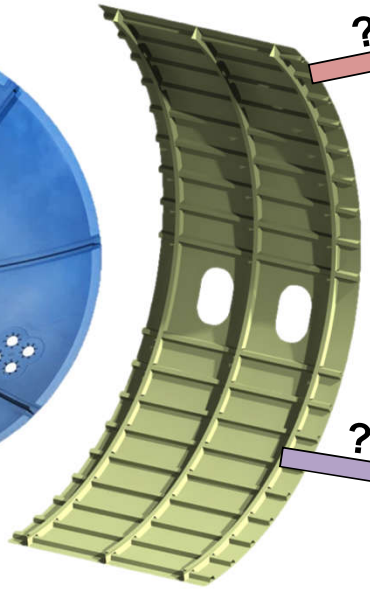
Hot-melt Adhesives

Spin Welding

Vibrational Welding

Ultrasonic Welding





Source: Premium AEROTEC GmbH

Hot Plate Welding

Hot Gas Welding

Radiant Welding
- Infrared Welding
- Focused Infrared Welding
- Laser Welding
- Solar Energy

Induction Welding

Microwave Heating

Dielectric Heating

Resistance Welding

Fusion Bonding Processes for Thermoplastic Composites

Suitable Joining Technologies for Aerospace Components

Co-consolidation

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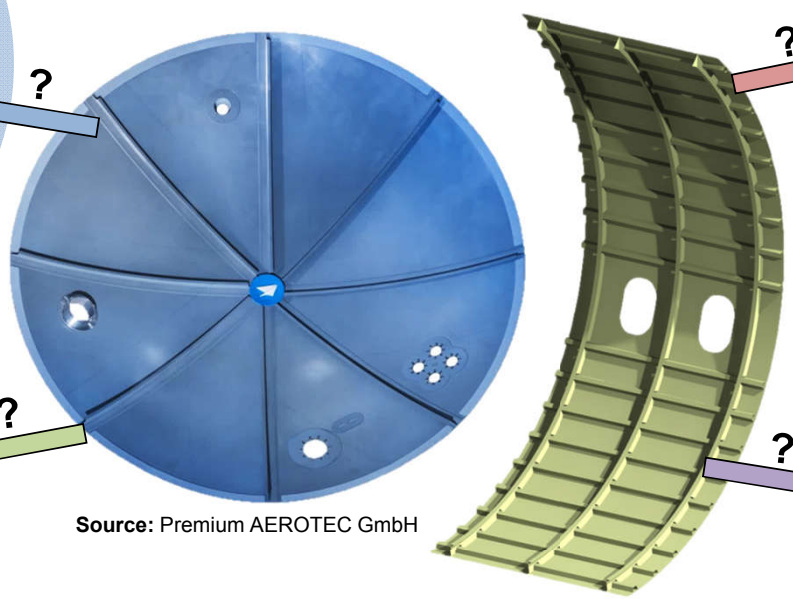


