LOCAL SURFACE TOUGHENING – IMPROVEMENT OF STRESS RESISTANCE BY USING TPU

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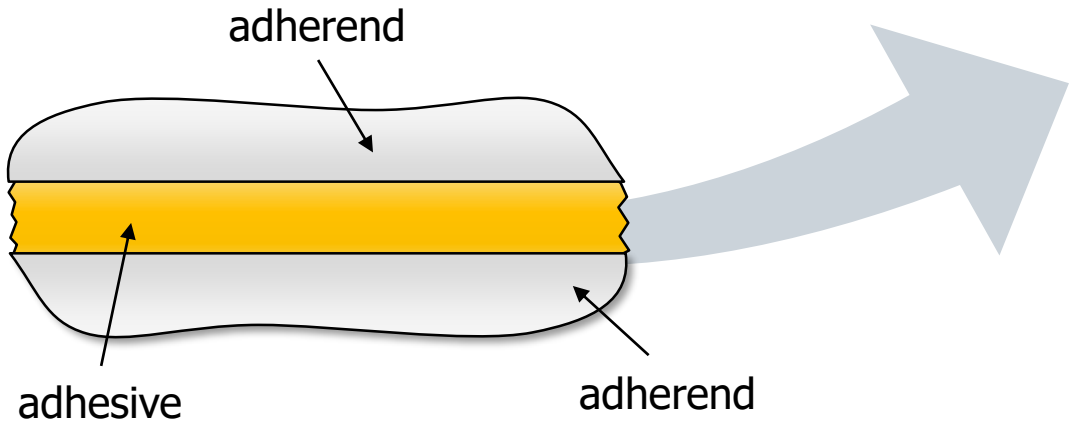
DLR

Bonding of primary structure in aviation

- Aim: Pure adhesive bonds (weight saving, tolerance, no corrosion, sealing, damping, …)
- The joint strength must last over the hole operating time!
- Environmental condition -55°C – 80°C



ideal bondline

Bonding of primary structure in aviation

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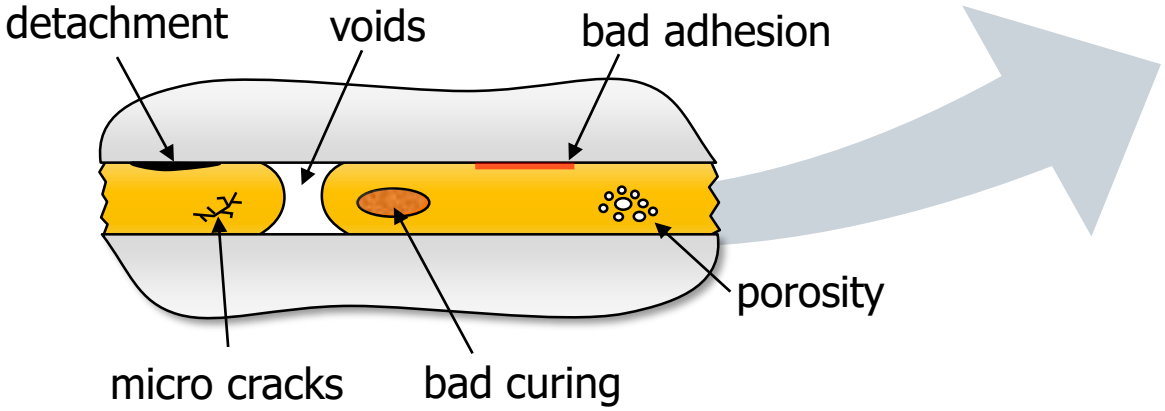
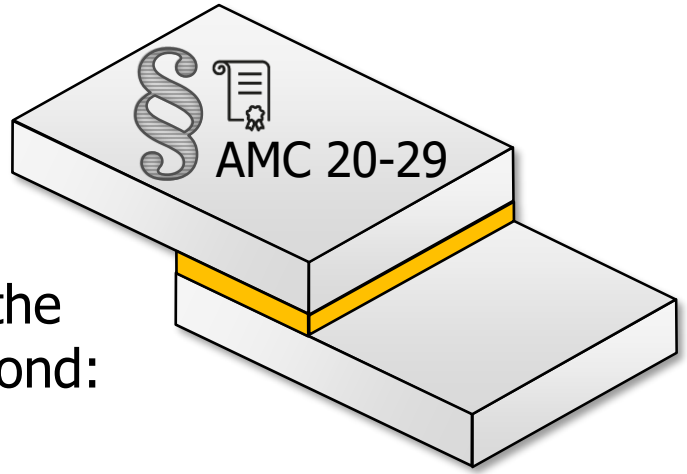


real bondline
with defects

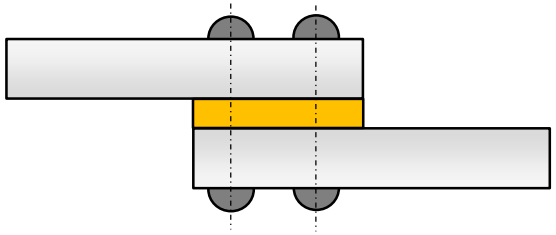
Certification requirements for structural adhesive bonds in aviation



EASA CS 25

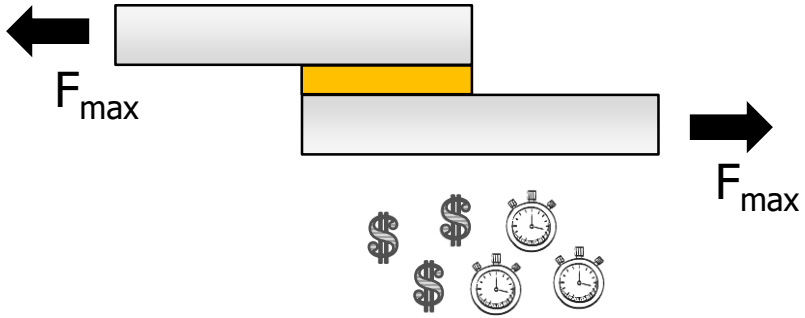
Proof of the adhesive bond:

(i) Additional design elements

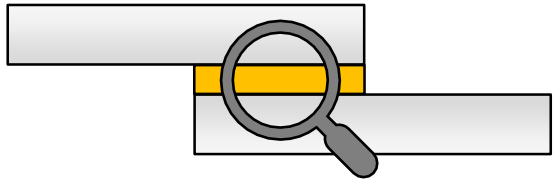


Disadvantage:

