# A Degree of Bonding Evolution Study of Co-consolidated PEEK/PEI Composite Materials during Welding

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# Introduction – Thermoplastic composites joining techniques

Increasing parts complexity → **Joining Techniques** ← Fast/reliable processes

Joining Techniques:

## Adhesive Bonding

- x Chemically incompatible
- x Extensive surface preparation

## Welding

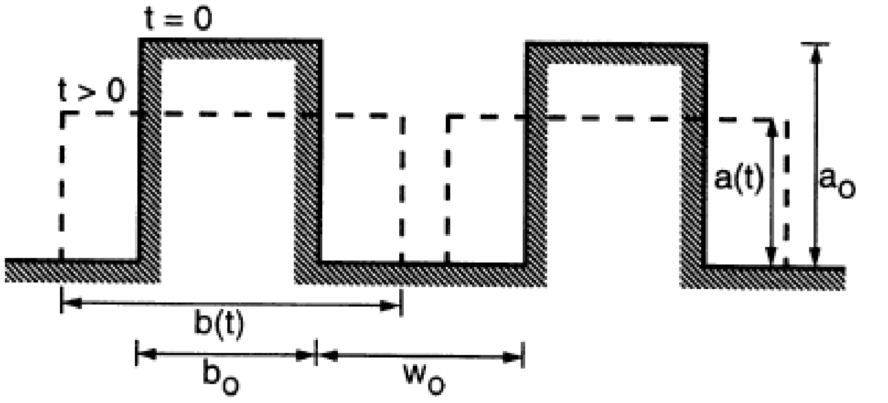
- ✓ Chemically compatible
- ✓ Low weight penalty

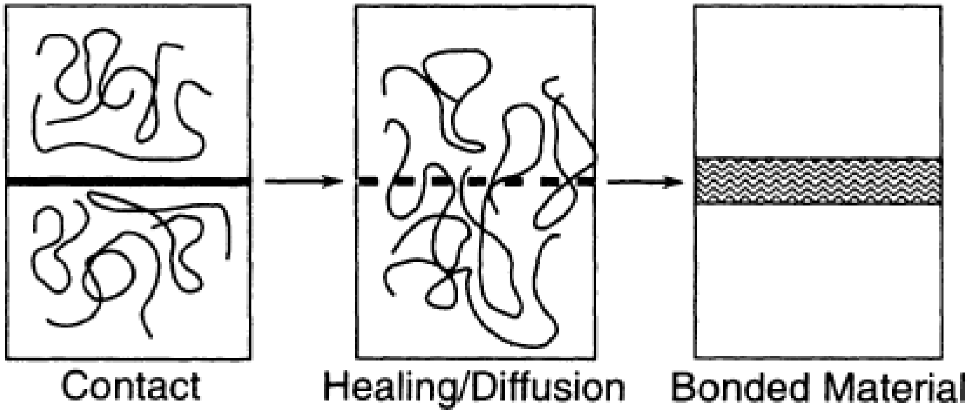
## Mechanical Fastening

- x Drilling of holes
- x Weight penalty
- x Corrosion issues

# Introduction – Polymer welding theory

- Thermoplastic polymers ability to melt/soften and to be reprocessed.
- Two main mechanisms: Intimate contact and healing.




Degree of intimate contact depends on:

- Initial roughness (asperities dimensions)
- Viscosity (function of temperature)
- Applied pressure
- Process time

Degree of healing depends on:

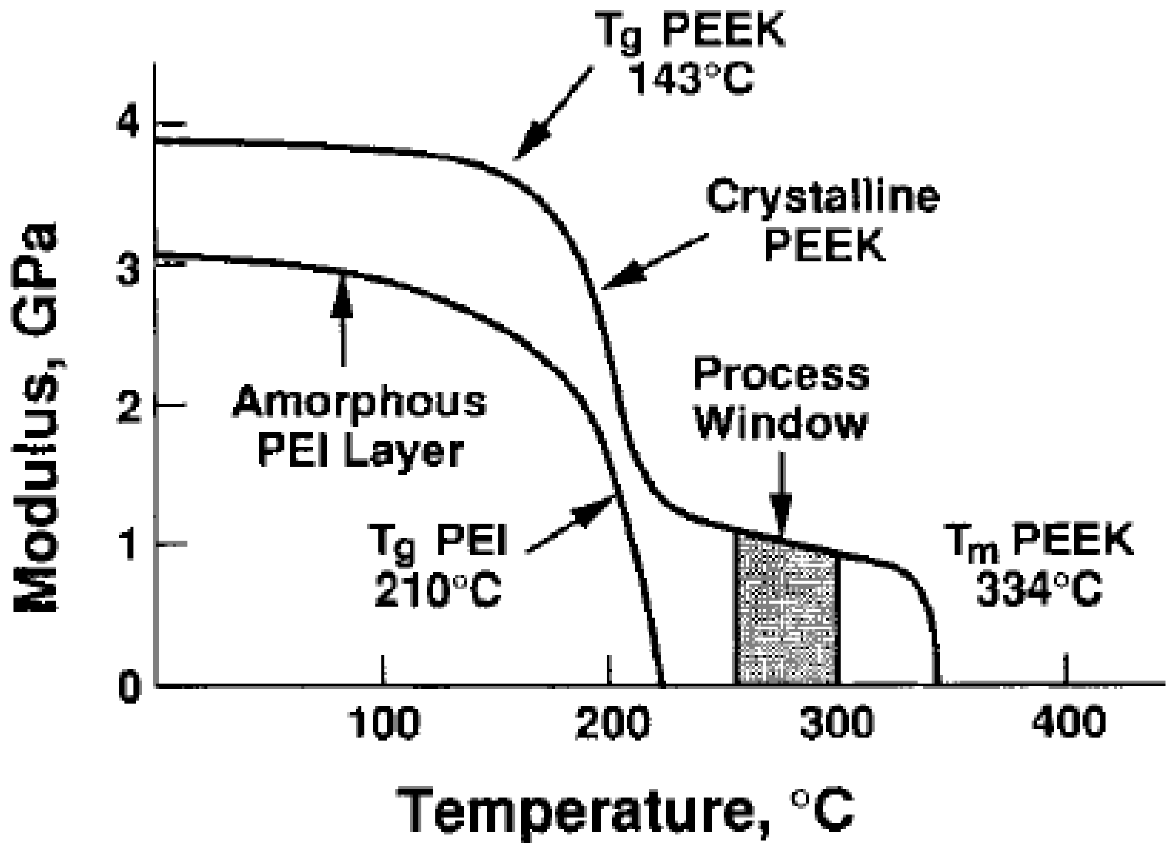
- Reptation time (polymer chain movement)
- Interface temperature
- Process time

Both figures: Butler et al., Journal of Thermoplastic Composite Materials, 1998

# Introduction – Thermabond$^{TM}$ process

- Weld a thermoplastic adherent (Poly-ether-ether-ketone or PEEK) by adding a surfacial layer of an amorphous polymer with a lower processing temperature (Poly-ether-imide or PEI).

- Welding occurs at the amorphous polymer processing temperature, but below the main adherent melting point.

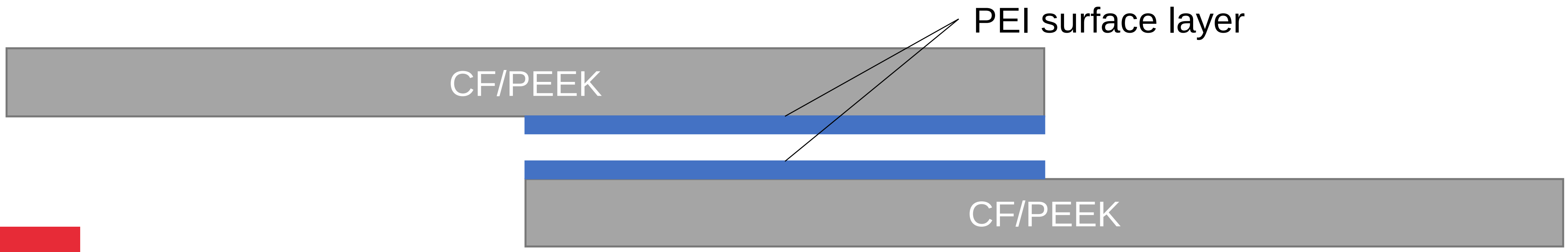



Smiley et al., Polymer Engineering and Science, 1991

# Objective

Mechanical properties depend on:

- Welding pressure and temperature, process time.
- Degree of intimate contact and degree of healing.
- PEEK-PEI interface strength.
- PEI mechanical properties.
- **PEI surface layer thickness (objective of this study).**