Source: Premium AEROTEC GmbH

Spin Welding

Vibrational Welding

Ultrasonic Welding

Induction Welding

Microwave Heating

Dielectric Heating

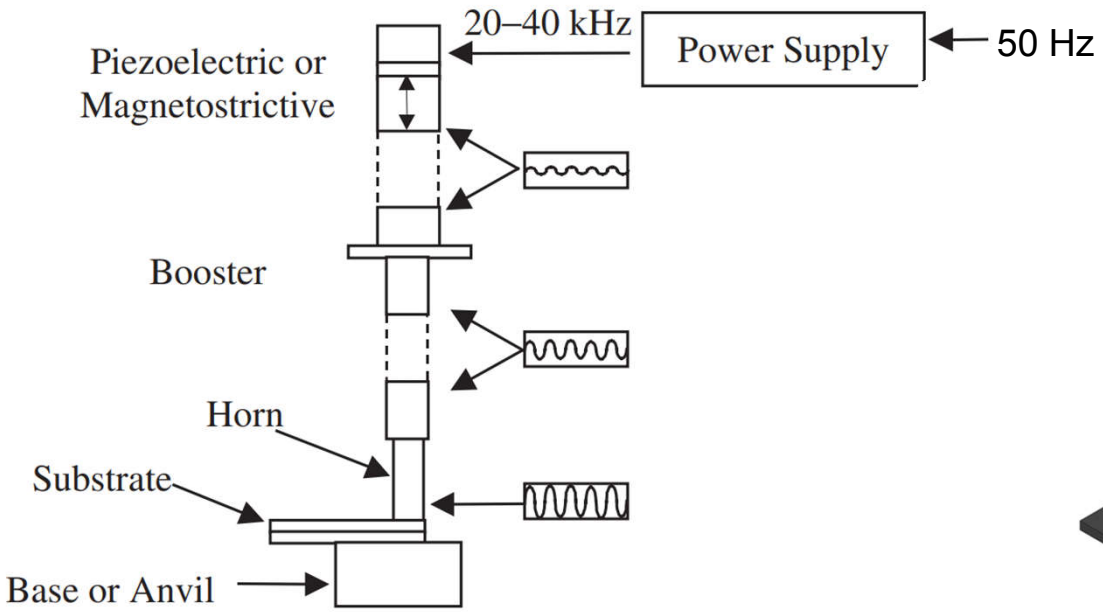
Resistance Welding

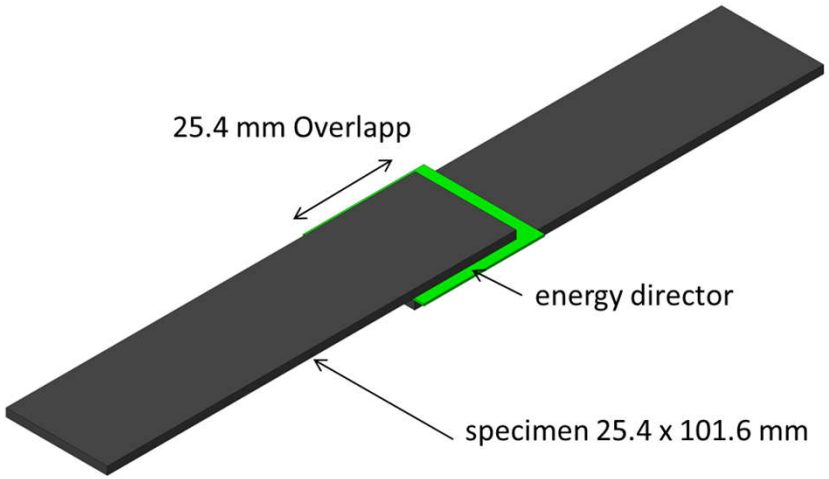
Welding Technologies in Focus

Ultrasonic Welding (USW)

Ultrasonic Welding

Process Principle



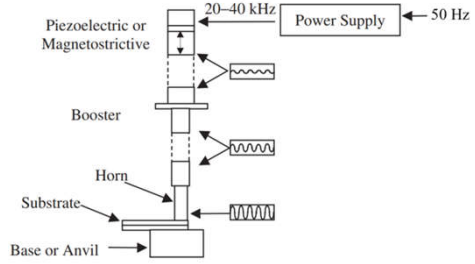


