The effect of welding parameters on interface temperature and mechanical properties for ultrasonic welding of flax/polypropylene composite without energy director

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Outline

- Context and objective
- Methodology
- Ultrasonic welding
- Conclusion & Outlooks

1 Context and objective

2 Methodology

3 Ultrasonic welding

4 Conclusion & Outlooks

Automobile, Sports, Building...

Urban furniture...

Welding of thermoplastic composites

Differing in how heat is generated at the interface

Thermal

- Hot plate welding
- Hot gaz welding
- Infrared welding
- Laser welding

External heat input to the interfaces + Contacting the 2 surfaces under pressure

Electromagnetic

- Induction welding
- Dielectric welding
- Micro-wave welding
- Resistance welding

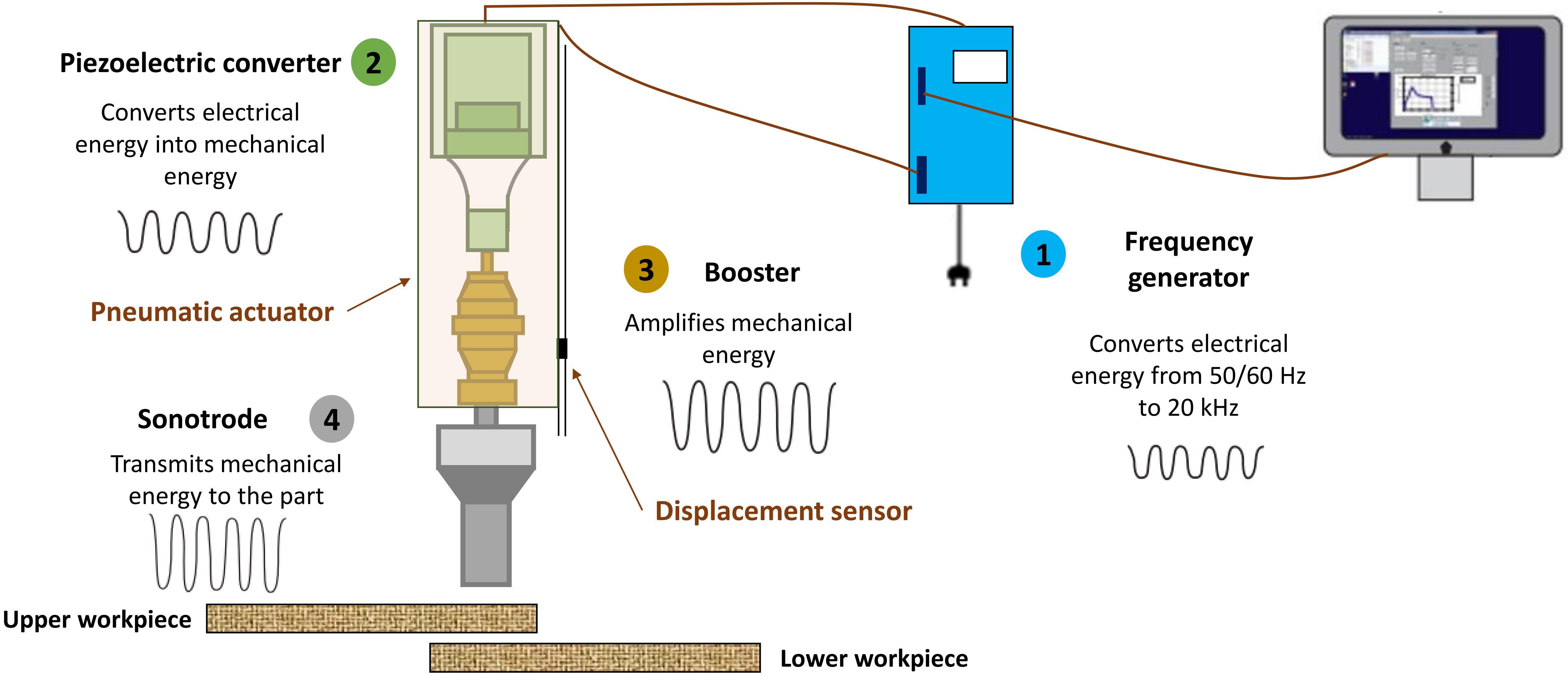
Interface heating by an high-frequency field + Contacting the 2 surfaces under pressure

Friction

- Friction stir welding
- Vibration welding
- **Ultrasonic welding**
- Rotational welding

Friction at the interface + Pressure cooling

YOUSEFPOUR, Ali, HOJJATI, Mehdi, et IMMARIGEON, Jean-Pierre. Fusion bonding/welding of thermoplastic composites. Journal of Thermoplastic composite materials, 2004, vol. 17, no 4, p. 303-341.


Piezoelectric converter 2
Converts electrical energy into mechanical energy
Pneumatic actuator
Sonotrode 4
Transmits mechanical energy to the part
Upper workpiece
Lower workpiece
3 Booster
Amplifies mechanical energy
Displacement sensor
1 Frequency generator
Converts electrical energy from 50/60 Hz to 20 kHz

Analyzing the influence of ultrasonic welding parameters on the mechanical properties and temperature profiles generated during the welding process

Determining the optimal ultrasonic welding parameters for thermoplastic composites reinforced with flax fibers

Achieving strong welds and enhancing the reliability of the welding process

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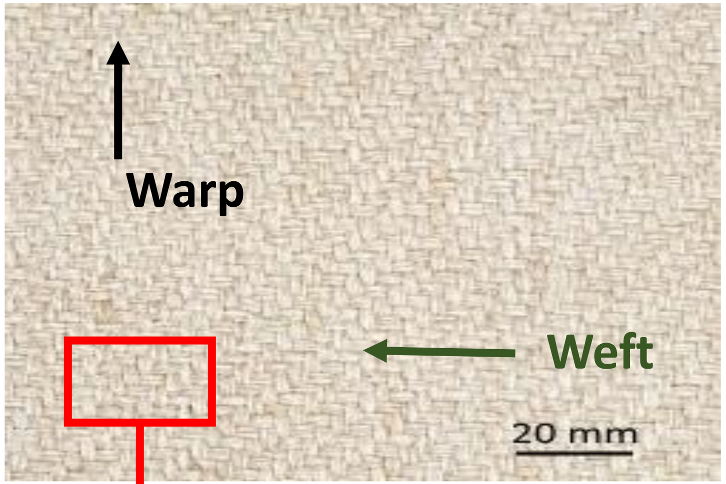
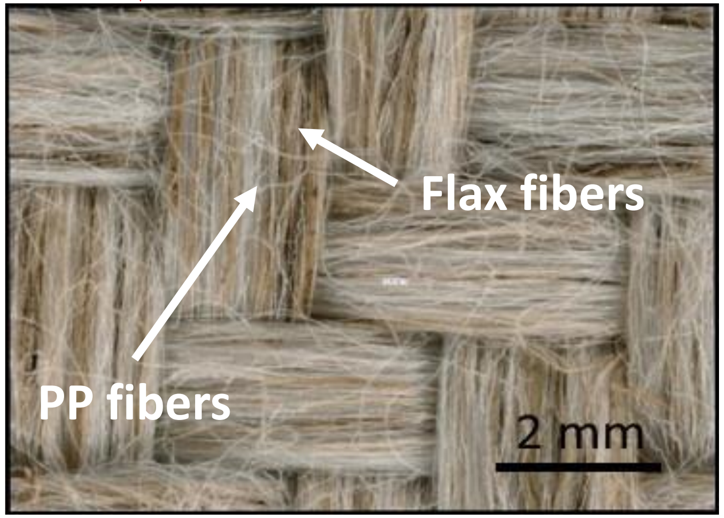
Lincore Flax/PP

Manufacturing process | Ultrasonic welding | Caracterisation





LINCORE® PP FF P2 40 400

Depestele

PP : Polypropylene matrix

FF : Flax fabrics

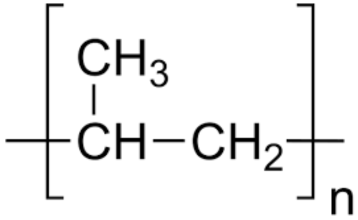
T2 : Twill 2/2

40 : Flax content in wieight (%)

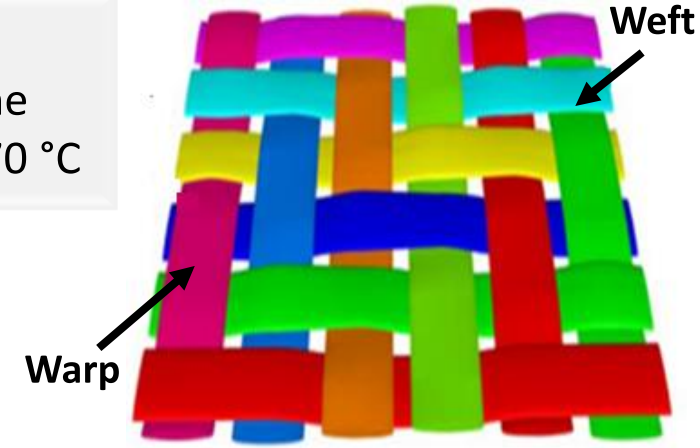
440 : Nominal weight (g/m2)