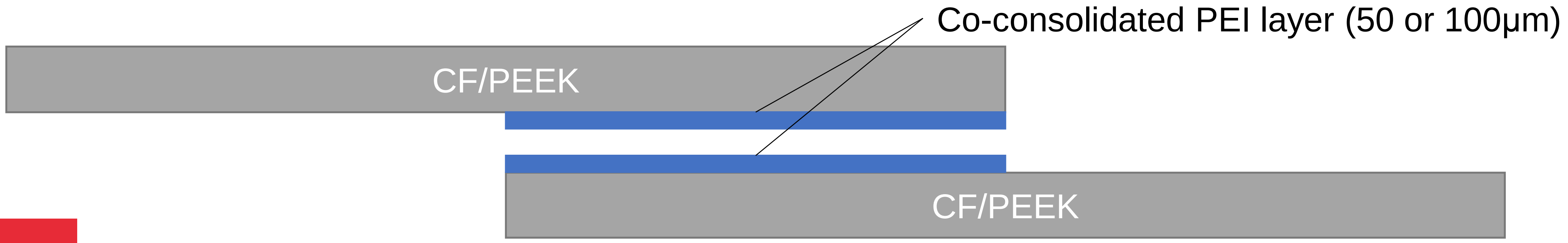


# Materials

Adherent:

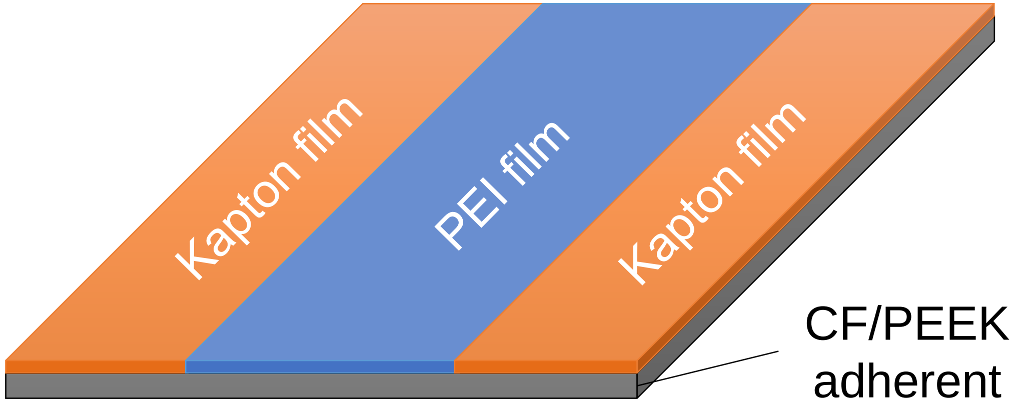
- CF/PEEK laminates $[0]_{16}$ (hot press 20min @ 380°C @ 2MPa).
- Co-consolidated PEI ULTEM1010 layer on the surface.

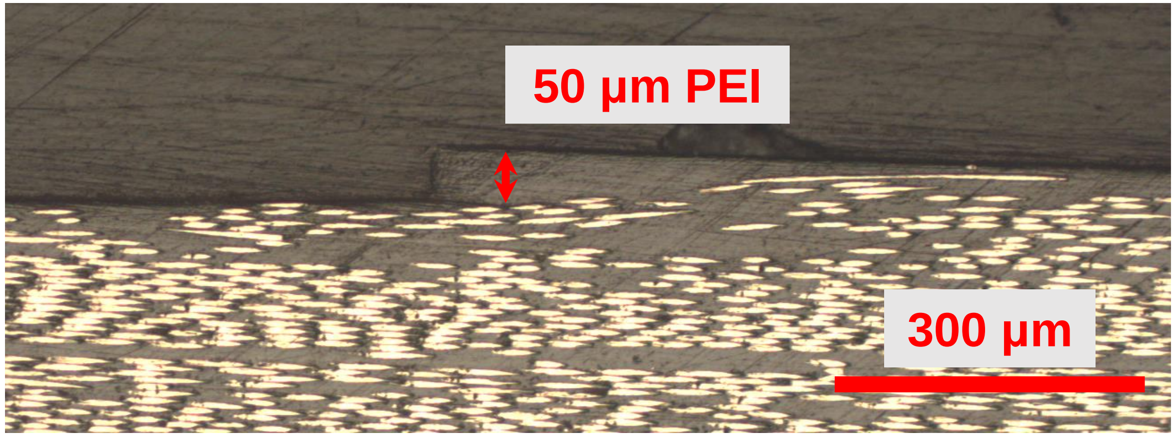
  → Co-consolidation = PEI layer is added on the CF/PEEK plies and consolidated with the laminate in the hot press in one single step.
- PEI layer thickness varies between 50 and 100 microns.