Source: Adapted from: A. Yousefpour, M. Hojjati, and J.-P. Immarigeon, "Fusion Bonding/ Welding of Thermoplastic Composites," *Journal of Thermoplastic Composite Materials*, vol. 17, pp. 303–341, Jul. 2004.

Ultrasonic Welding

From Process Principle to Industrial Implementation

Principle of USW



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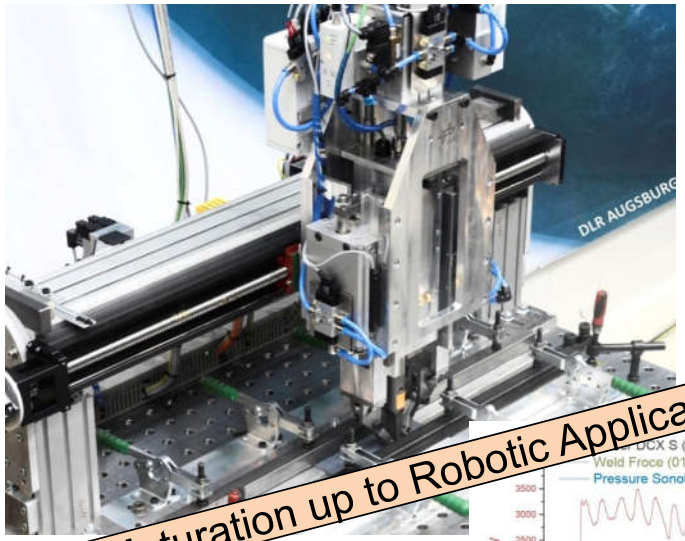
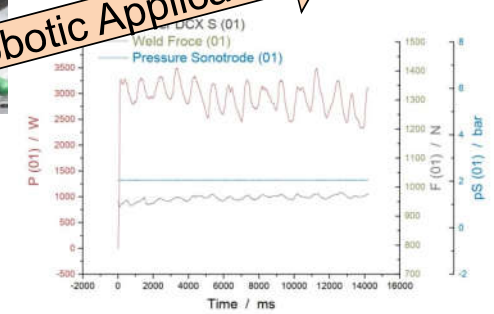
Technology Validation