(ii) Load tests



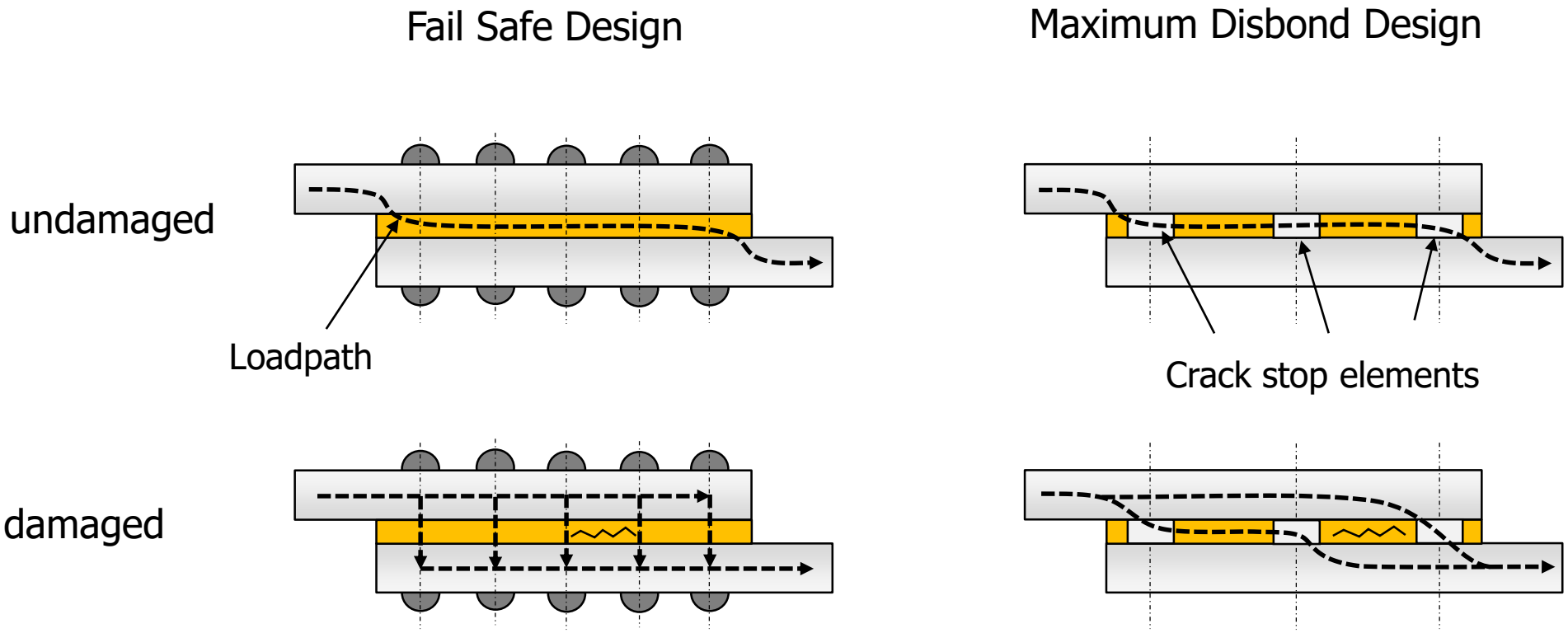
(iii) Inspection



Does not exist.

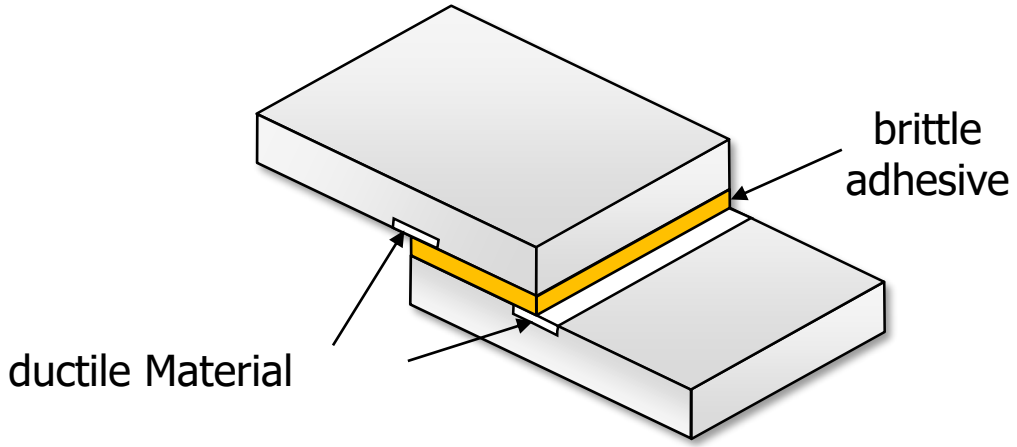
CS = Certification Specification
AMC = Acceptable Means of Compliance

From the bolted to the bonded joint



Aim: Robust pure adhesive bond with crack-stop effect!

Local Surface Toughening (ST) - Concept



Increase in joint strength

The targeted arrangement of the local surface modification in the bond improves the load distribution and thus increases the bond strength.

Crack stop

Crack growth in the bonded joint is stopped by means of localized surface toughening and the resulting reduction in stress concentrations.

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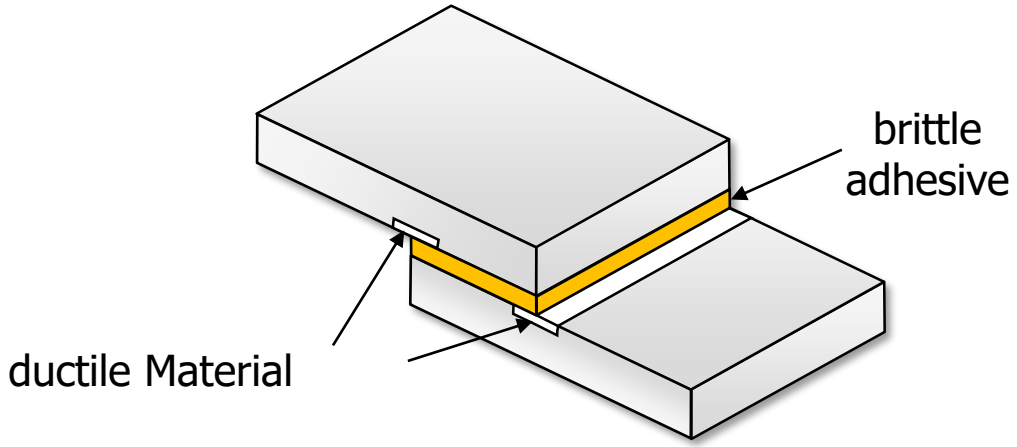