# Co-consolidated PEI surface layer

PEI thickness is controlled by adding kapton film beside the PEI layer during the consolidation step in a hot press, ensuring a **PEI-rich surface layer**.



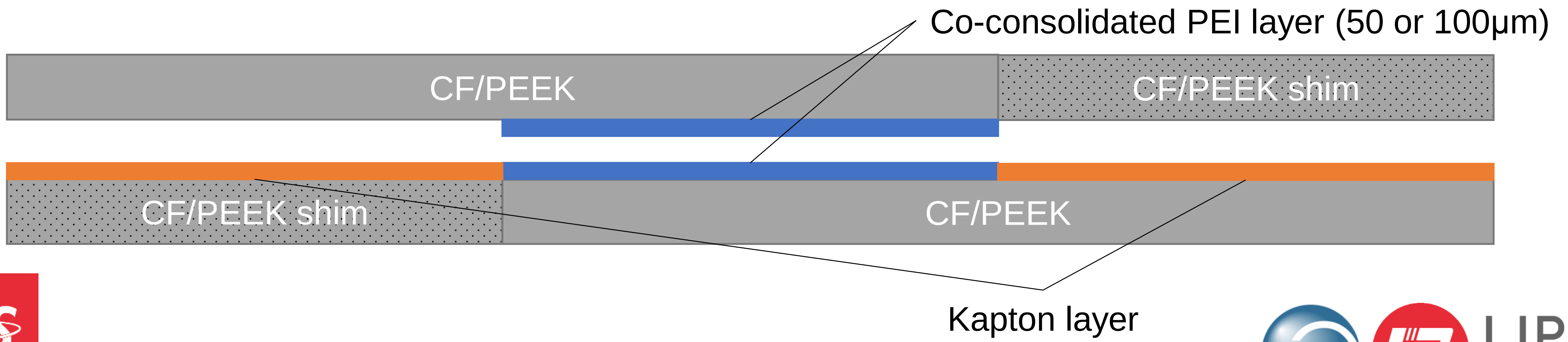


Optical microscope images

# Welding in hot press

Welding of single-lap shear (SLS) specimens is conducted in a hot press, ensuring control of the process temperature and applied pressure.

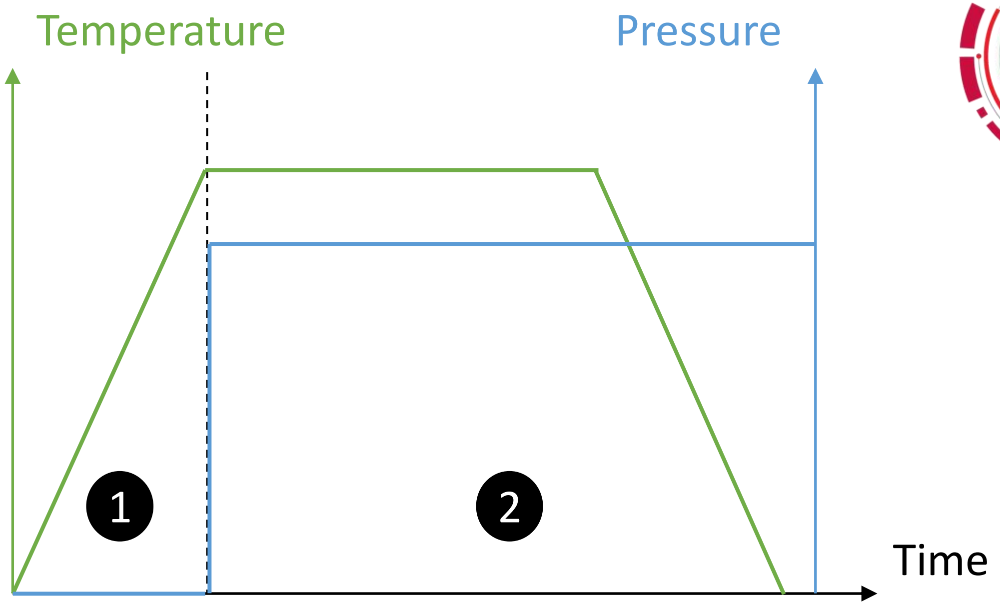
Shims are added to adjust the adherent position in the SLS geometry and ensure flat contact and homogeneous pressure application.

