LOCAL SURFACE TOUGHENING – A BOLTLESS CRACK STOPPING TECHNOLOGY FOR AEROSPACE STRUCTURES

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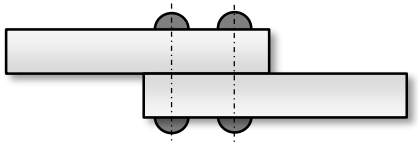
DLR

Bonding vs. Bolting

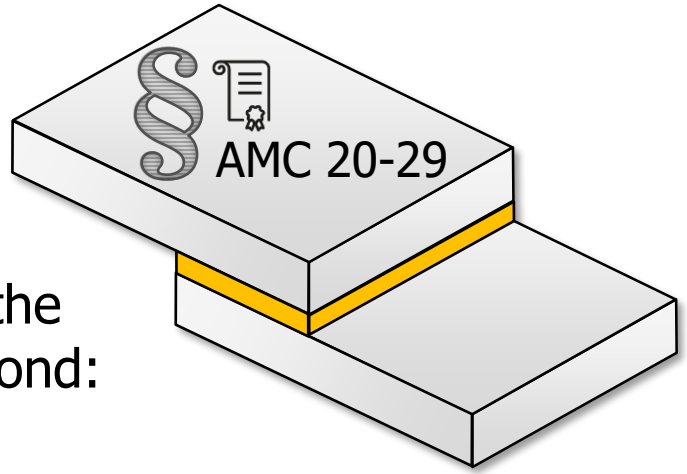
Advantage	Disadvantage
bonding	
less stress peaks	thickness limitation
stiff joint	difficult quality assurance
good fatigue properties	complex and expensive manufacturing
protection against corrosion	environmental influenced
Low mass	Not demountable
good damage tolerance	
good for FRP	
tolerance compensation	
bolting	
demountable	high stress peaks
no thickness limitation	crack formation
easy quality assurance	rivets damage FRP
not environmental influenced	sensitive to corrosion
	tolerance of the drill holes
	mass increase
	no tolerance compensation



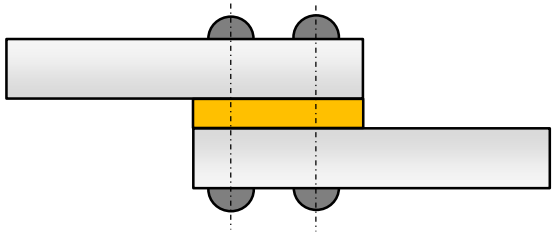
Certification requirements for structural adhesive bonds in aviation

EASA CS 25

Proof of the adhesive bond:

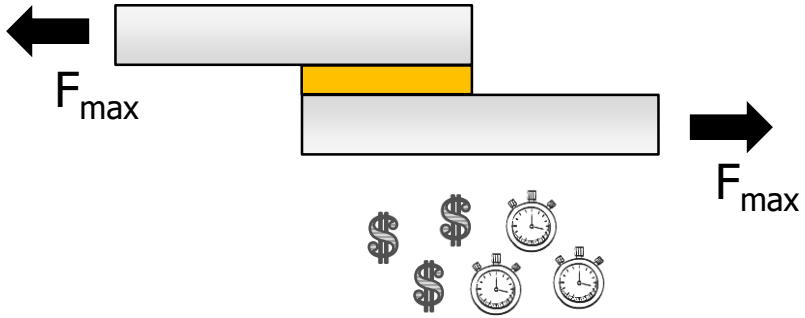


(i) Additional design elements

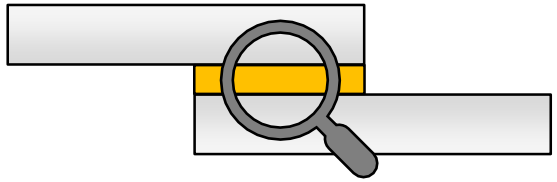


Disadvantage:

(ii) Load tests



(iii) Inspection



Does not exist.