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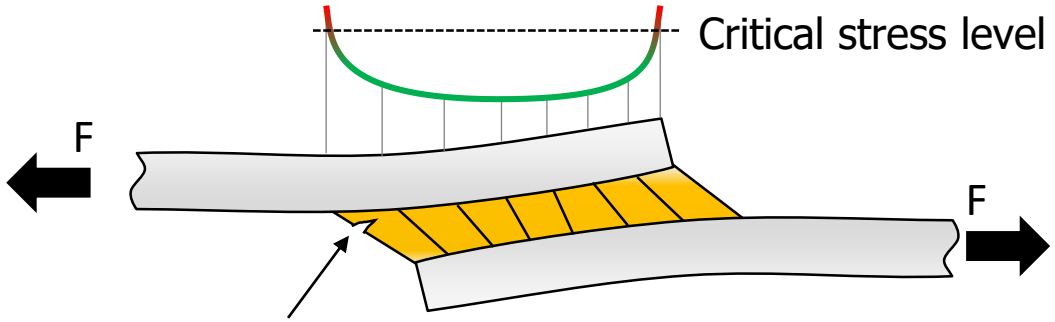
Is not part of this presentation!

https://elib.dlr.de/205164/

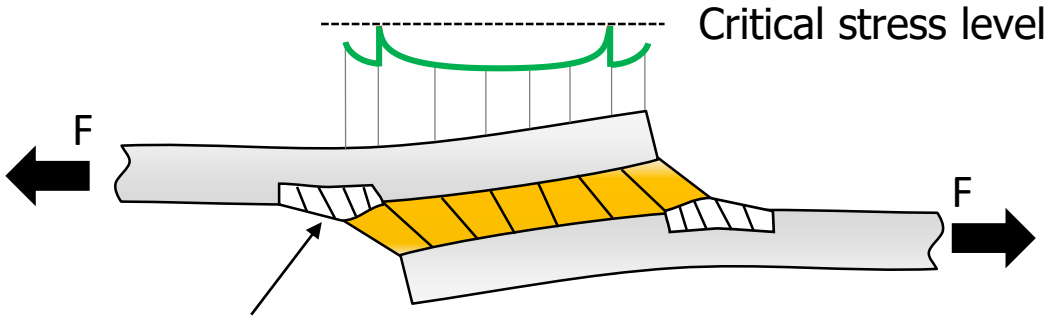
Local Surface Toughening - How it works

Reference



Stress concentrations lead to crack formation

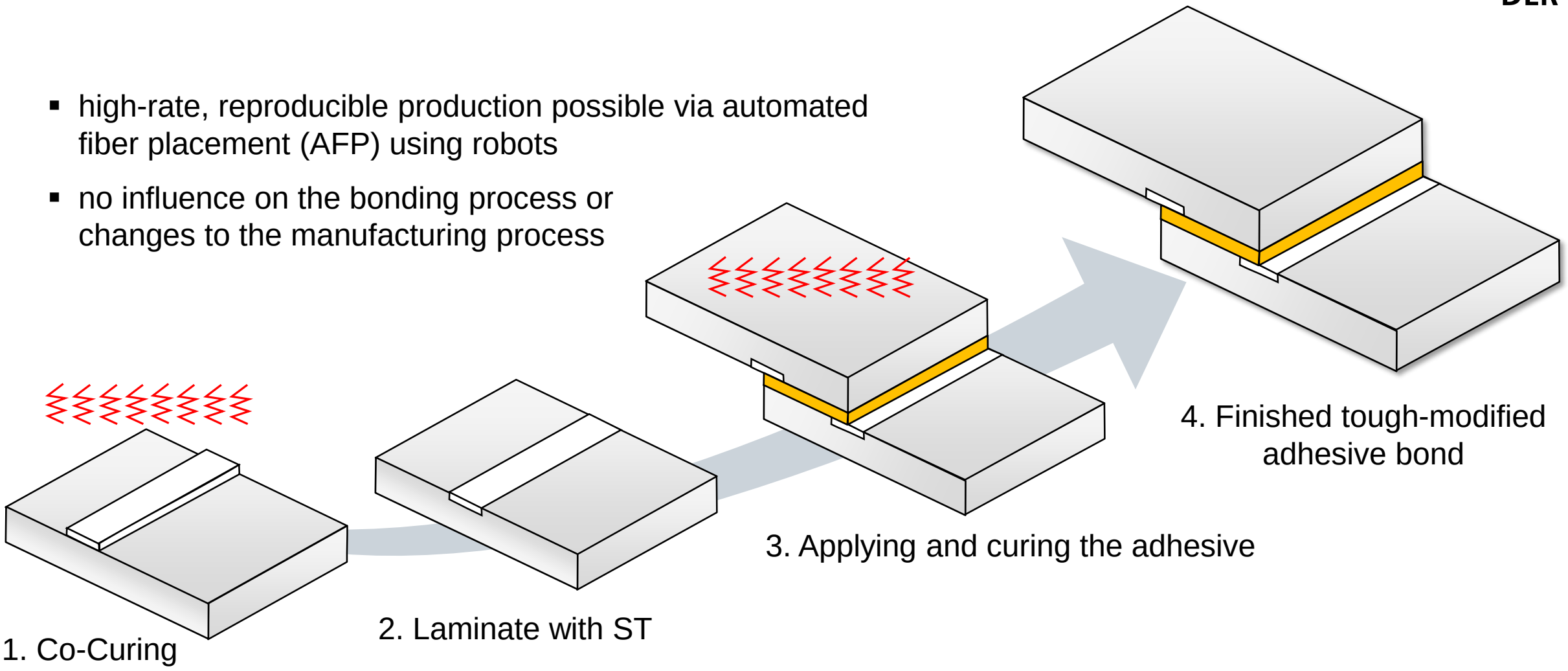
ST



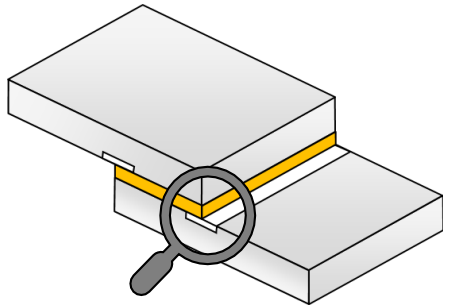
Ductile material absorbs strains and reduces stress concentrations