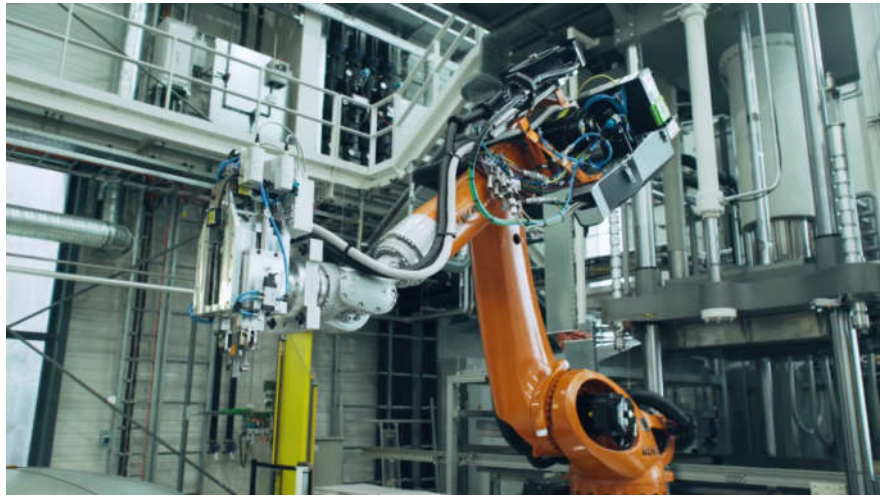


Technology Maturation up to Robotic Application

Robotic Application

Ultrasonic Welding

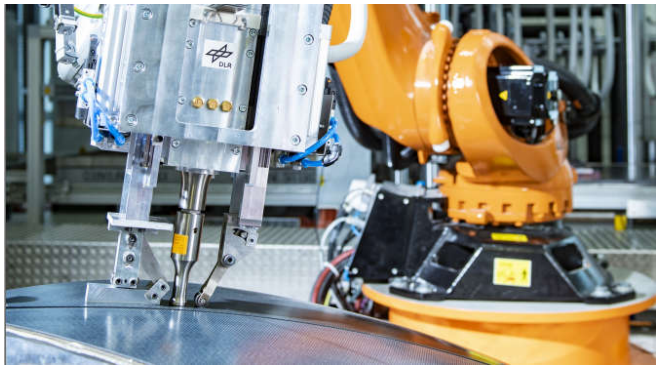
Latest Achievements



- cUS Endeffector mounted on a KUKA KR210 R3100 robot on a 8m linear track
- Different welding test have been performed on plane and curved specimen
- Achieved welding factor for CF/PPS ~ 0.61 (working on improvement)

Flat specimen welding (PPS, PEEK, PEKK)

Stringer welding onto skin (PEKK)