CS = Certification Specification
AMC = Acceptable Means of Compliance

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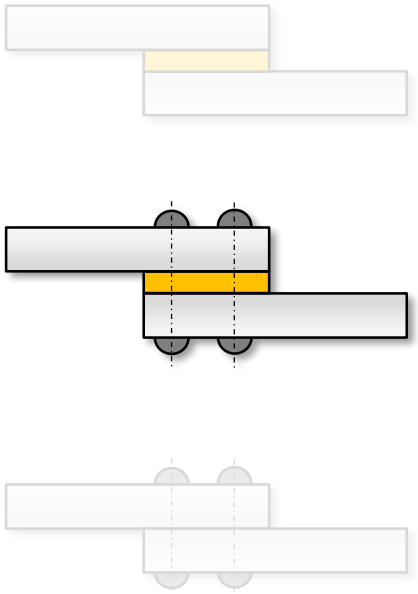
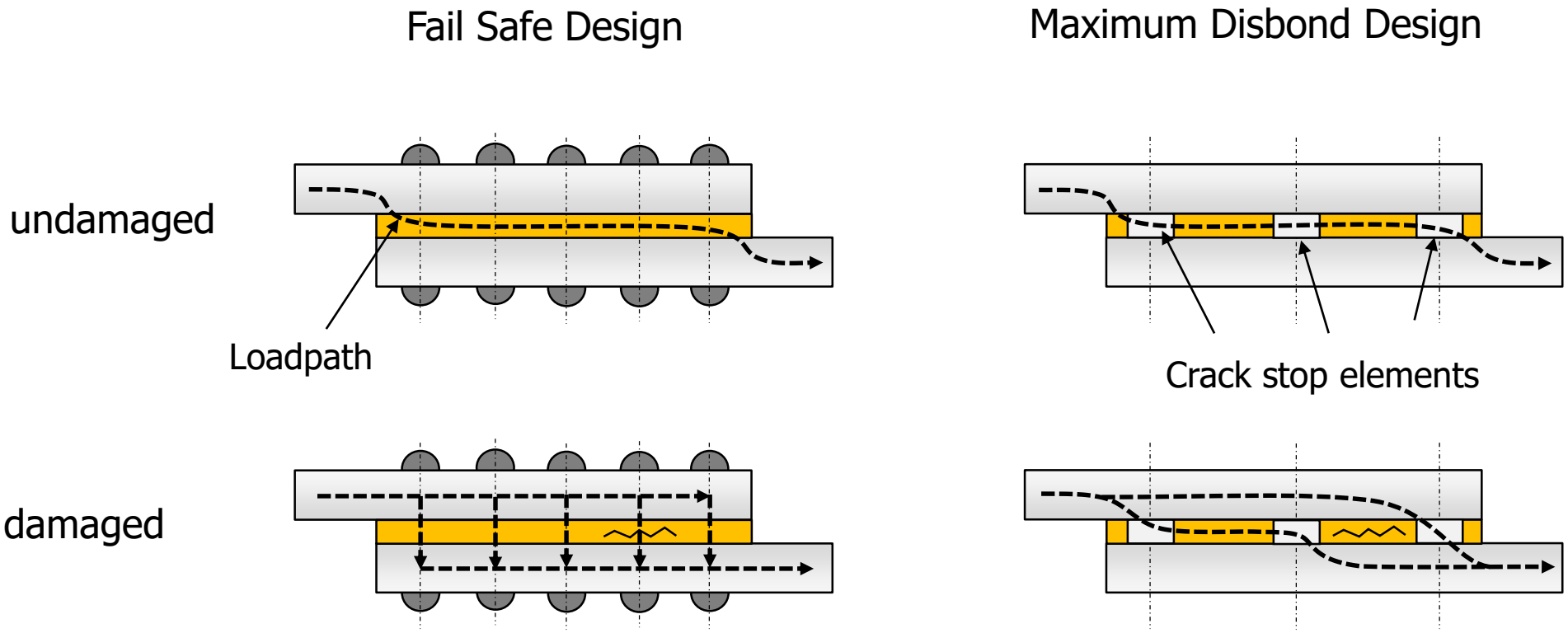
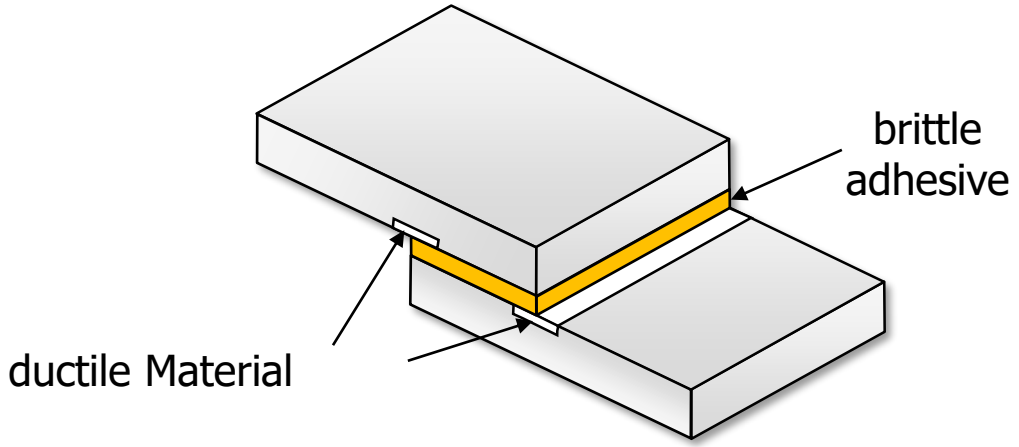