Manufacturing using the prepreg process as an example

- high-rate, reproducible production possible via automated fiber placement (AFP) using robots
- no influence on the bonding process or changes to the manufacturing process



Crosssection and materials

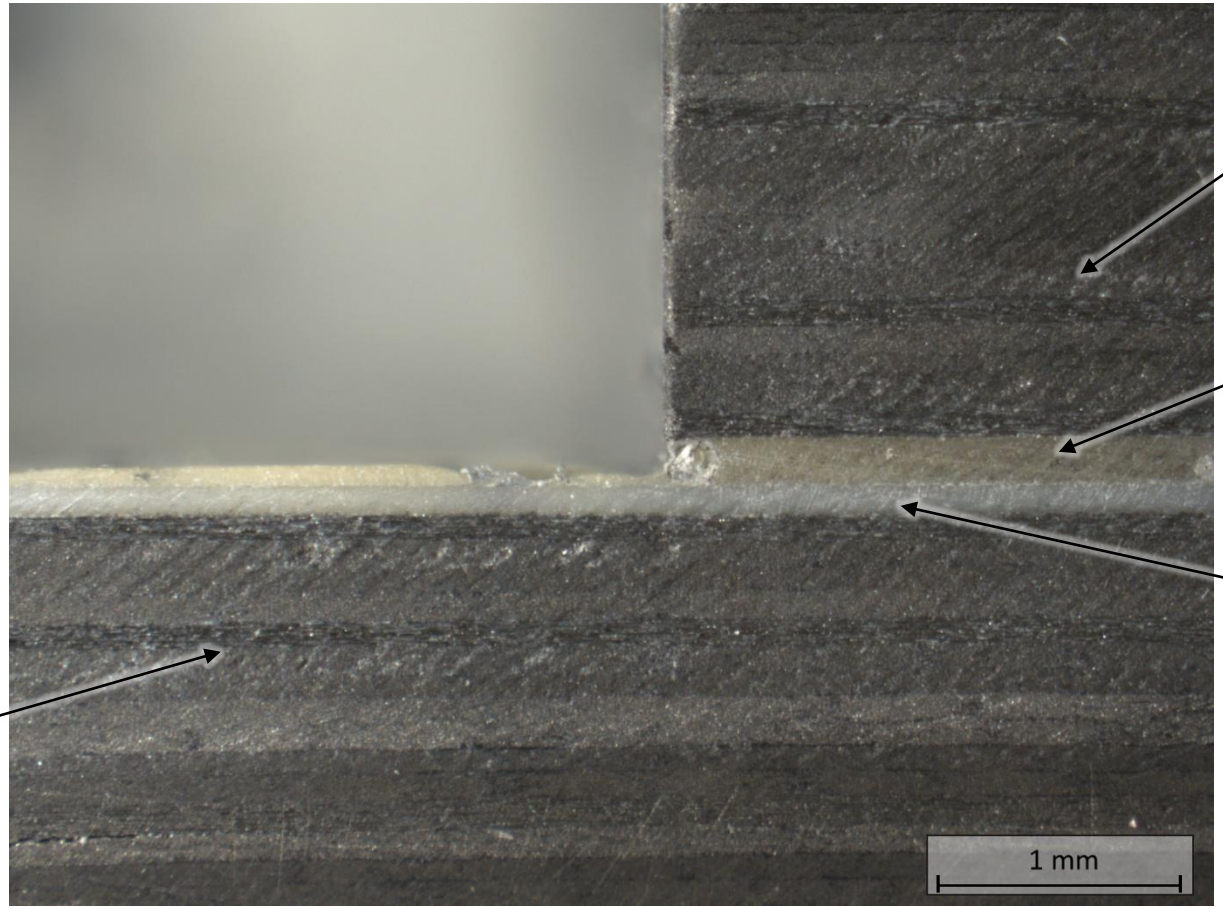


Young‘s modulus:

$E_{8552\ IM7}$ = 60.600 MPa

E_{EA9695} = 2.577 MPa

E_{PVDF} = 1.716 MPa



Adherend 2
8552 IM7

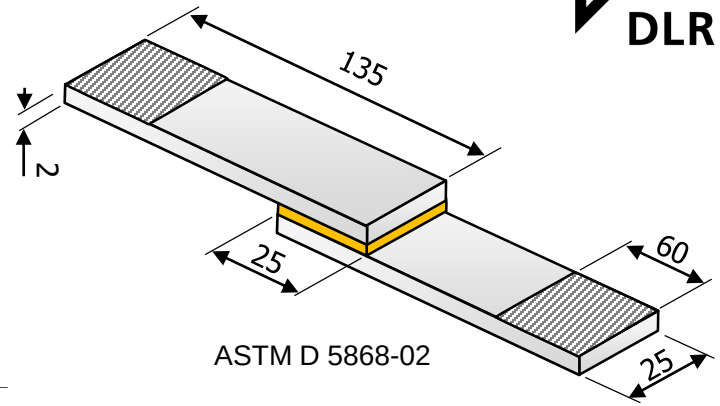
Film adhesive
EA9695 NW
t_{Kl} ~0,12 mm)