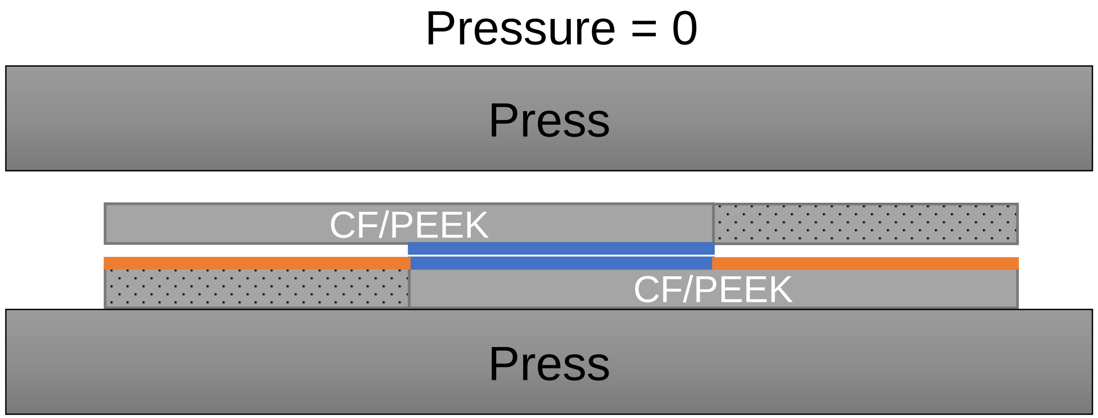


# Welding in hot press

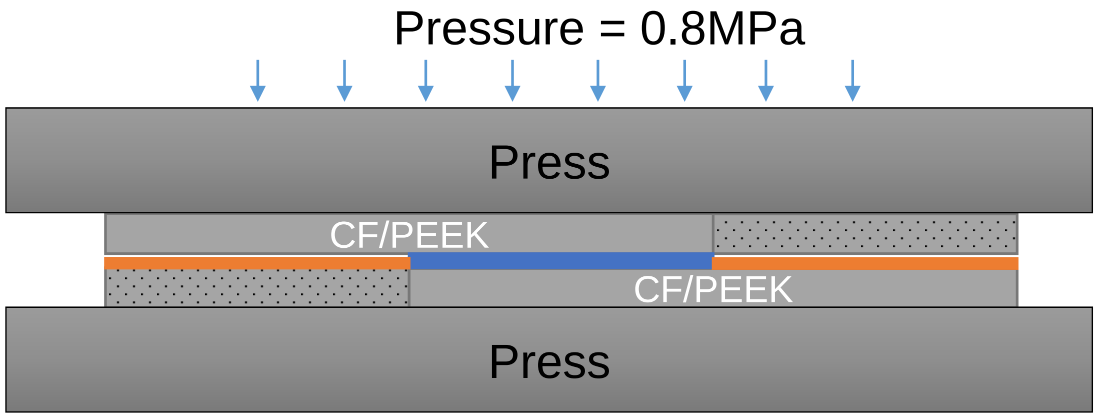
Process steps:

- Heat up to joining temperature @ 0MPa
- Bonding phase @ 0.8MPa
- Cool down under pressure



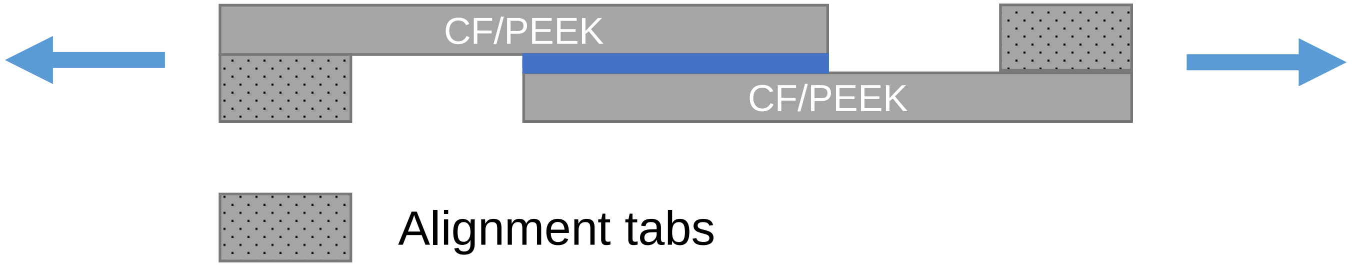

1 - Heating phase




2 - Bonding phase (+ Cooling)

# SLS mechanical testing

After bonding in hot press, 25.4mm wide SLS samples are cut.
SLS samples are tested following standard ASTM D5868.