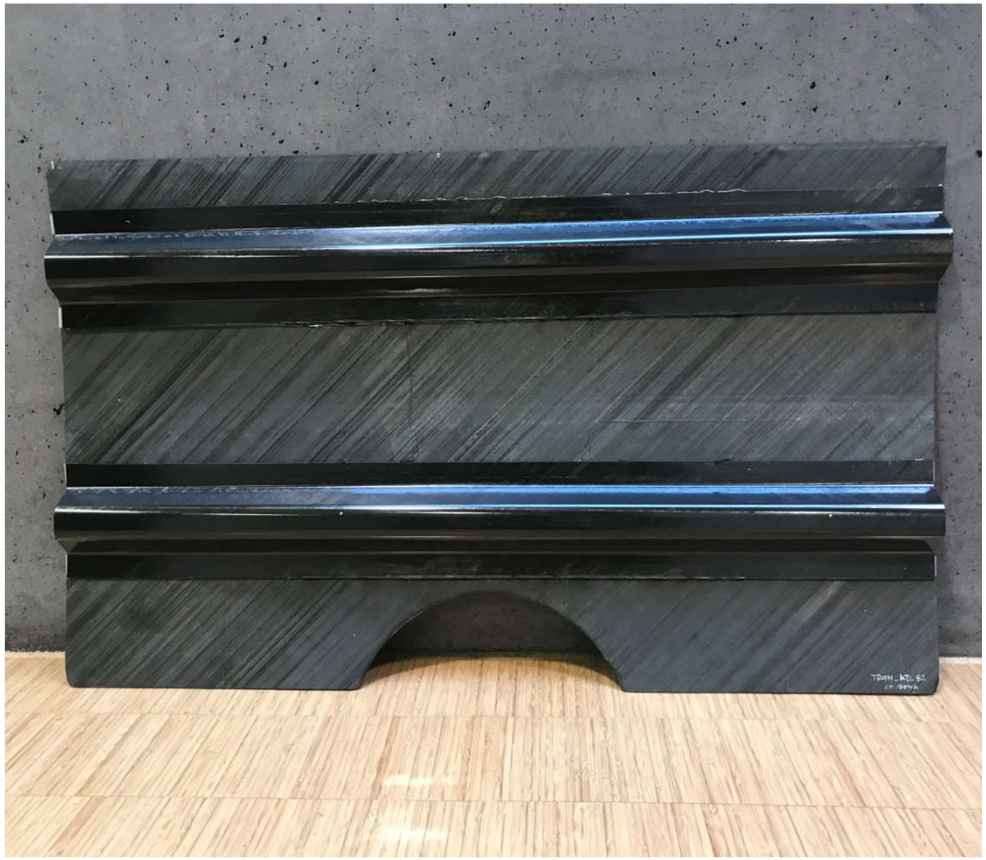


Welding of curved structure (PPS)

Ultrasonic Welding

Technology Demonstration

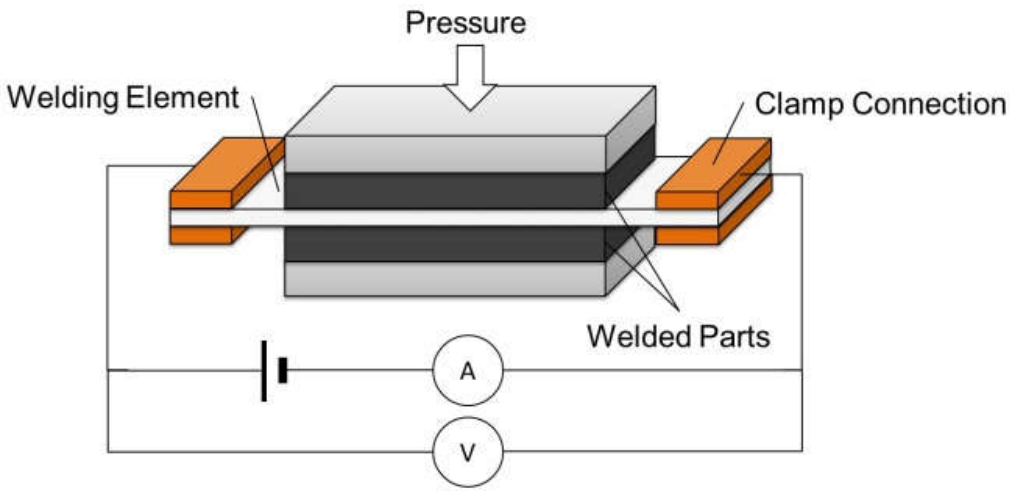
- Skin segment of a standard single aisle fuselage (*r*~2m, Section 16)
  - Dimension: 940mm x 580mm
  - Materials: Toho Tenax E TPUD-HTS45 PEKK (12“, i.e. 305mm tapes)
- Laminate of 104 cut pieces for P&P
- Welding of Stringers using cUW-Technology



Resistance Welding (RW)

Resistance Welding

Process Principle

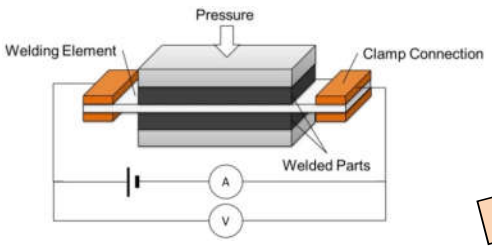


Source: Adapted from: D. Stavrov and H. E. N. Bersee, “Thermal Aspects in Resistance Welding of Thermoplastic Composites,” 2003.