ST-Material
PVDF
t_{ST} ~0,1 mm

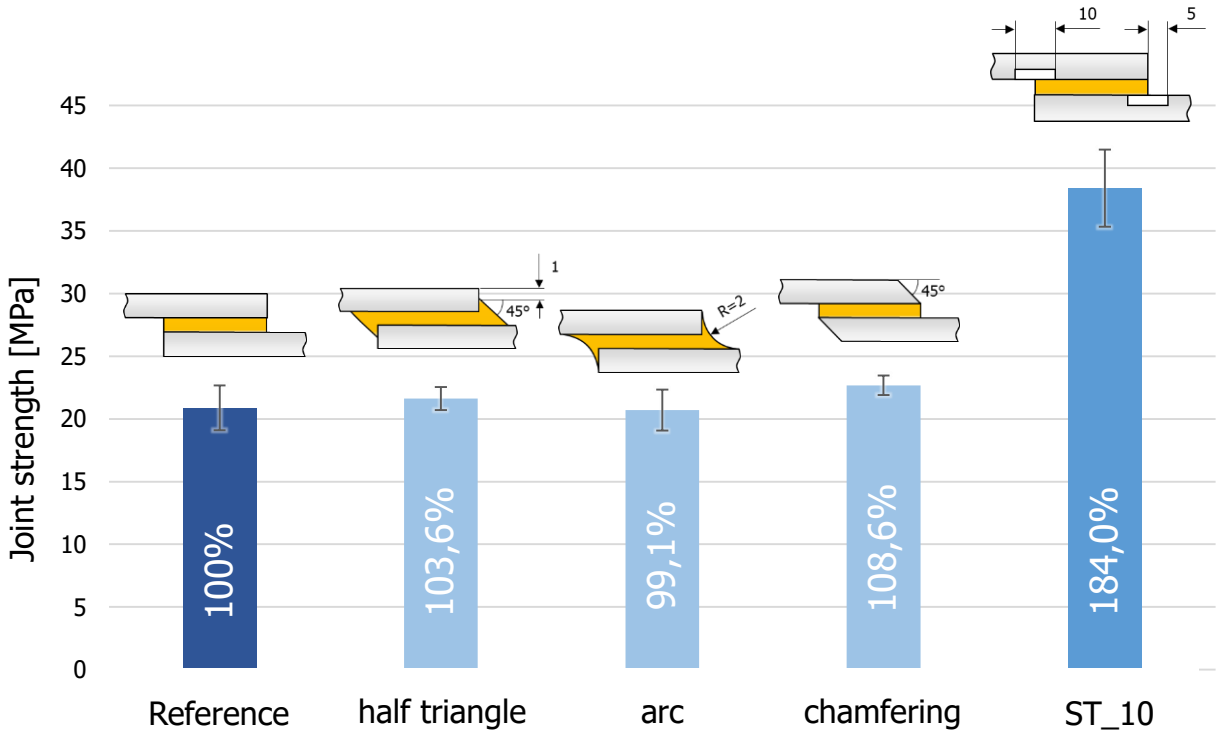
Adherend 1
8552 IM7

Strength increase under quasi-static load

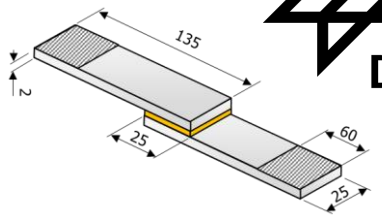
- strength-enhancing methods from literature without much effect
- increase in strength due to ST by 84%