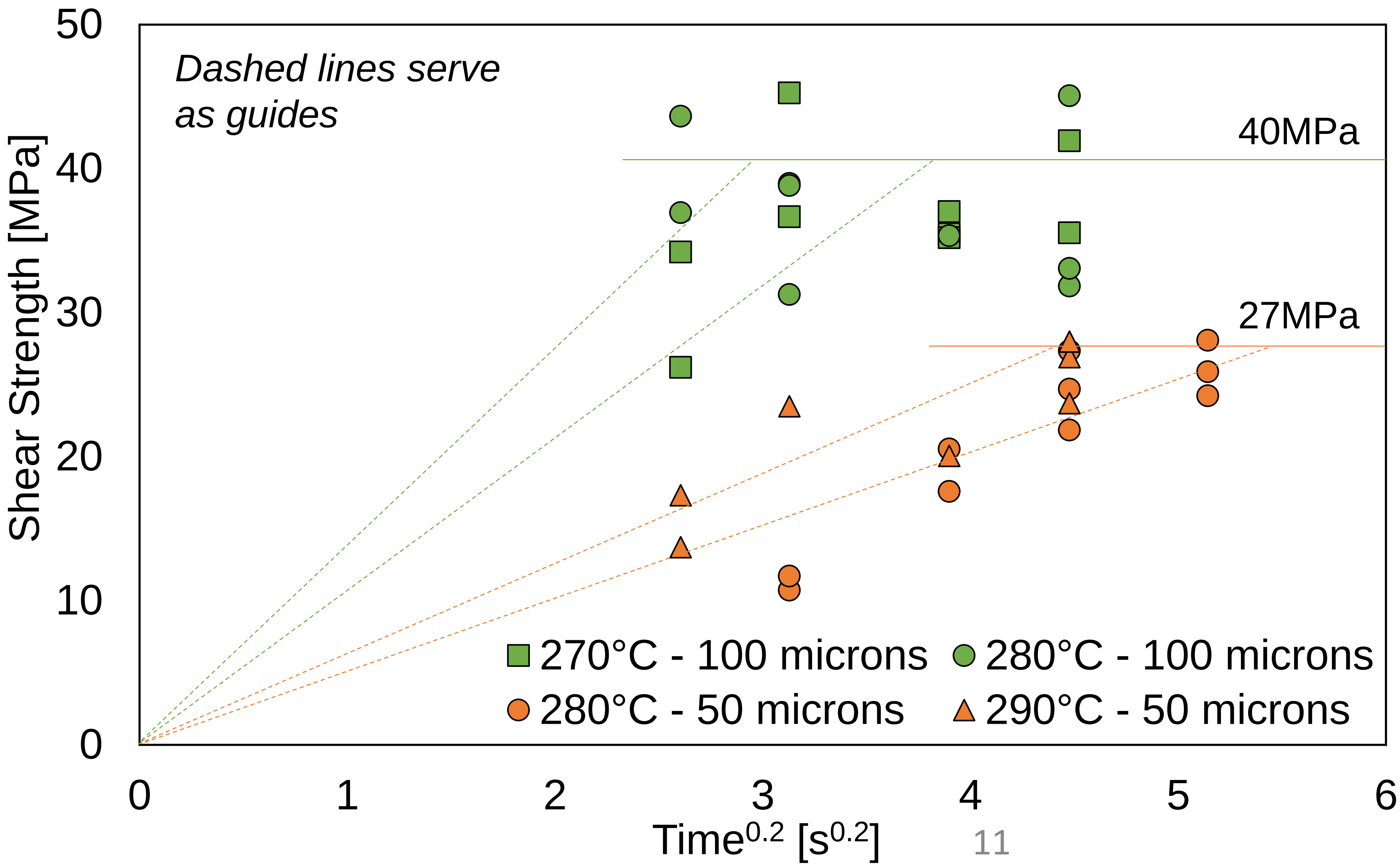



ASTM D5868 test parameters:

- Overlap = 25.4mm x 25.4mm
- Loading rate = 13mm/min
- 100kN load cell

# Results – SLS shear strength

Shear strength at failure is presented as a function of pressure time.