From the bolted to the bonded joint



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

Local Surface Toughening (ST) - Concept



Increase in joint strength

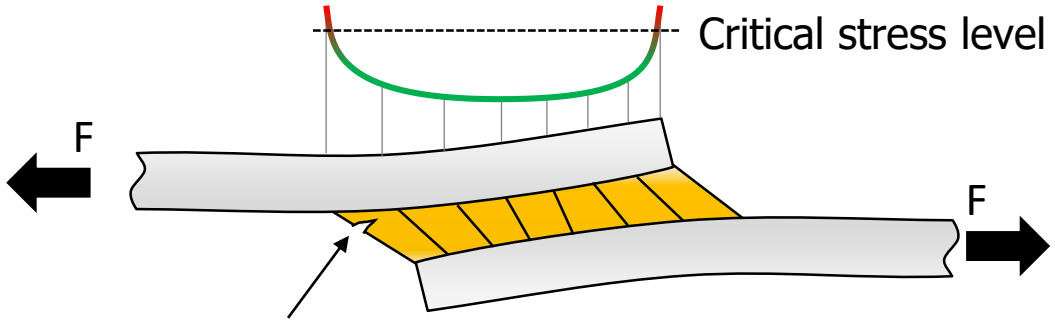
The targeted arrangement of the local surface modification in the bond improves the load distribution and thus increases the bond strength.