PP matrix

- Semi-crystalline
- $T_f\ =\ 150$ à 170 °C

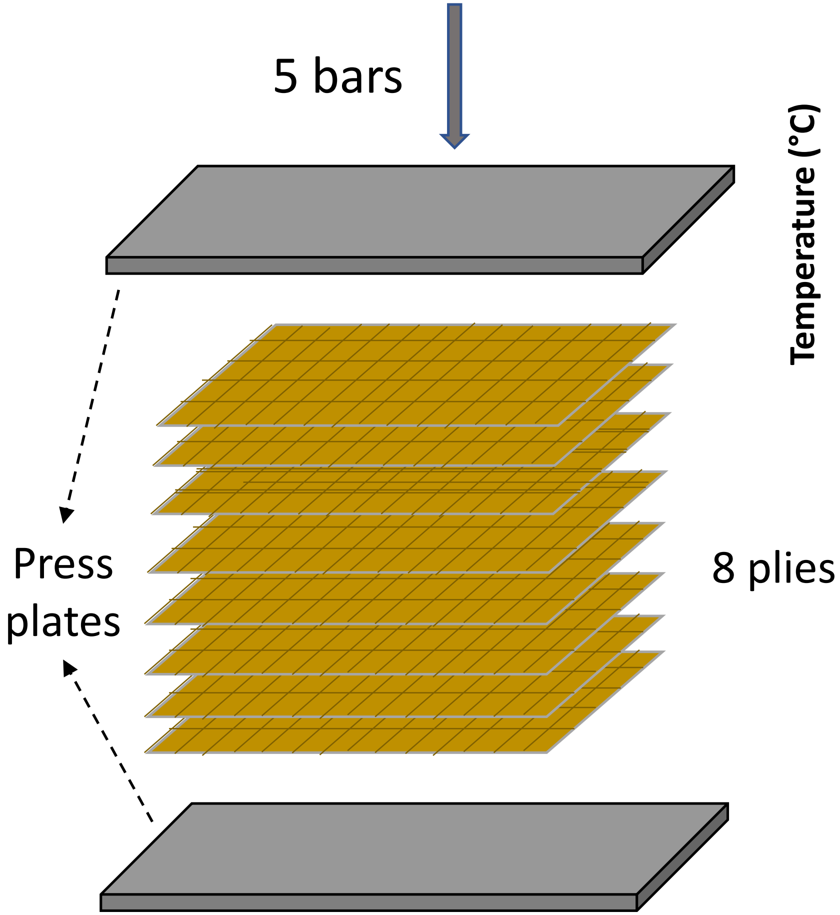


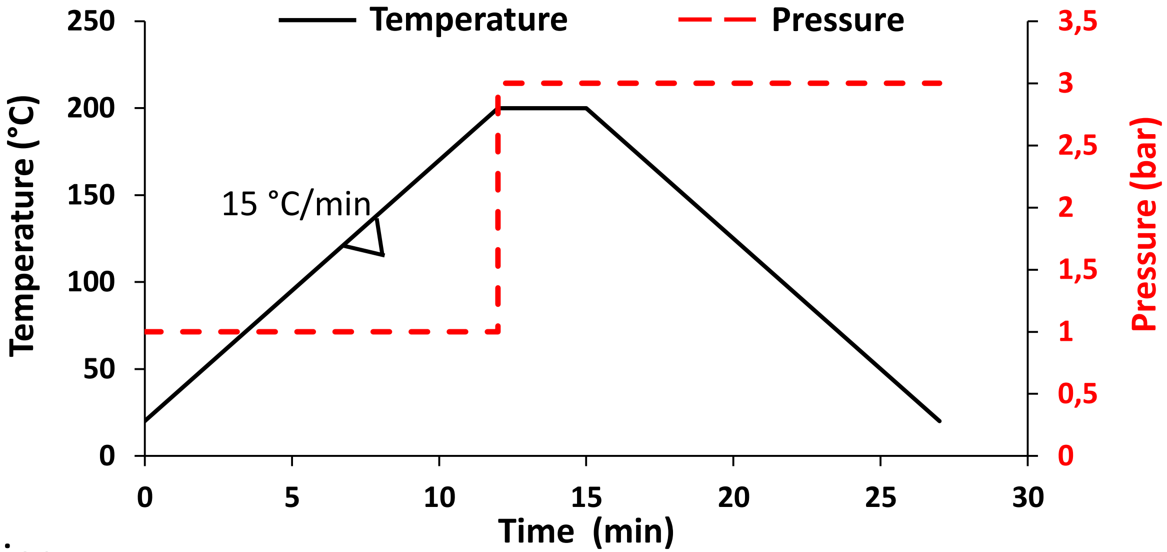
Twill 2/2



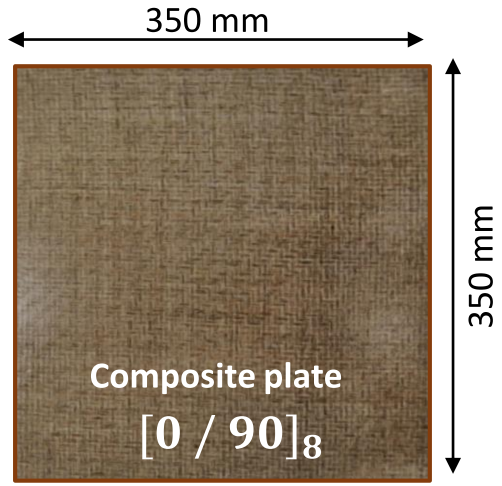
Lincore Flax/PP | **Manufacturing process** | Ultrasonic welding | Caracterisation