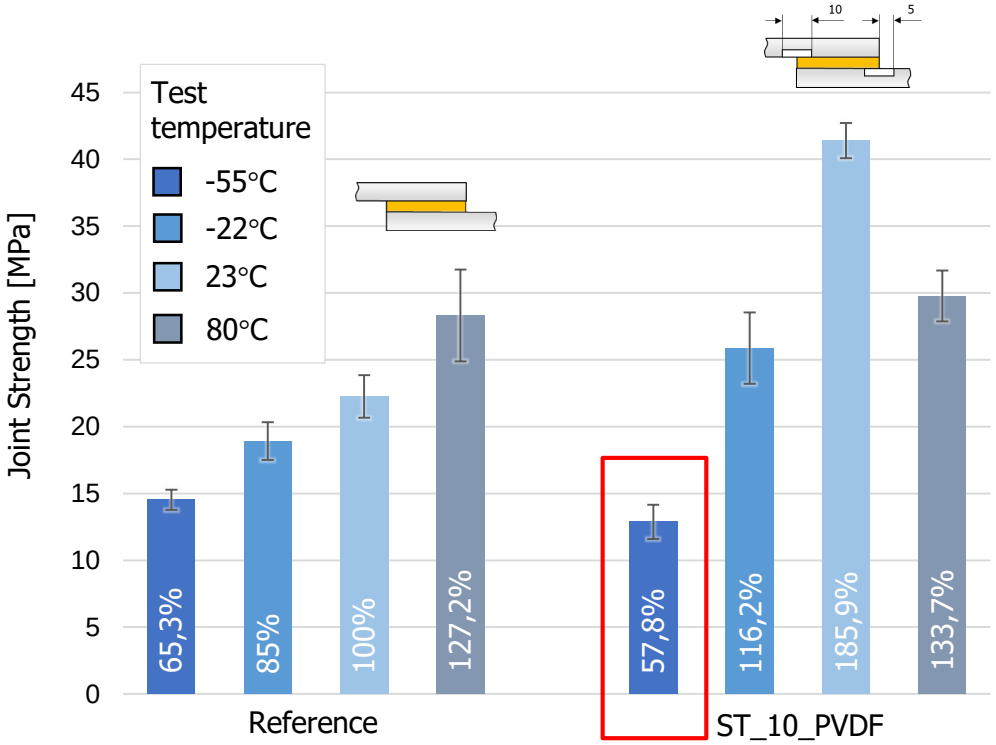
ASTM D 5868-02



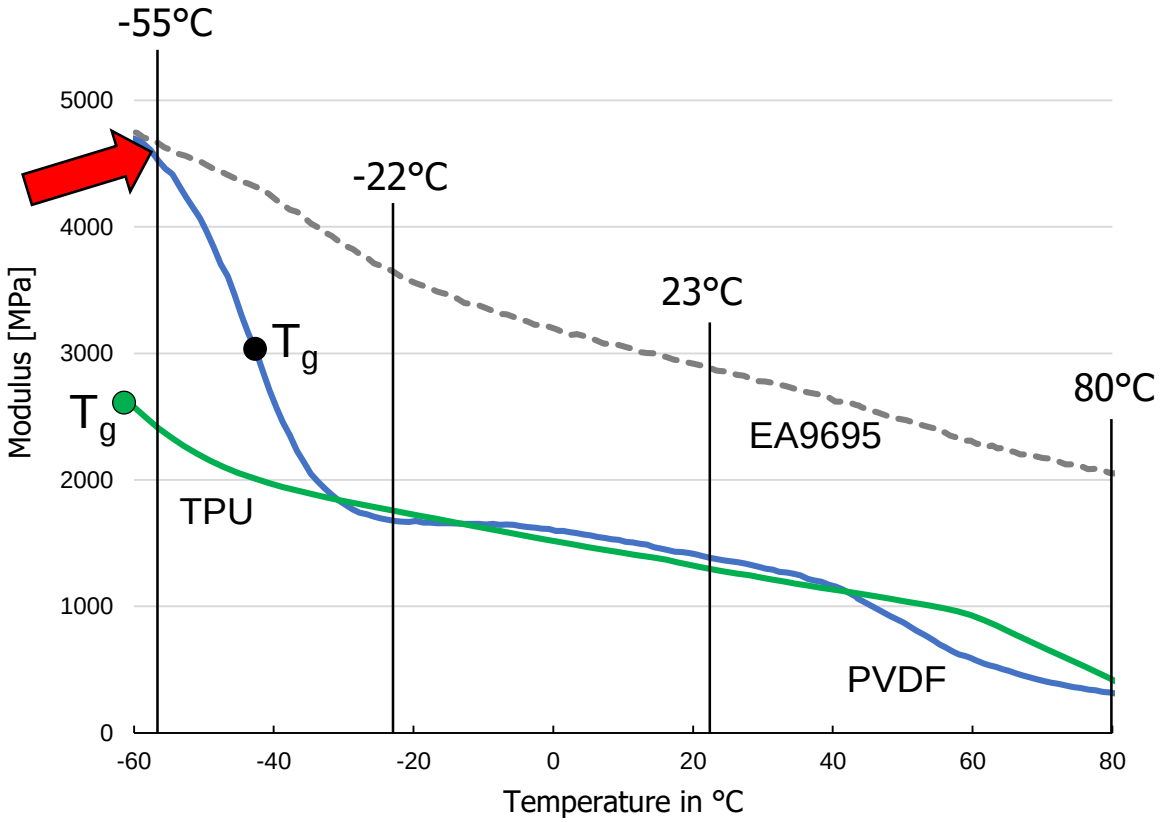
Problem with PVDF



SLS tests PVDF



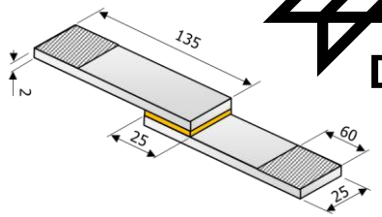
DMA



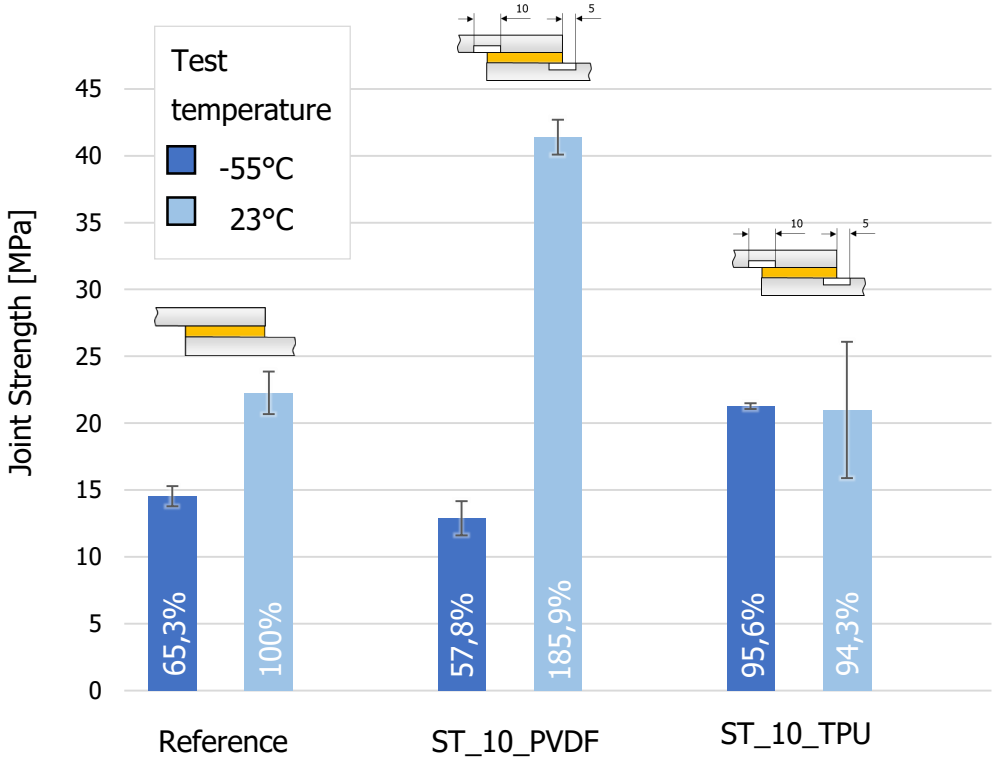
→TPU for next trials!