Crack stop

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

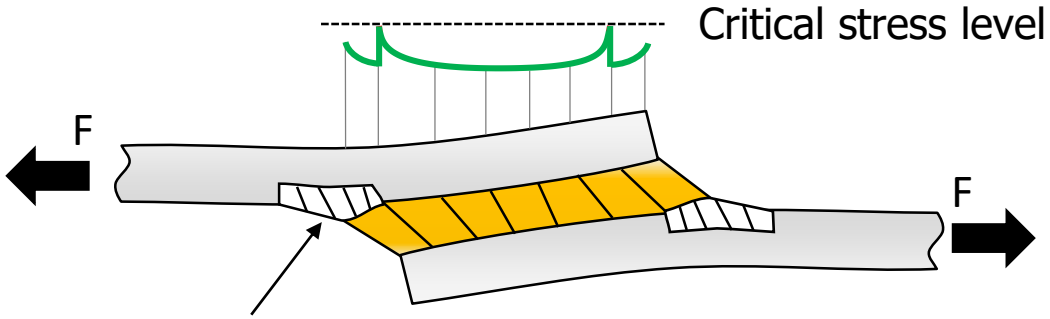
Local Surface Toughening - How it works

Reference



Stress concentrations lead to crack formation

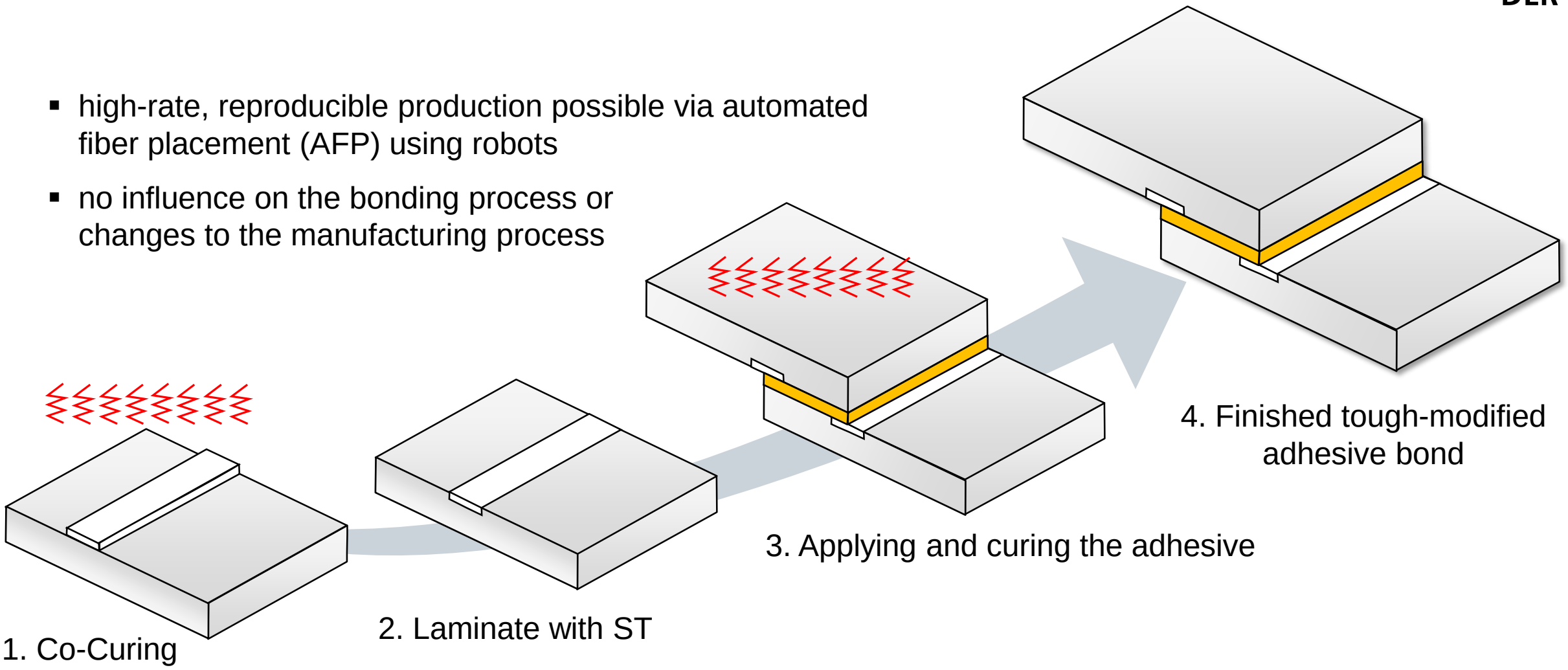
ST



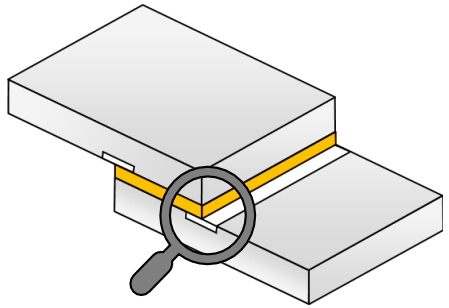
Ductile material absorbs strains and reduces stress concentrations