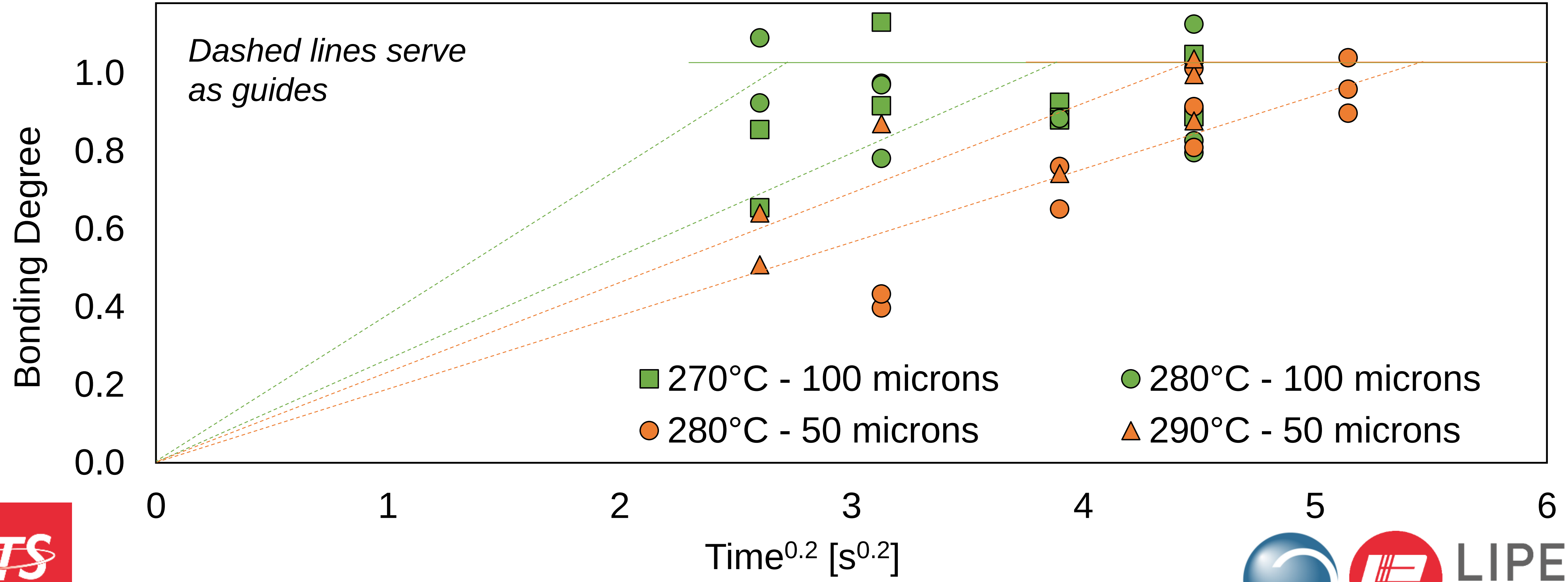



With thicker co-consolidated PEI layer (100µm):

- Higher strength
- Faster increase in bonding strength

# Results – Degree of bonding

Maximum degree of bonding is reached faster for 100µm than for 50µm of PEI surface layer thickness.



# Analysis

Higher strength with thicker PEI layer:

- Larger bondline thickness has been shown to improve mechanical properties.
- If PEI is too thin, it can flow and leave PEEK apparent in the welding area. Due to the low temperature, PEEK will not weld, reducing the effective welding surface area.

Faster bonding with thicker PEI layer:

- The viscosity is higher in presence of fibers, which reduces the intimate contact evolution. With thicker PEI layer, fiber migration does not reach the welding line, and therefore does not affect the local viscosity.

# Conclusion

- Procedure to test degree of bonding evolution of co-consolidated PEI on PEEK laminates using a hot press was presented. This procedure can be applied to other pairs of thermoplastic materials.

- Importance of co-consolidated PEI thickness on processing time and bonding strength has been demonstrated. It appears that a thicker PEI surface layer (100μm vs. 50μm) improves the welding strength and reduces the processing time.

# Acknowledgements

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NanoXplore Performance Through Carbon Chemistry

Mëkanic

Université Laval

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Dyze Design

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PRIMA Les matériaux pour avancer

LIPEC Laboratoire d'ingénierie des polymères et composites