- **Thermocompression**



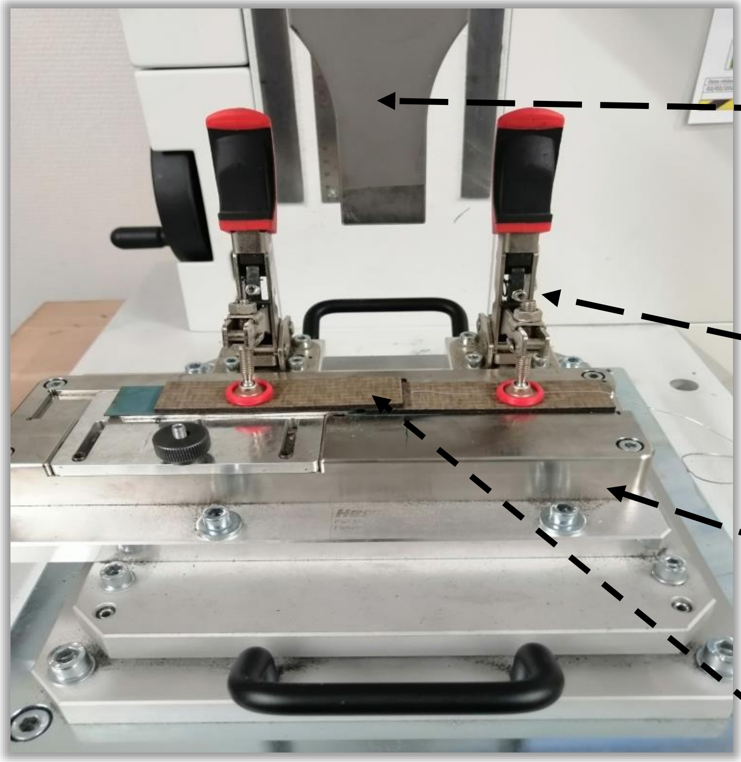


200 °C, 3 min



Ultrasonic welding

Pneumatic machine Herrmann
20 kHz – 3600 W

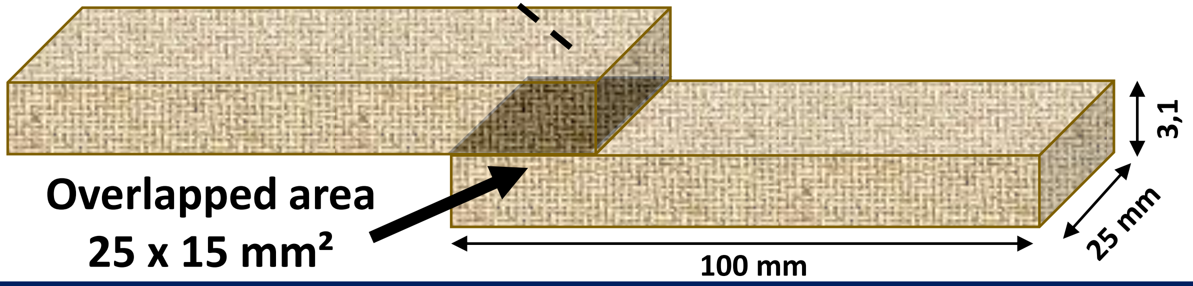


Rectangular sonotrode 25 x 40 mm²

Clamp fixation

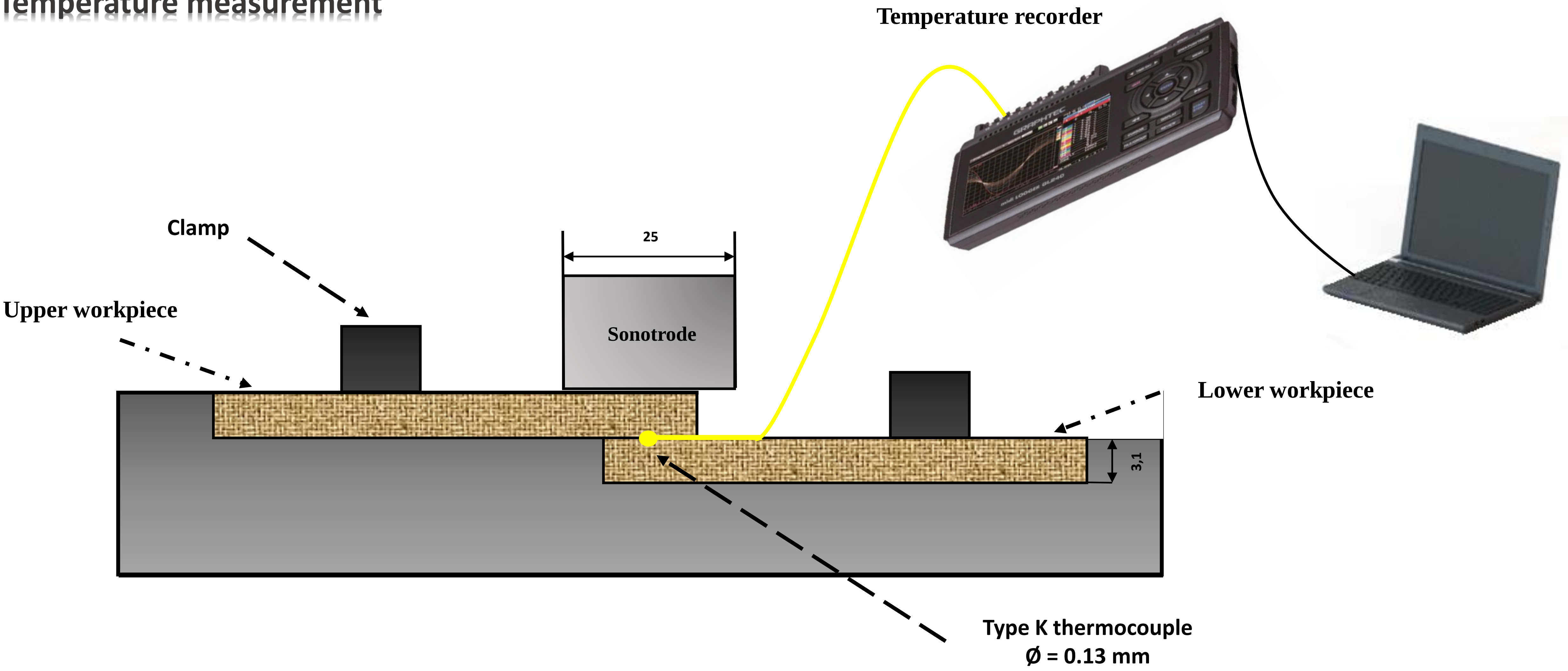
Anvil

Time mode	✓ Welding time ✓ Welding force ✓ Amplitude (35 µm) ✓ Consolidation time (2s) ✓ Consolidation force
Energy mode	✓ Energy ✓ Welding force ✓ Amplitude (35 µm) ✓ Consolidation time (2s) ✓ Consolidation force
Displacement mode	✓ Displacement ✓ Welding force ✓ Amplitude (35 µm) ✓ Consolidation time (2s) ✓ Consolidation force



Overlapped area
25 x 15 mm²

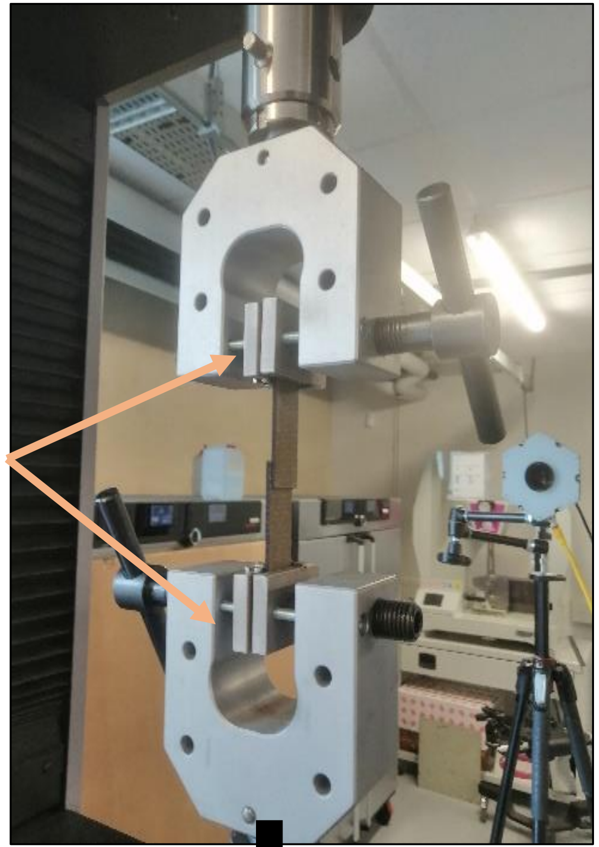
➢ Temperature measurement



➢ Mechanical testing : Lap shear strength (LSS)

ASTM D1002

2 mm/min



Misaligned jaws

25 mm

15 mm

$$\color{red}{LSS1} = \frac{Peak\ load}{\color{red}{Total\ overlap\ area}}$$

LSS1 quantifies the effectiveness of the joint

$$\color{blue}{LSS2} = \frac{Peak\ load}{\color{blue}{Effective\ welded\ area}}$$

LSS2 defines the weld quality

VILLEGAS, Irene Fernandez et BERSEE, Harald EN. Ultrasonic welding of advanced thermoplastic composites: An investigation on energy-directing surfaces. Advances in Polymer Technology, 2010, vol. 29, no 2, p. 112-121.