PVDF: Nowoflon Copo FL2608, Nowofol
TPU: Elastollan 1165D13U, BASF

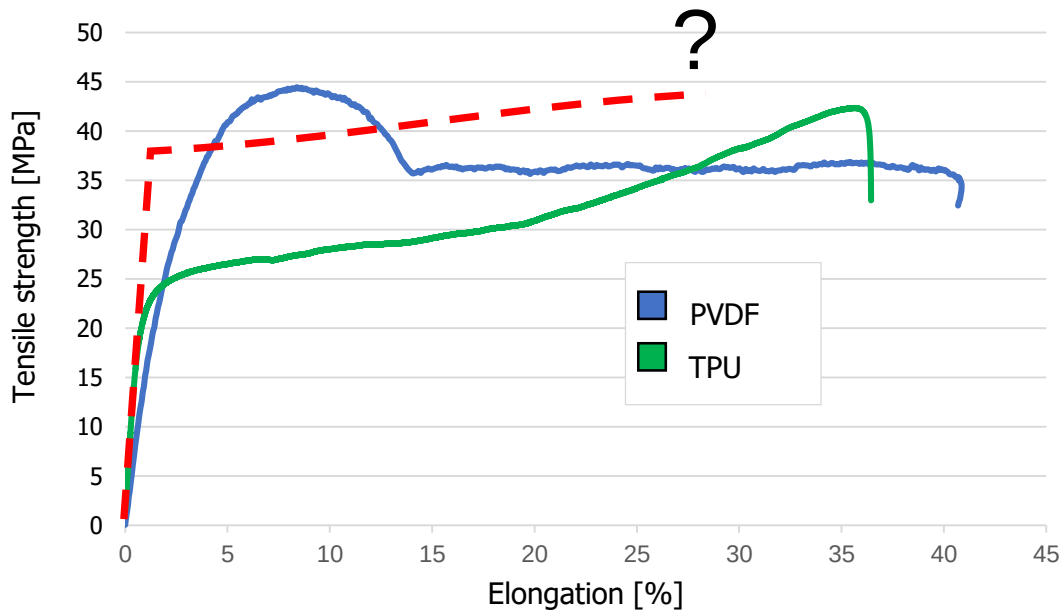
Comparison of PVDF and TPU - SLS



SLS tests PVDF and TPU

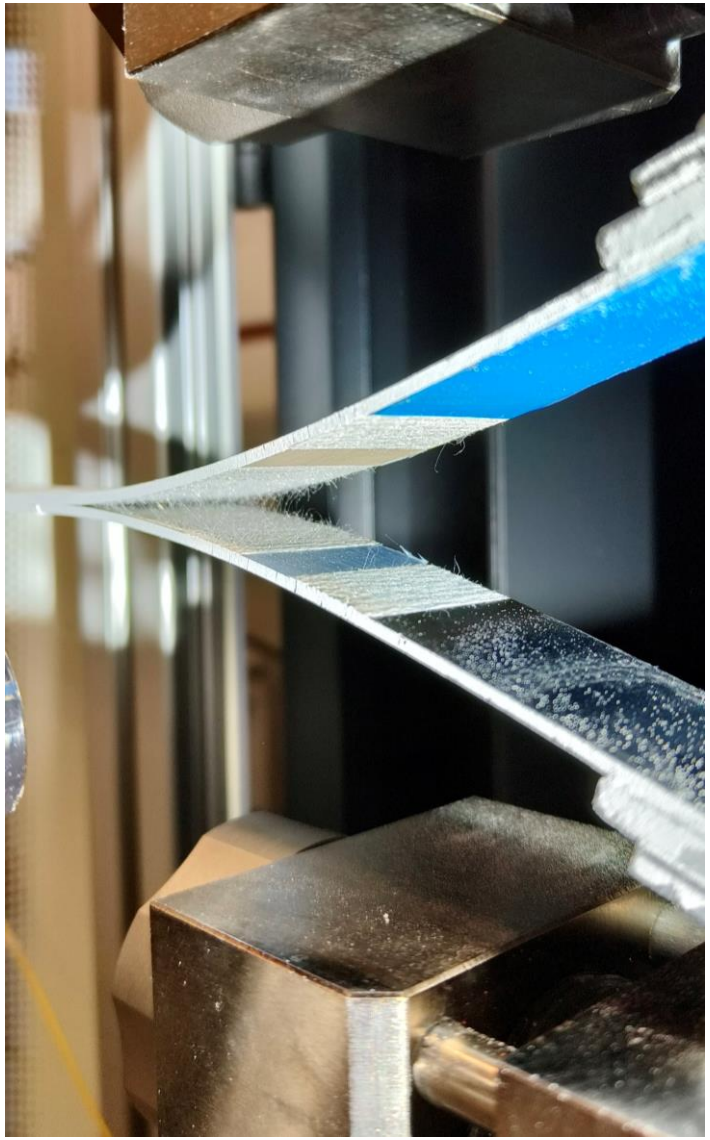


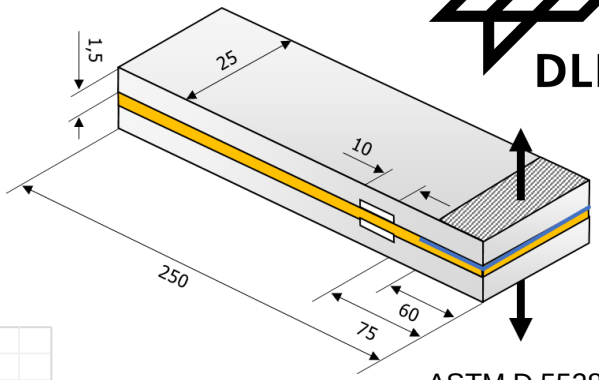
Tension test



→ Thesis: Strength of yield point increase at -55°C?
→ Use specimen design with higher internal strain of the ST-material?