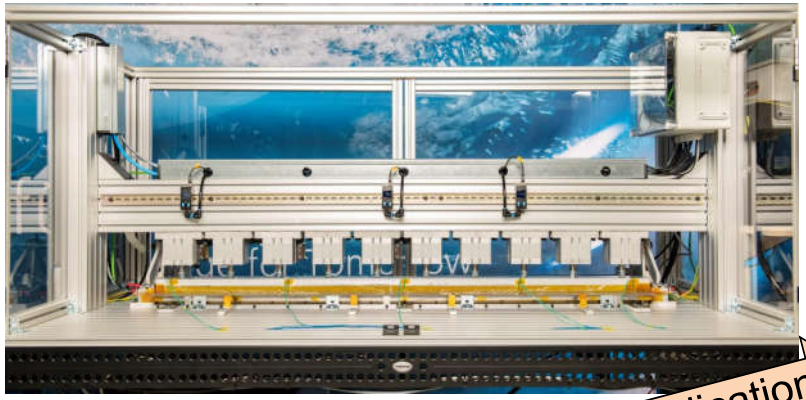
Resistance Welding

From Process Principle to Industrial Implementation

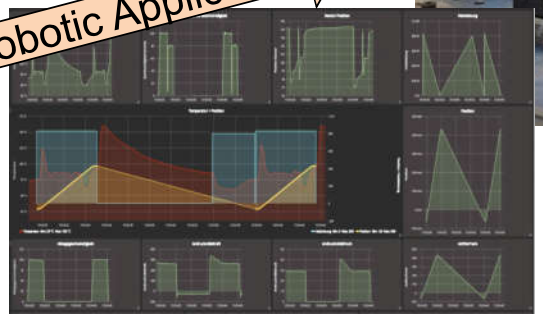
Principle of RW



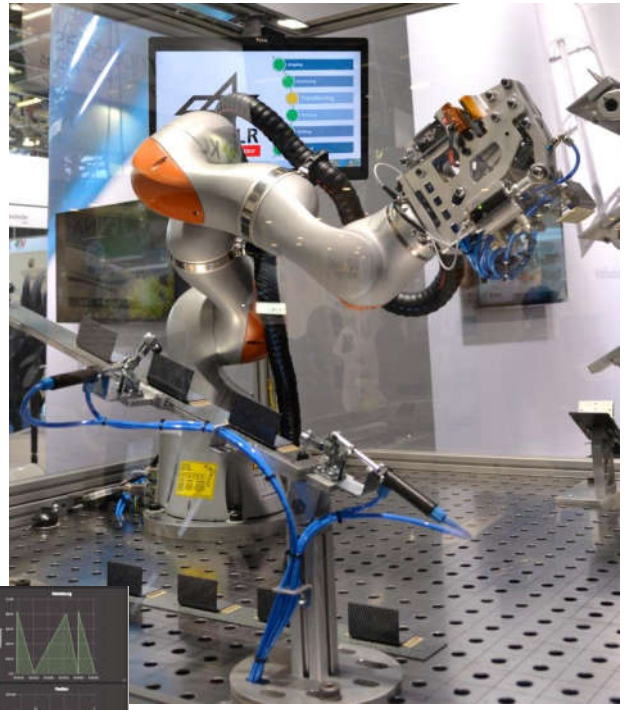
Technology Validation



Technology Maturation up to Robotic Application



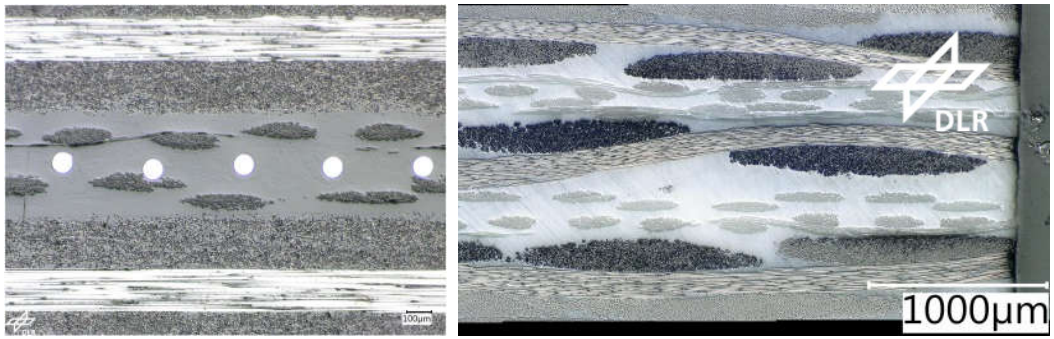
Robotic Application



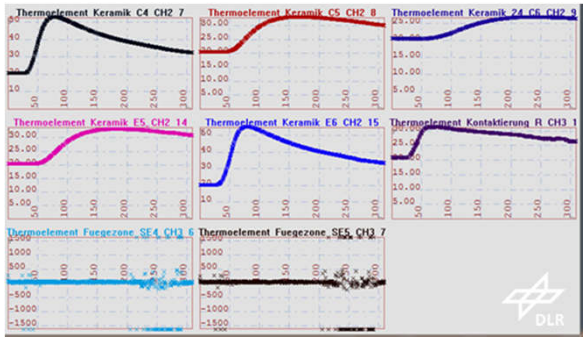
Resistance Welding

Latest Achievements

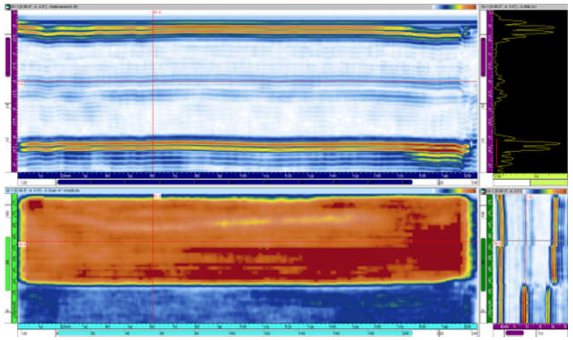
- Static RW-Process demonstrated for welds up to 1.5m using VA-Mesh and CF-Fabric as electrical conductor
- Applied In-Process Data Monitoring for RW test bench
- Achieved welding factor for CF/PPS ~ 0.77 (working on improvement)
- Low scatter of weld performance (1.9% @ SLS)
- Good temperature uniformity during processing
- …



Different electrical conductors for RW (VA-Mesh – left; CF-Fabric – right)