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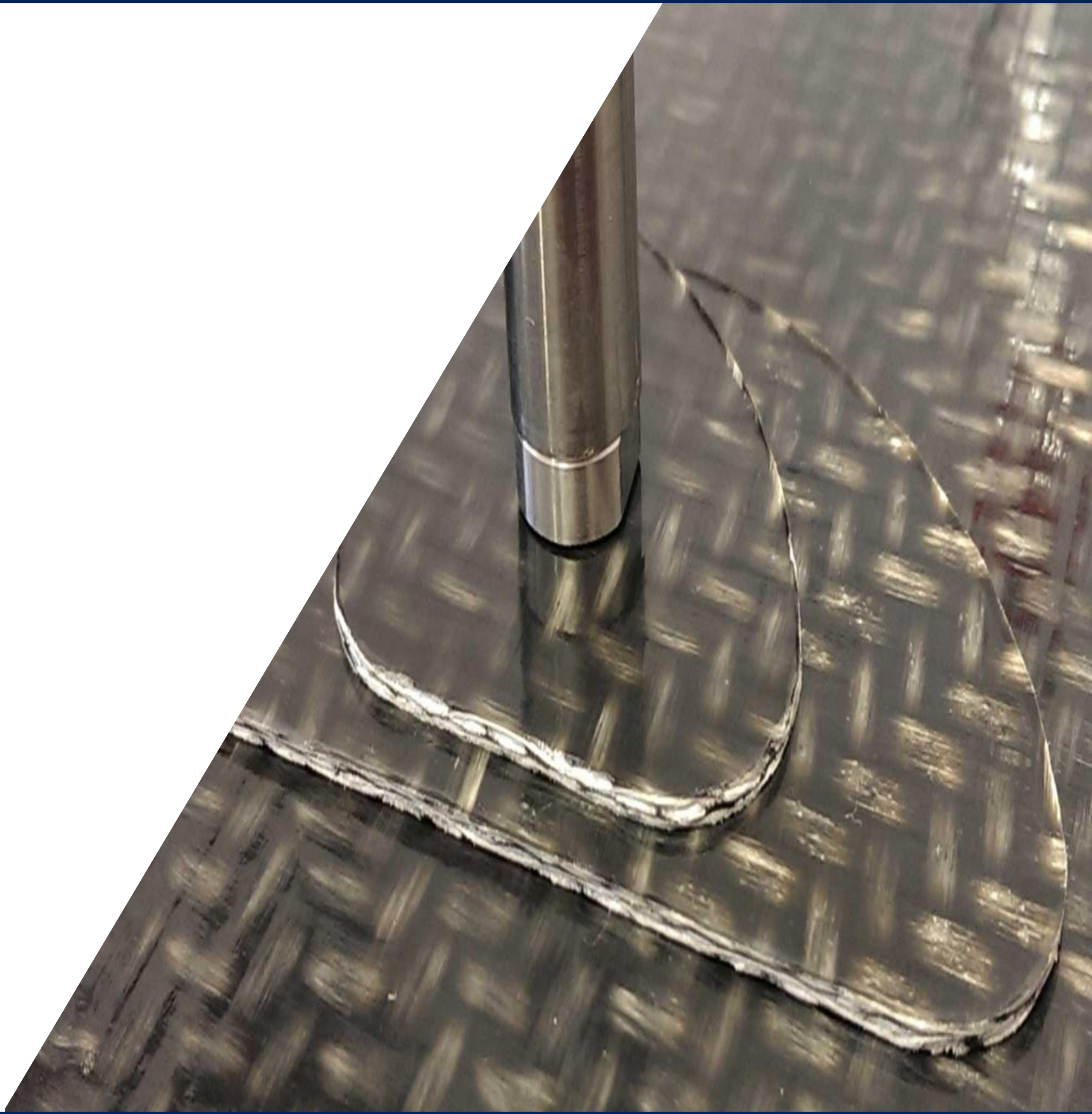