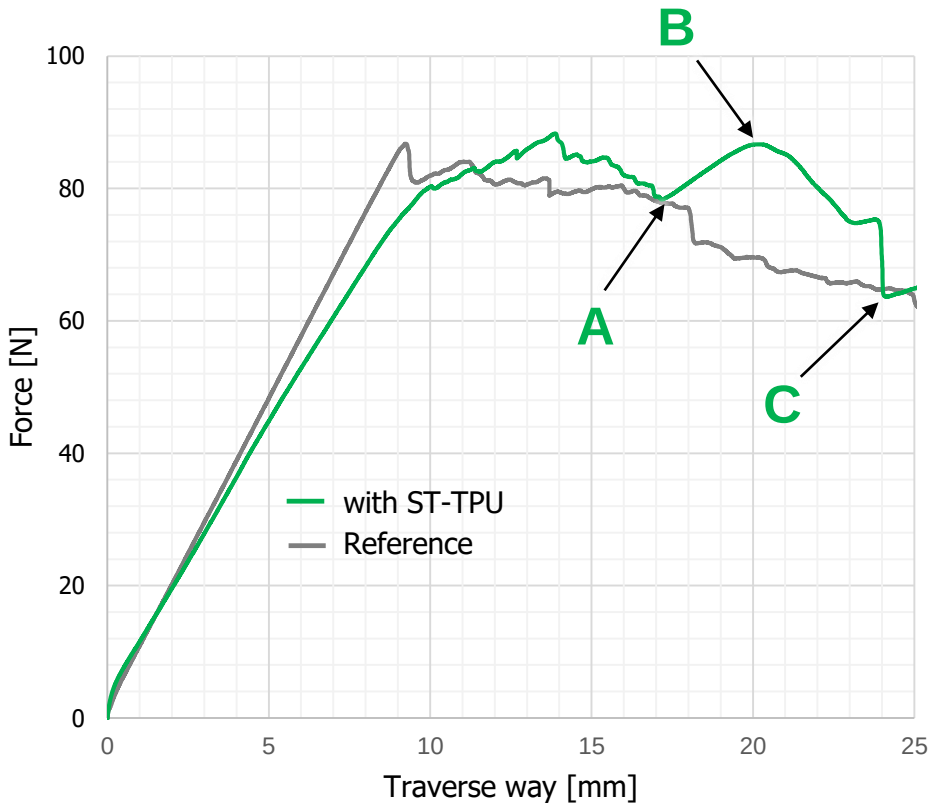
Double Cantilever Beam tests with TPU





ASTM D 5528-21

DCB test with TPU



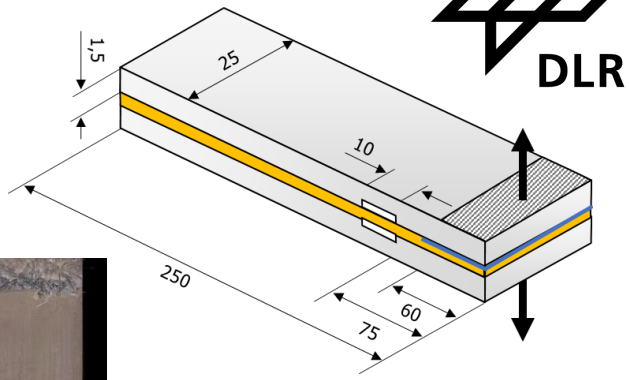
A: Crack stop

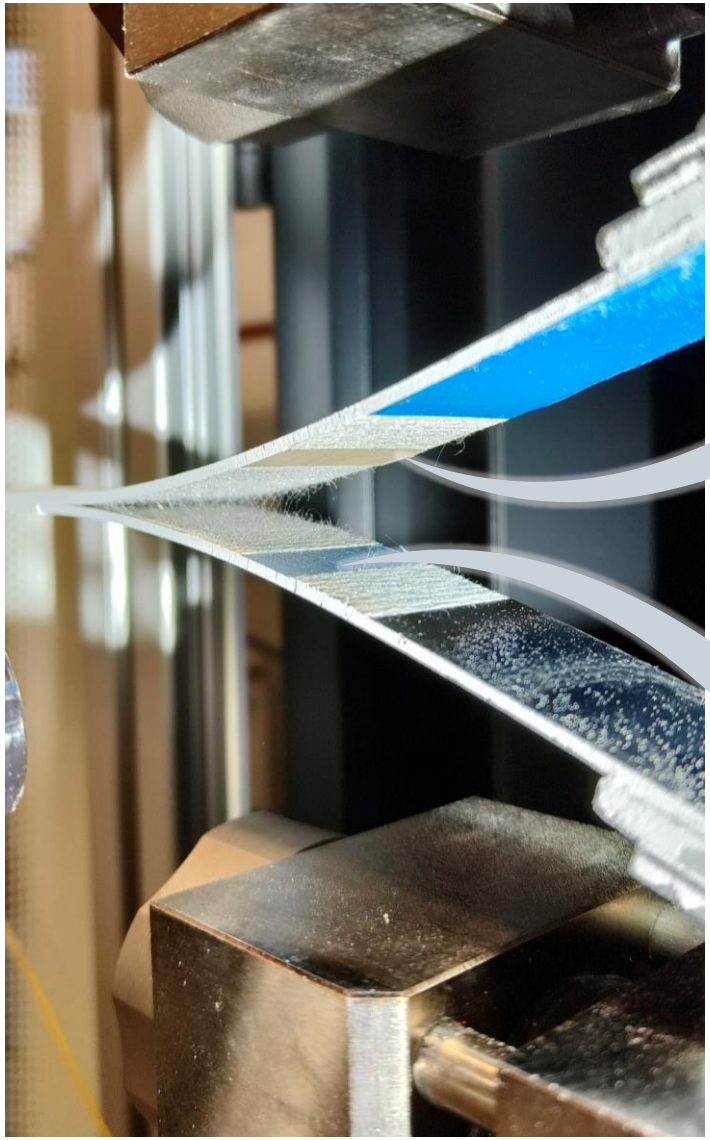
B: Crack starts again

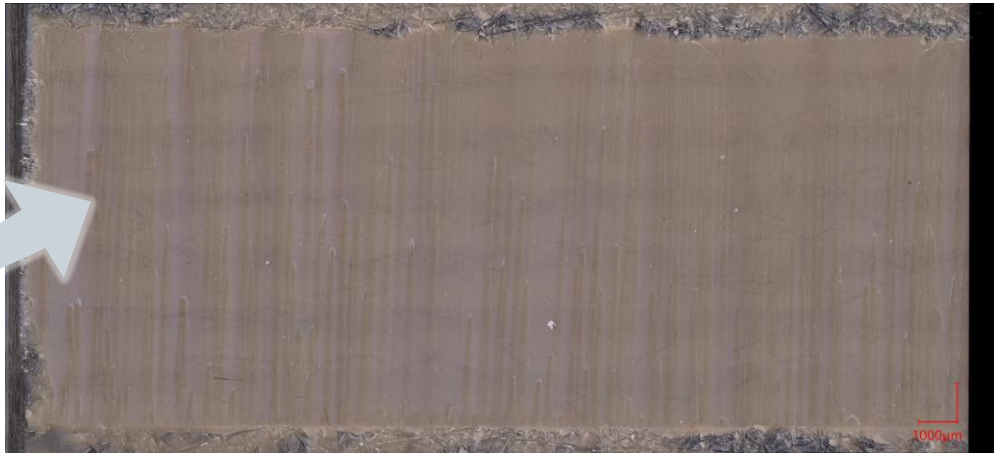
C: Crack jumps to the pure adhesive (end of crack stop element)

Increase of G_{IC} by ~30% (MBT)

Double Cantilever Beam tests with TPU







Surface near cohesive failure in TPU

Conclusion and Outlook

- ...increases the joint strength by up to 84% or until the joint component breaks
- ....is easy, quick and inexpensive to use.
- **...is a robust and pure adhesive bonded joint with a crack-stop effect!**

- but PVDF is not a suitable material for industrial applications…

→TPU can work as a ST-material but need a higher yield strength for Mode II load at RT

→TPU works at RT under Mode I direction with an increase of G_{IC} by ~30%

→Proof SLS-thesis with tension tests performed at -55°C

→Iterate material composition to increase the yield strength for better performance

Imprint

Topic: Local Surface Toughening – Improvement of Stress Resistance by using TPU

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Institute: Institute of Lightweight Systems

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