In-Process Data Monitoring

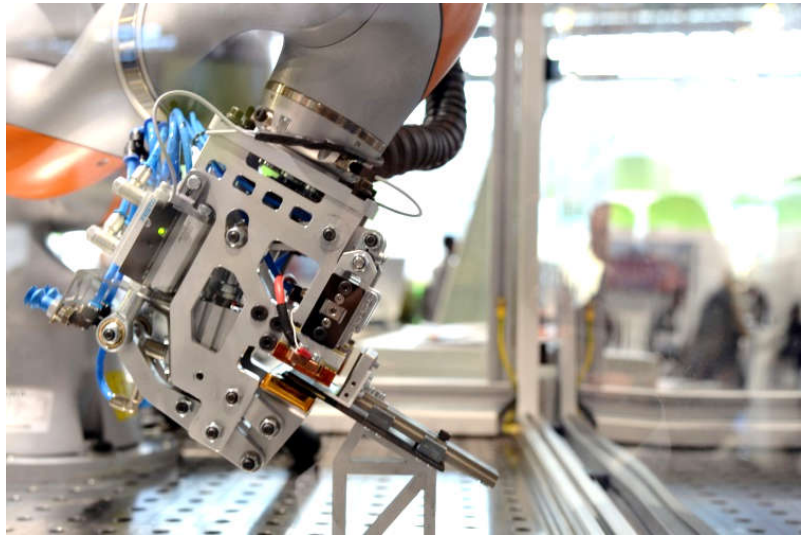


Ultrasonic Scan of CF/PPS Weld

Resistance Welding

Technology Demonstration

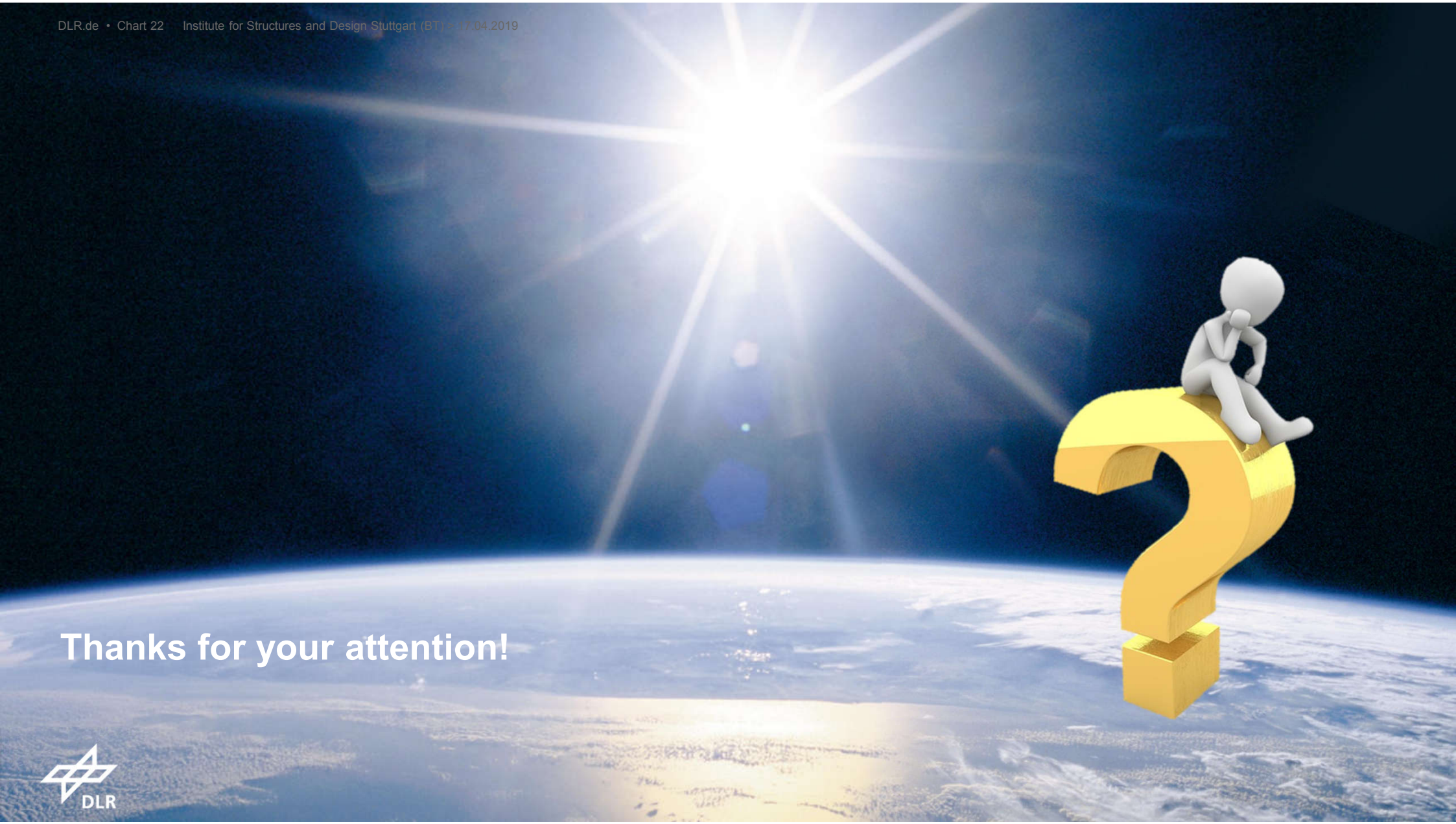
Sine Wave Beam (CF/PEI)



Clip Welding (CF/PEEK)

Quelle: Premium AEROTEC GmbH

Rear Pressure Bulkhead (CF/PPS)



Thanks for your attention!