Thermal analysis

Lap-shear-strength

Fractography analysis

- **Temperature profile**

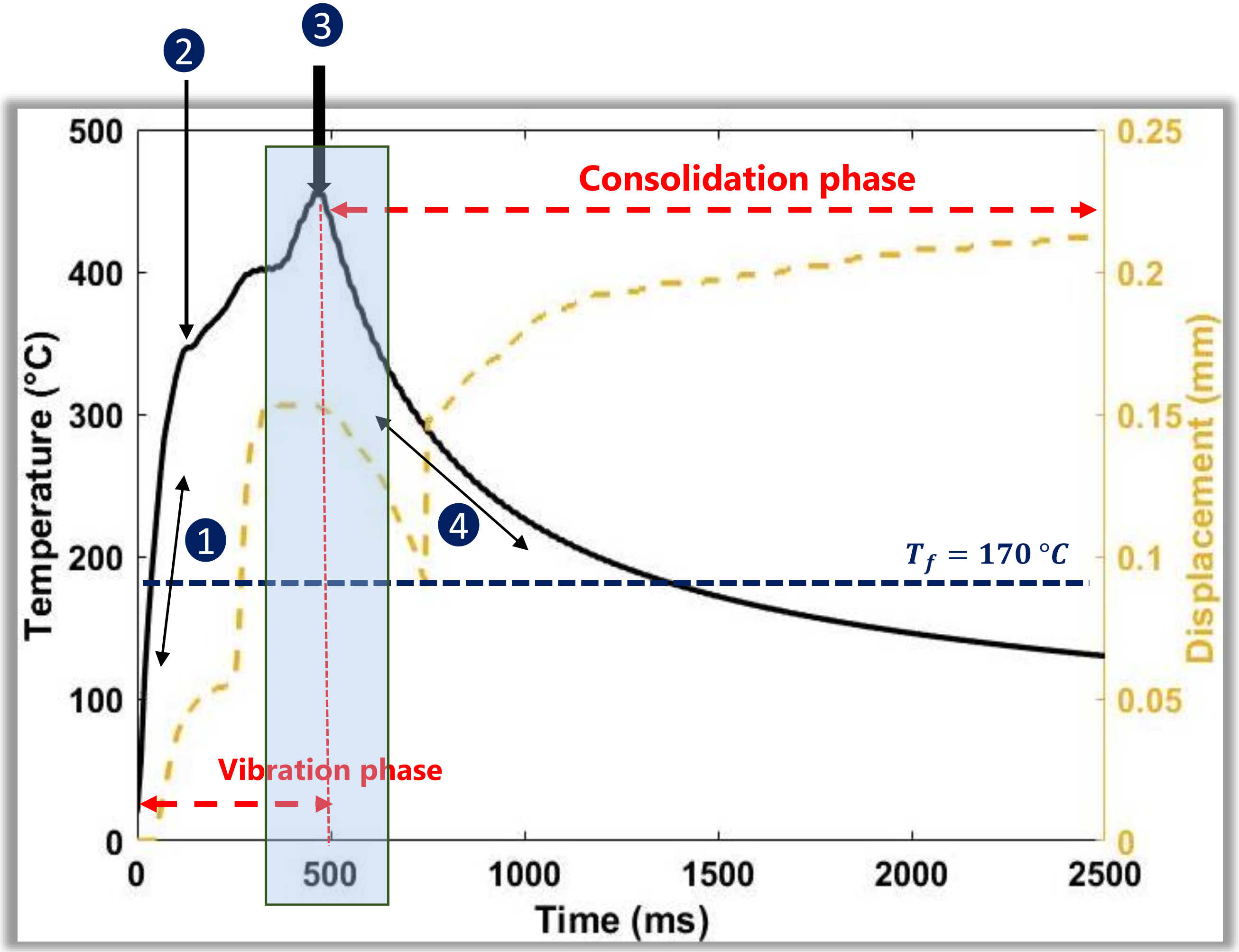
Amplitude = 35 µm

Welding time= 500 ms

Welding force= 400 N

Consolidation time= 2000 ms

Consolidation force = 400 N



1 Heating at 2500 °C/s

2 PP flow

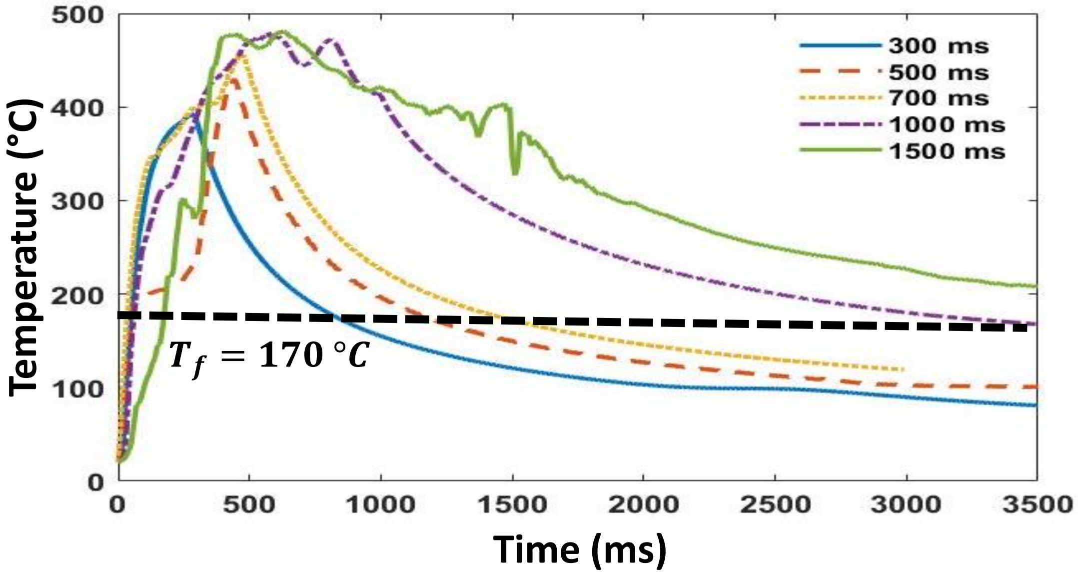
3 End of vibration

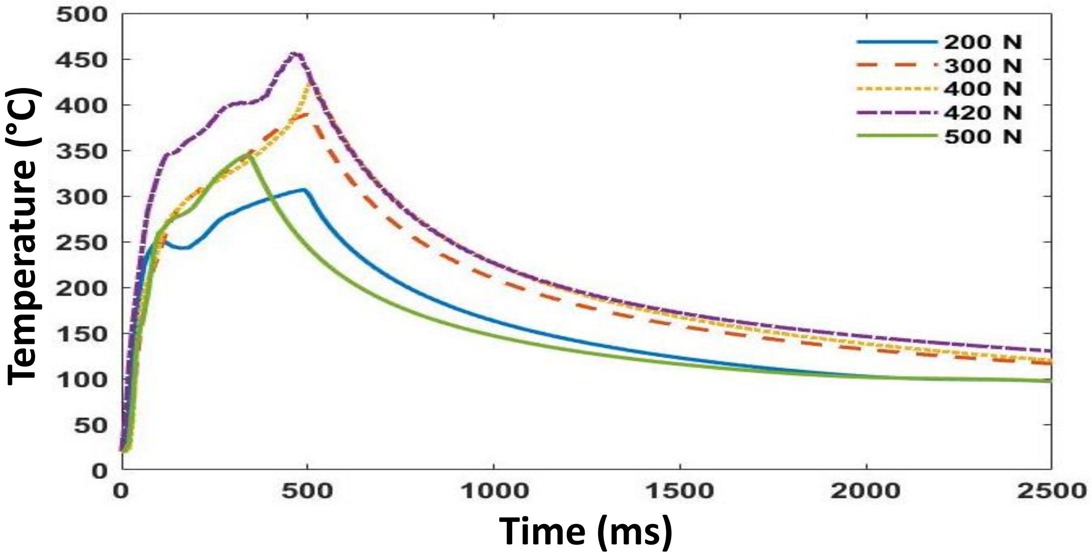
4 Cooling at 600 °C/s

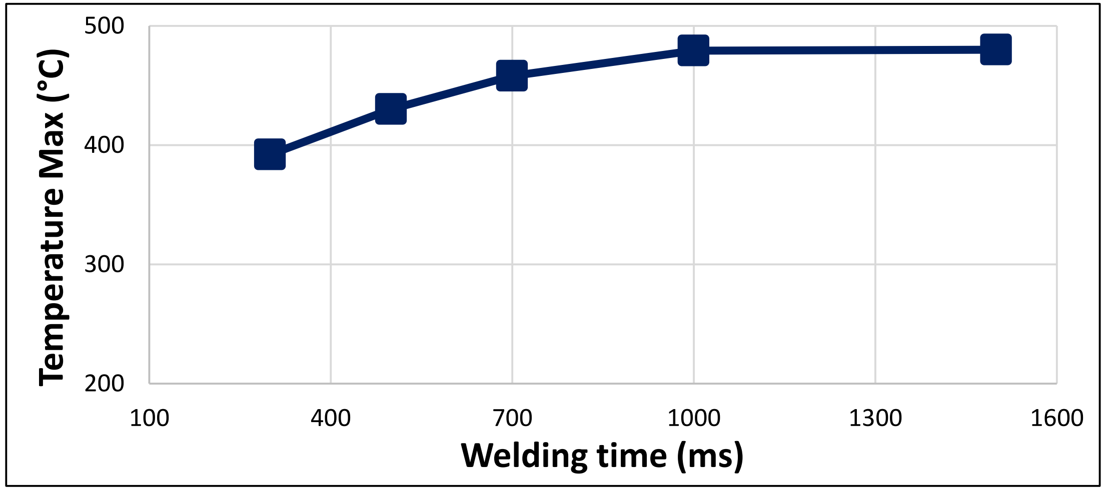
Thermal analysis

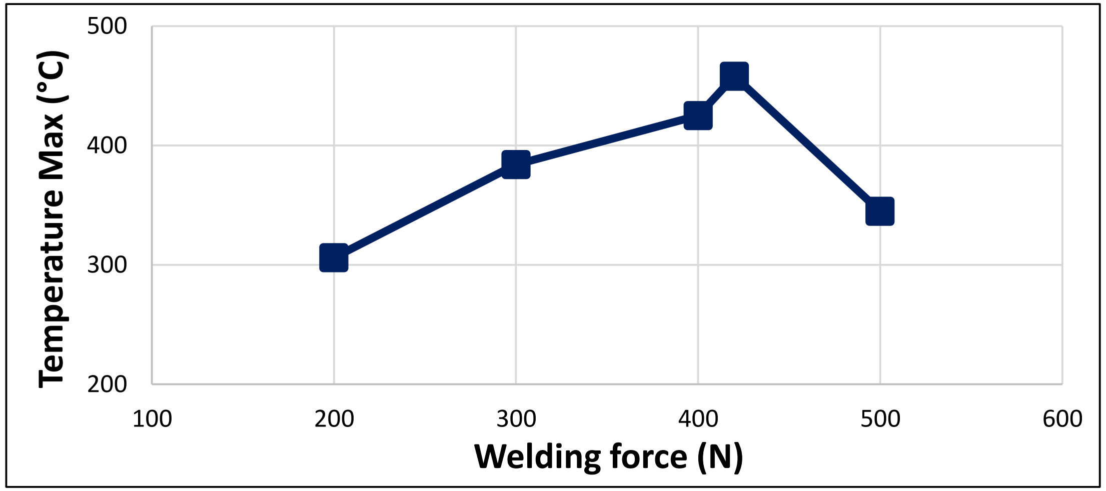
Lap-shear-strength

Fractography analysis

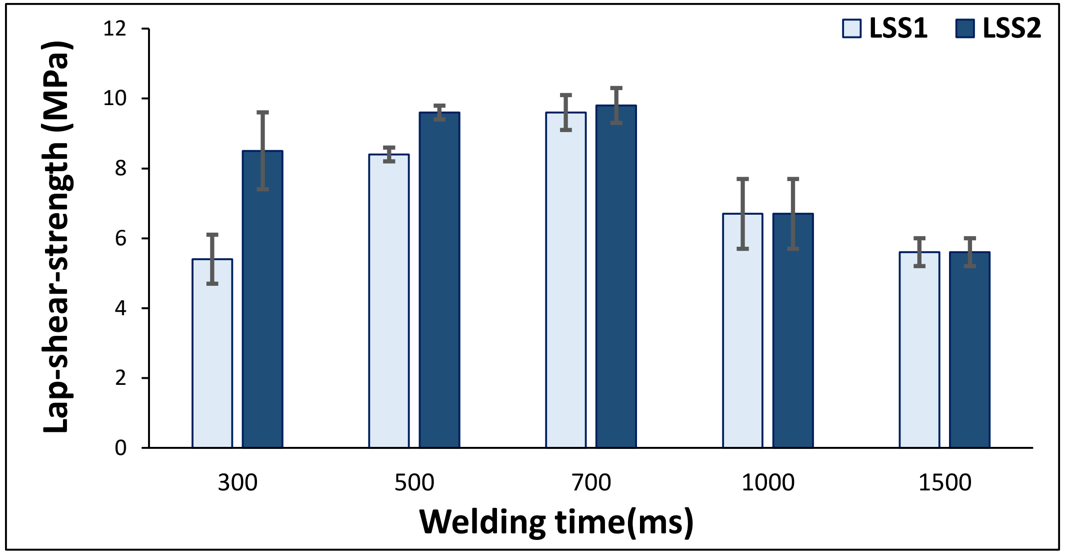


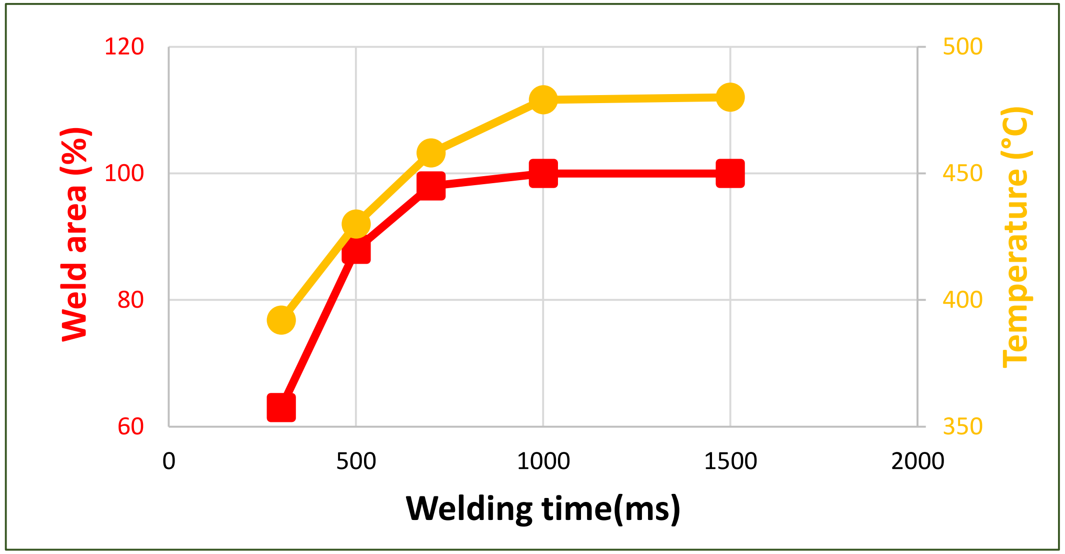






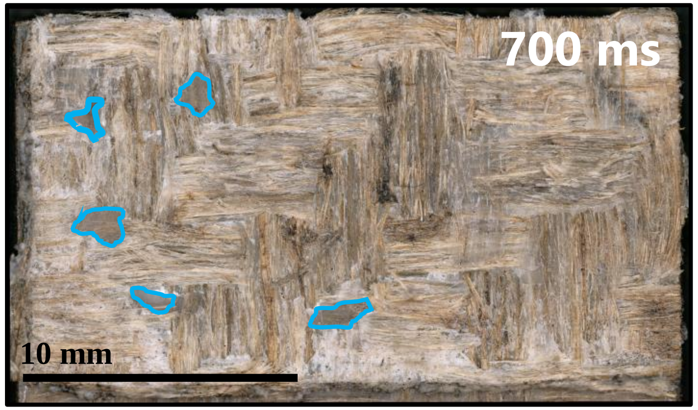
Thermal analysis | **Lap-shear-strength** | Fractography analysis