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

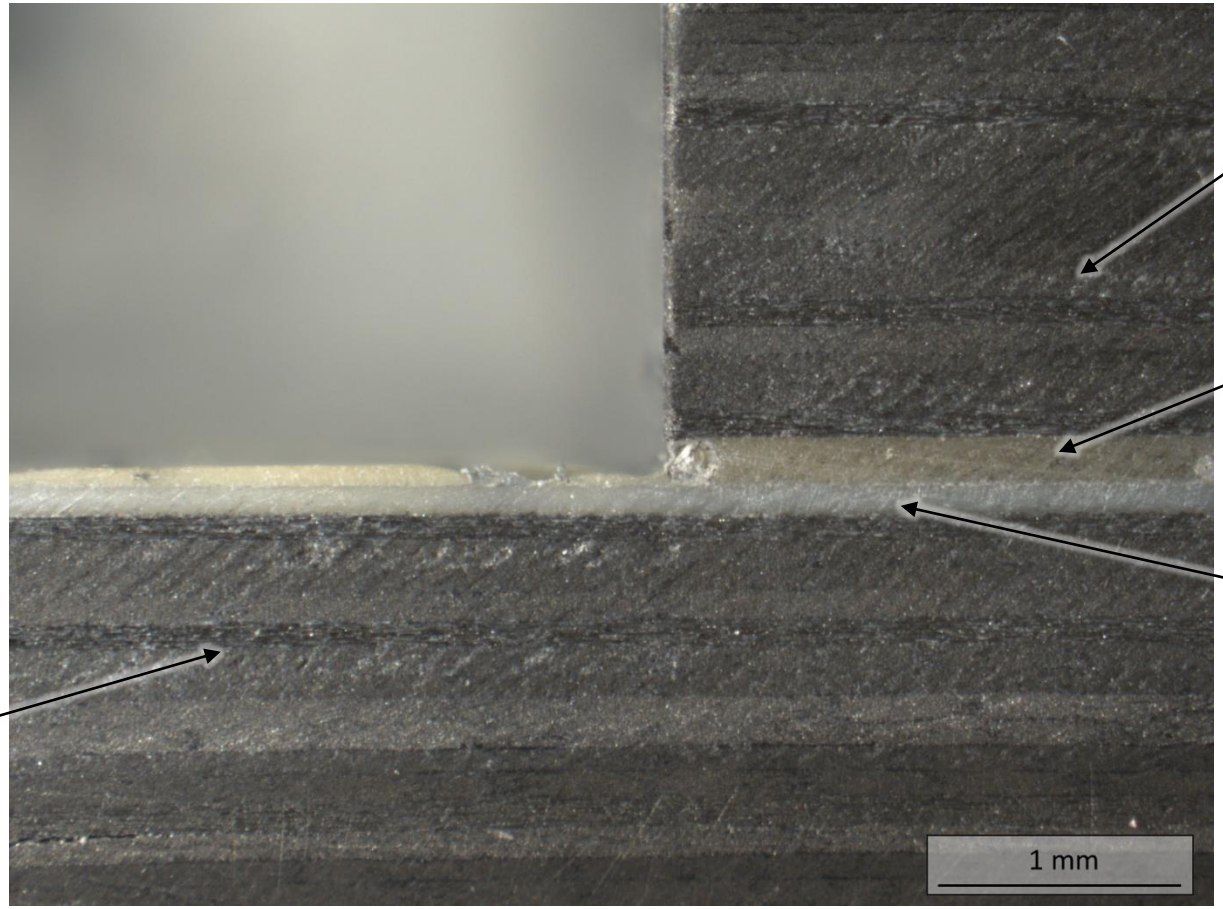


Modulus:

$E_{8552\ IM7}$ = 60.600 MPa

E_{EA9695} = 2.577 MPa

E_{PVDF} = 1.716 MPa



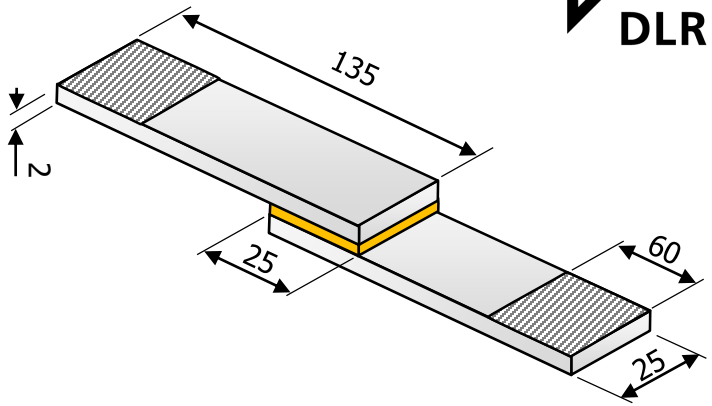
Adherend 2
8552 IM7

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

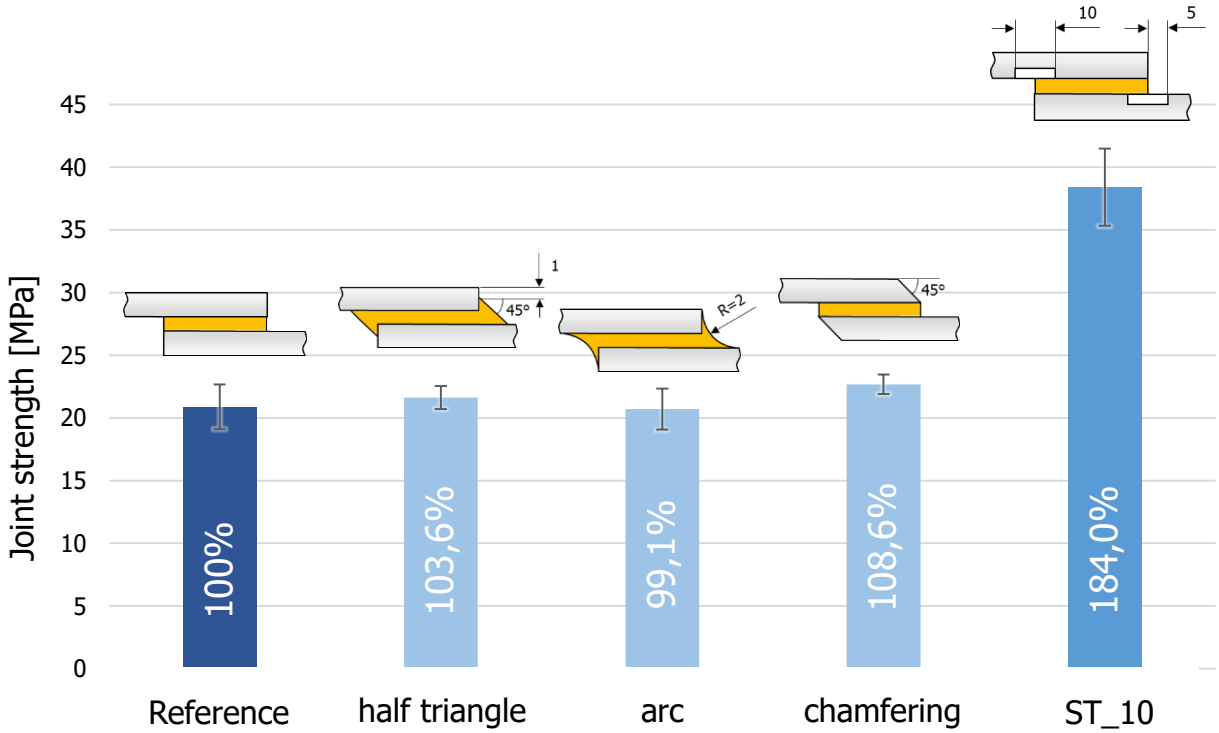
ST-Material
PVDF
t_{ST} ~0,1 mm

Adherend 1
8552 IM7

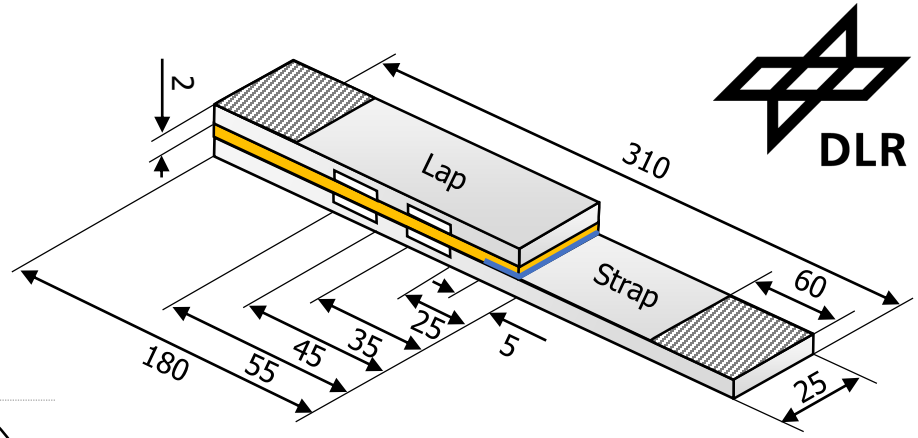
Strength increase under quasi-static load



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

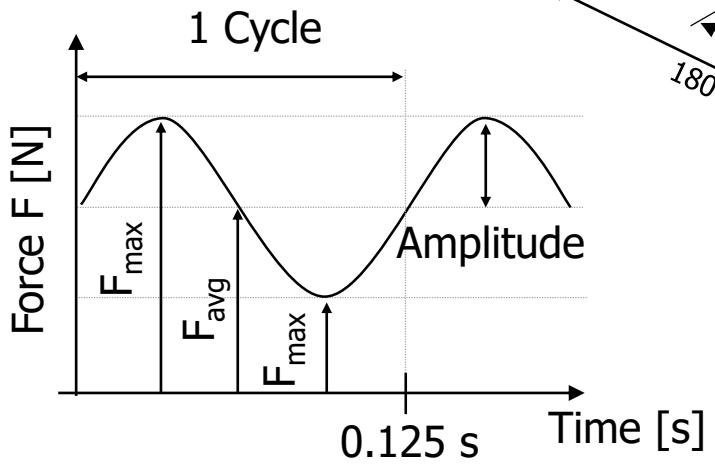


Fatigue strength increase

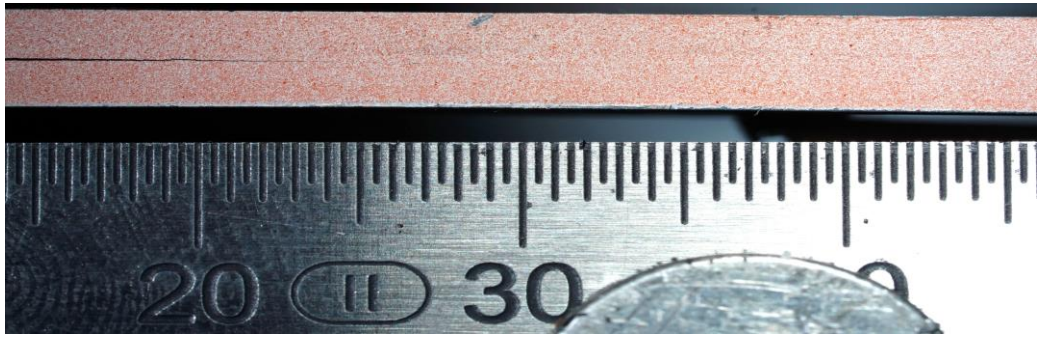


- Dynamic swelling load

Strain [µm m^{-1}]	F_{min} [N]	F_{max} [N]	F_{avg} [N]	Amplitude [N]
3000	928	9280	5104	4176
3500	1086	10860	5973	4887
4000	1243	12430	6837	5594