Welding time

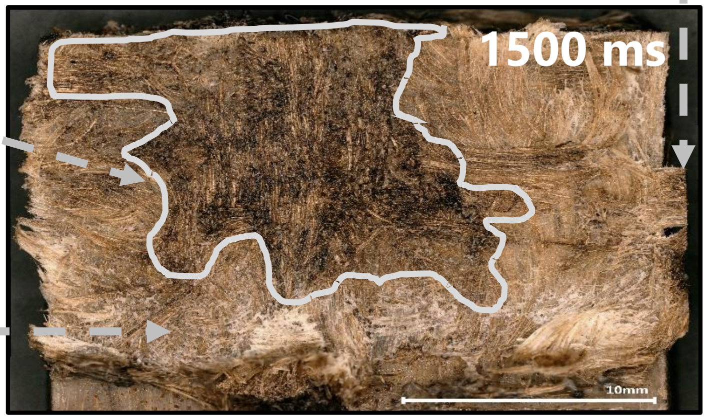
Unwelded area



Expulsion

Darkened area

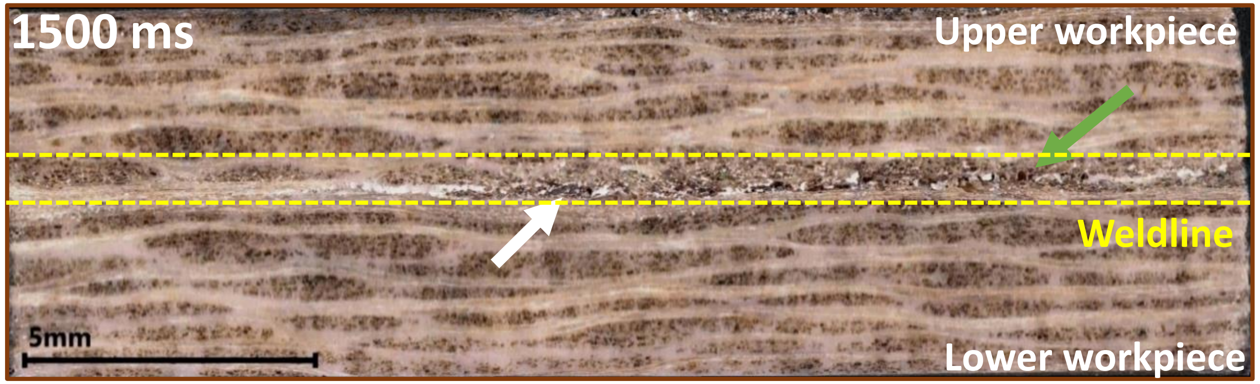
Fibre deformation

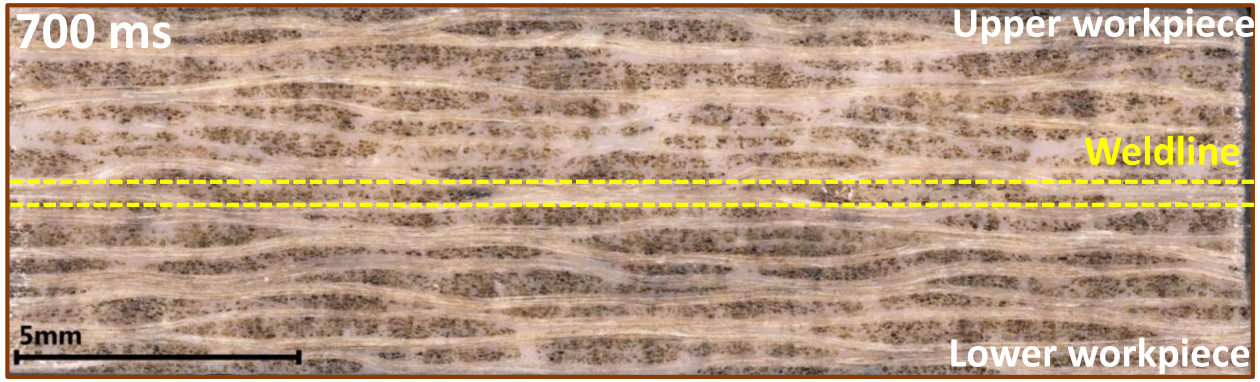


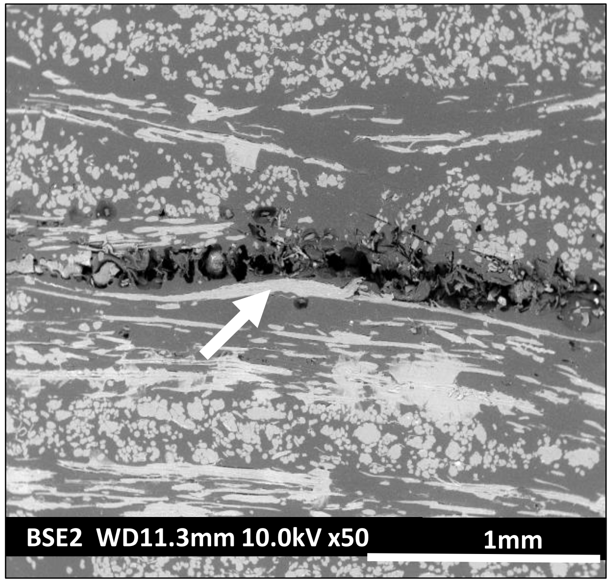
Under-welded | **Good-welded** | **Over-welded**

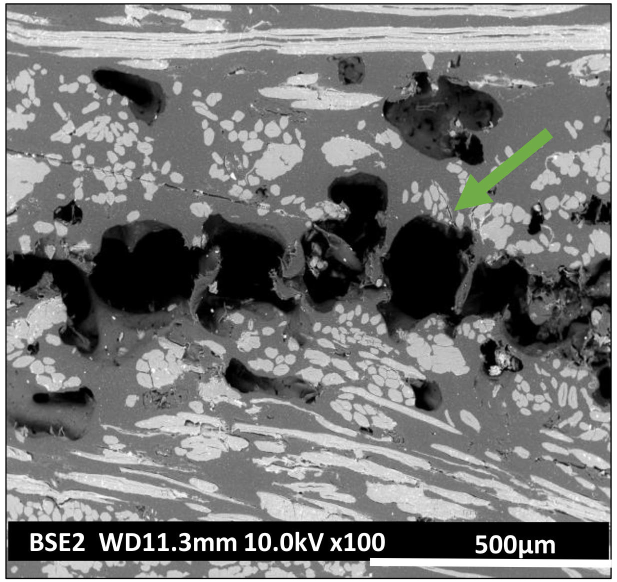
Thermal analysis | Lap-shear-strength | **Fractography analysis**