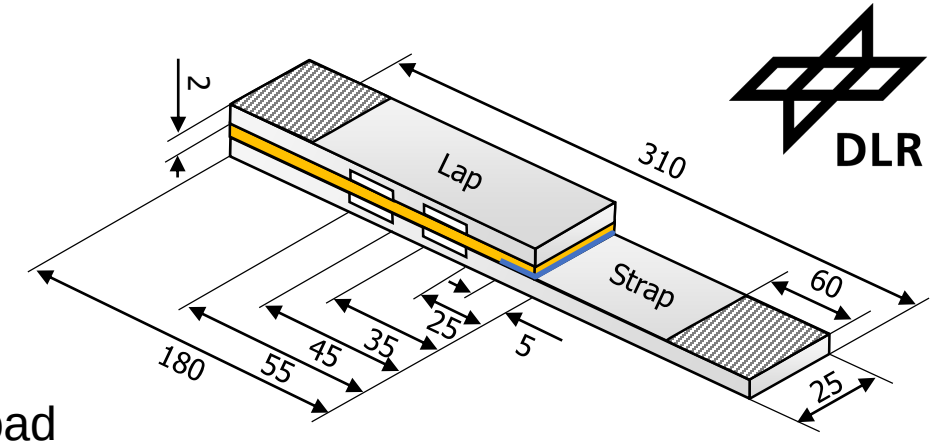


- Crack detection using optical measurement



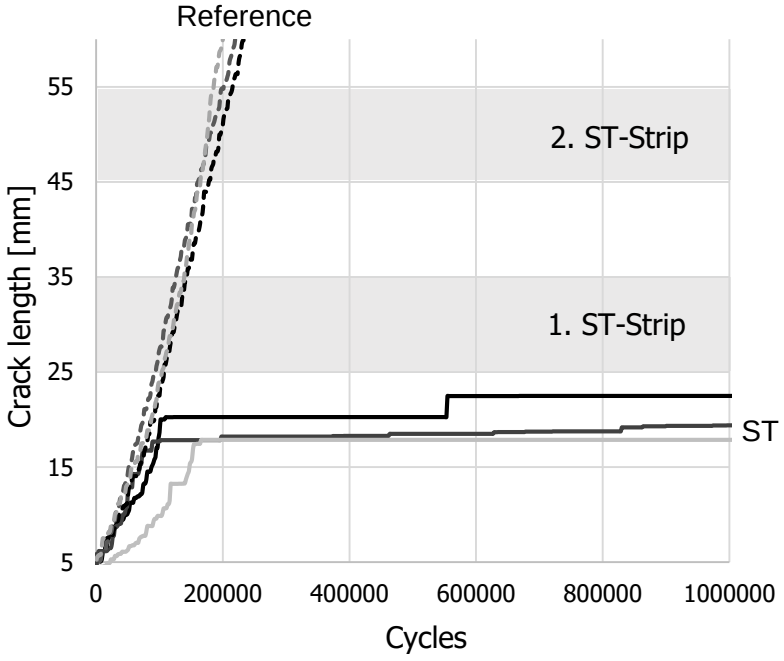
Crack detection of CLS specimen ST_01 3000µm m^{-1} at 1M cycles