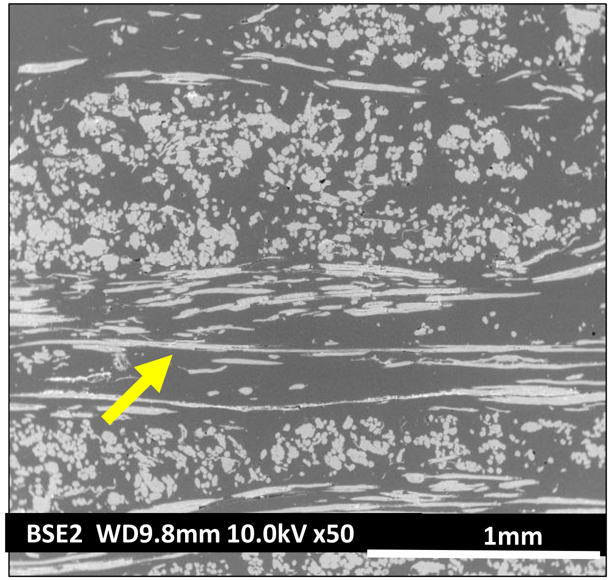
➢ Welding time

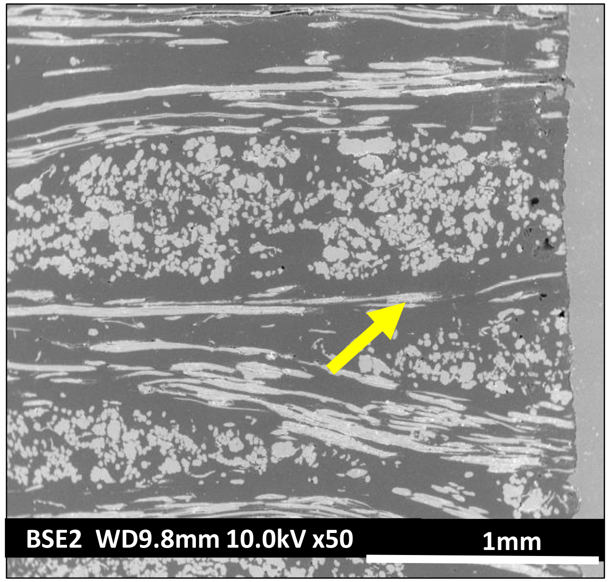










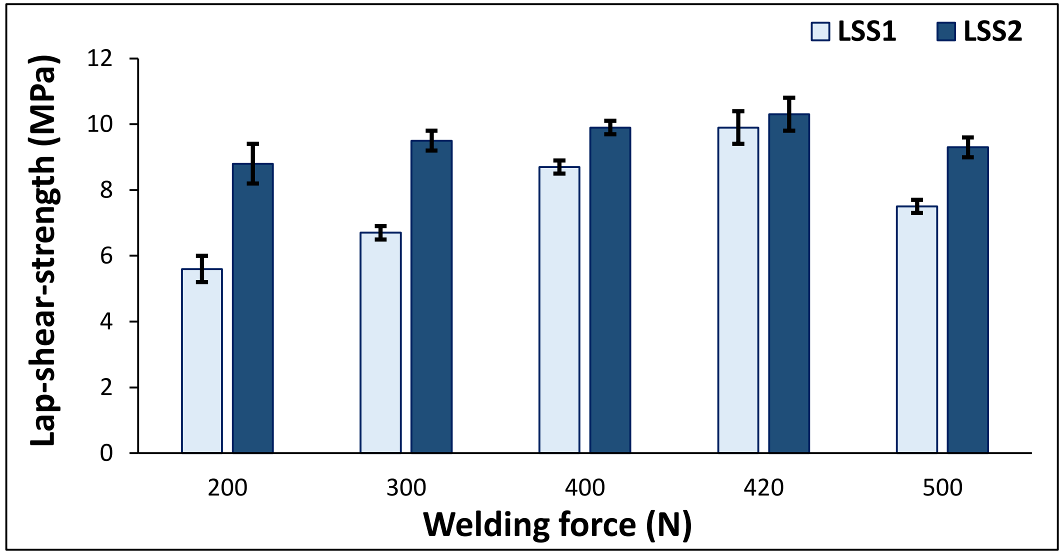


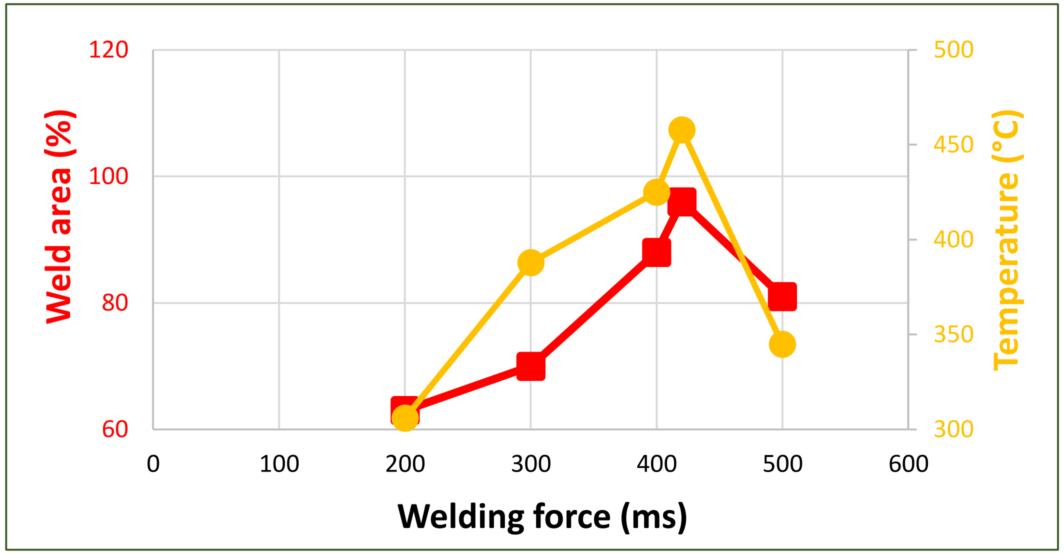
Thermal analysis

Lap-shear-strength

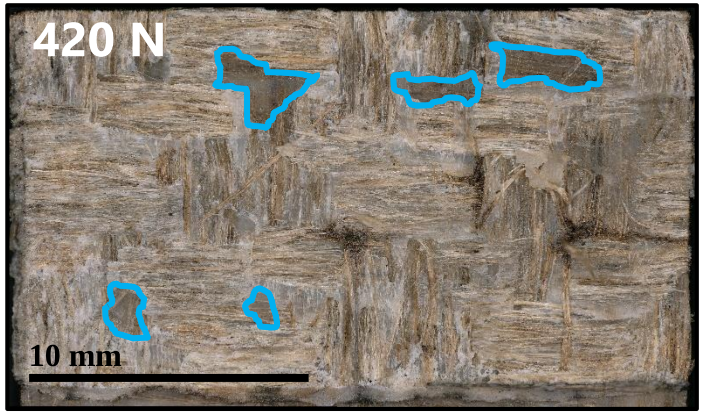
Fractography analysis

➢ Welding force





Unwelded area



Unwelded area

Under-welded

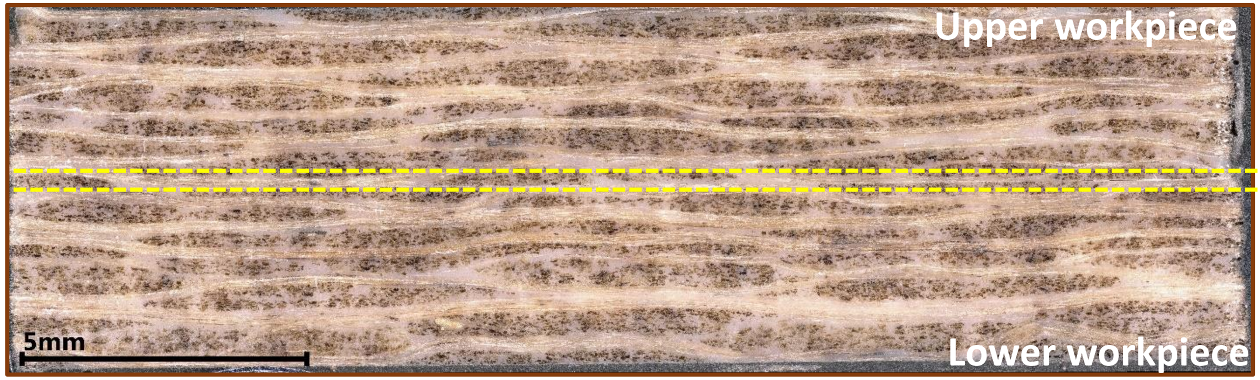
Good-welded

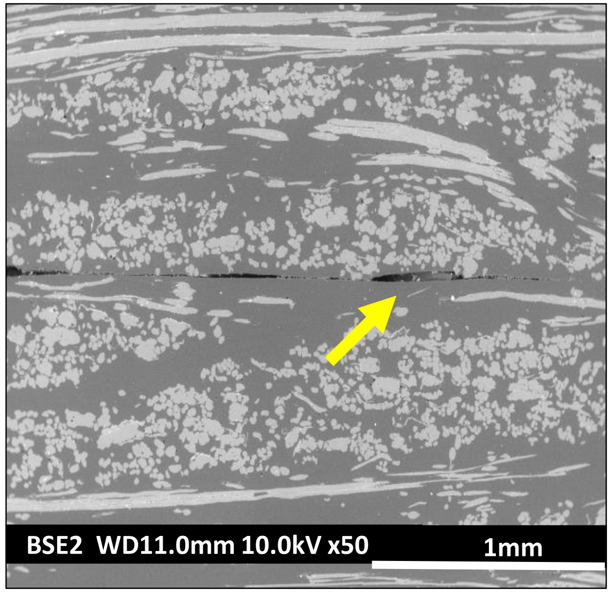
Under-welded

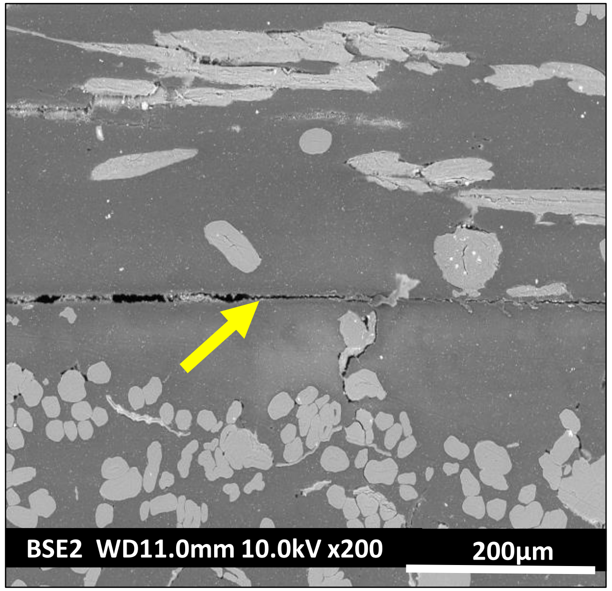
Thermal analysis | Lap-shear-strength | **Fractography analysis**

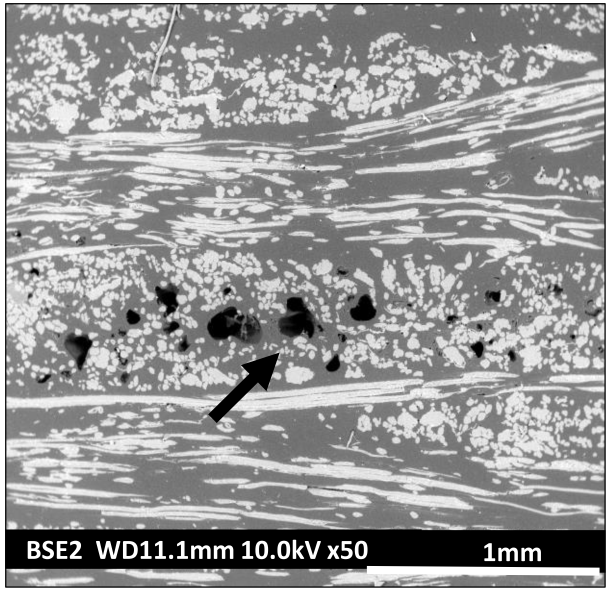
- **Welding force**

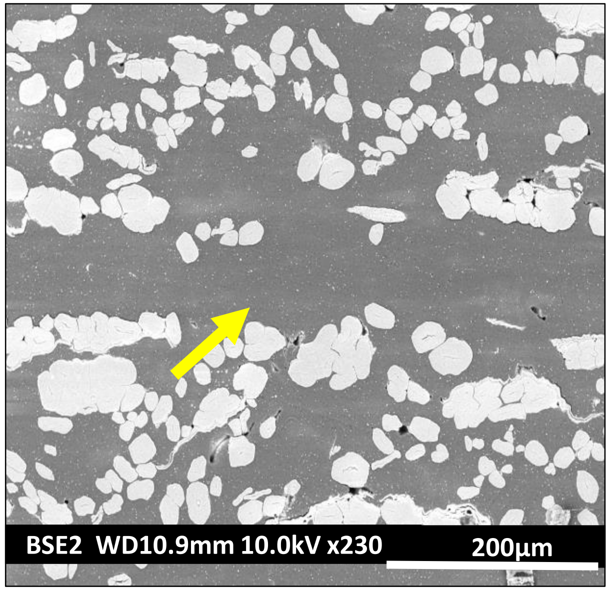
200 N | **420 N**











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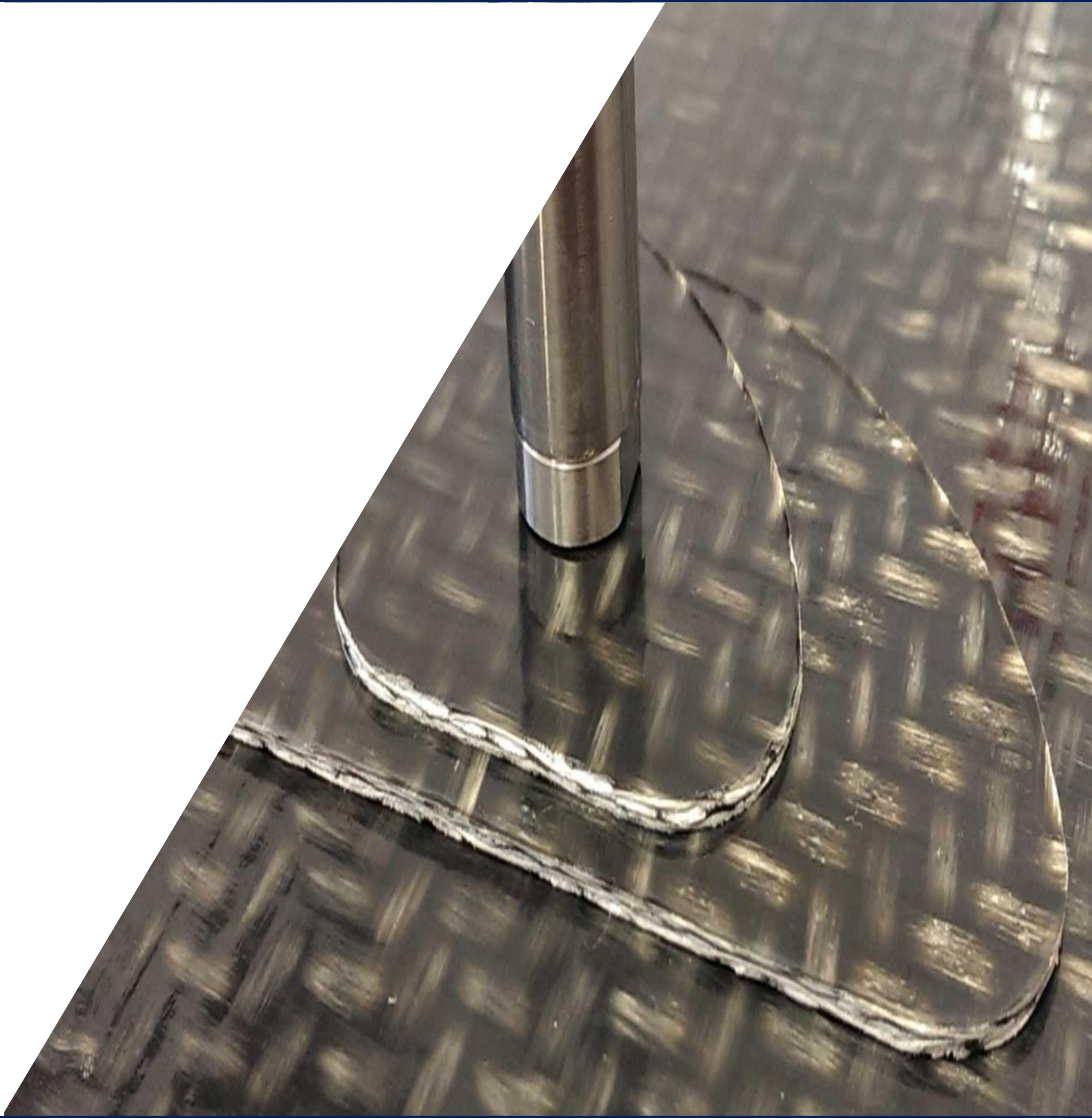

Conclusion

- ❑ Understanding the impact of parameters on temperature profile and mechanical strength of welds

Welding time

- The mechanical strength increases with the welding time
- Threshold : Burning of Flax Fiber

Welding force

- The mechanical strength increases with the welding force
- Threshold : absence of vibration

- ❑ Acquiring strong and reproducible welds
- ❑ Two optimal welding conditions:
  - ➢ 700 ms - 35 m - 400 N
  - ➢ 500 ms - 35 m - 420 N

Outlooks

- ❖ Study of physicochemical changes induced by the process (oxidation of fibers and matrix, modification of crystallinity)
- ❖ Comparison between time mode, energy mode and displacement mode
- ❖ Study of the effect of an energy director