Fatigue strength increase

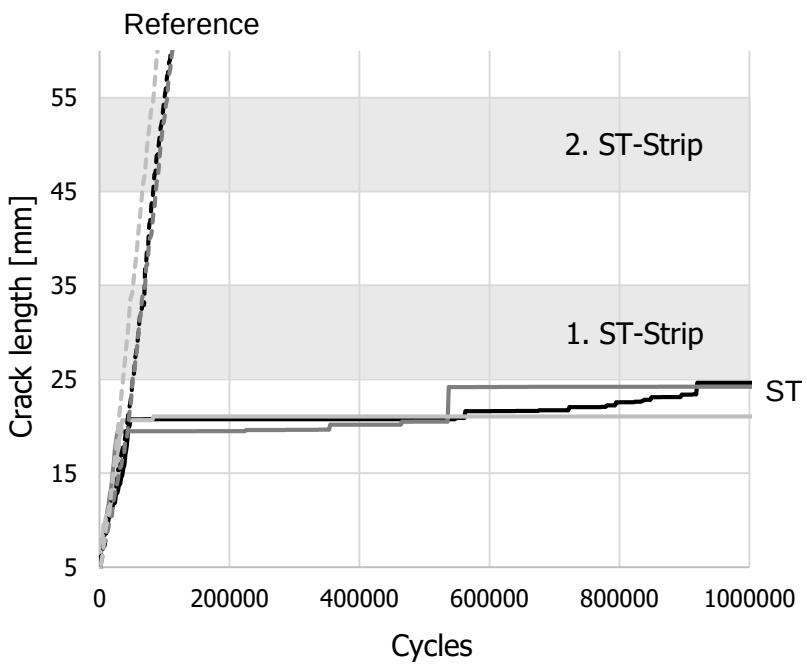


- safe crack stop up to 3000 µm m^{-1} ≙ operating load
- safe crack stop up to 3500 µm m^{-1} ≙ 117% of the operating load
- slowed crack stop up to 4000 µm m^{-1} ≙ 133% of the operating load

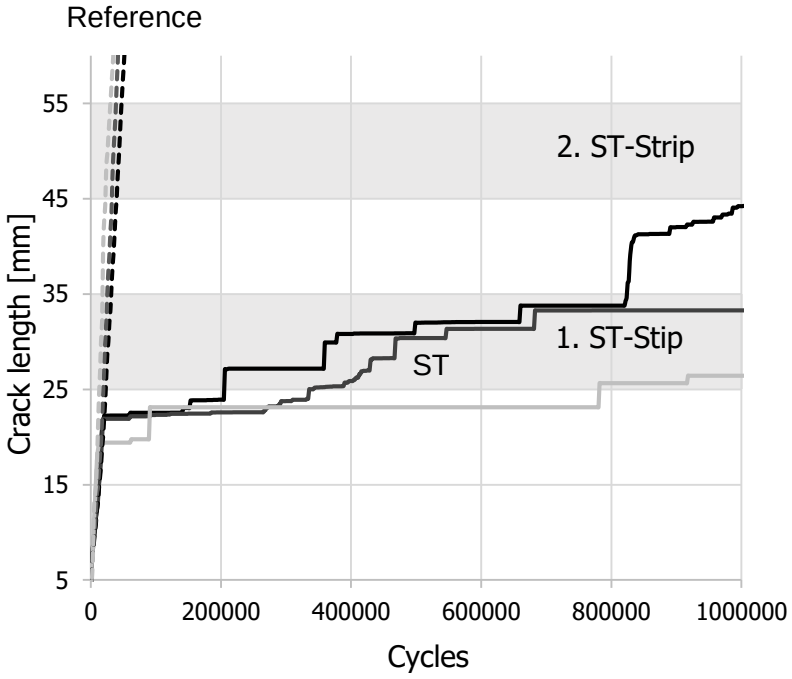
3000 µm m^{-1}



3500 µm m^{-1}



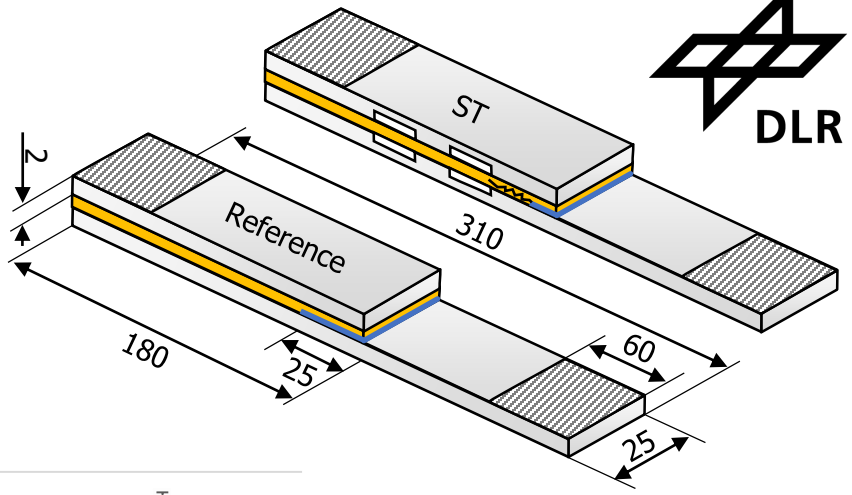
4000 µm m^{-1}

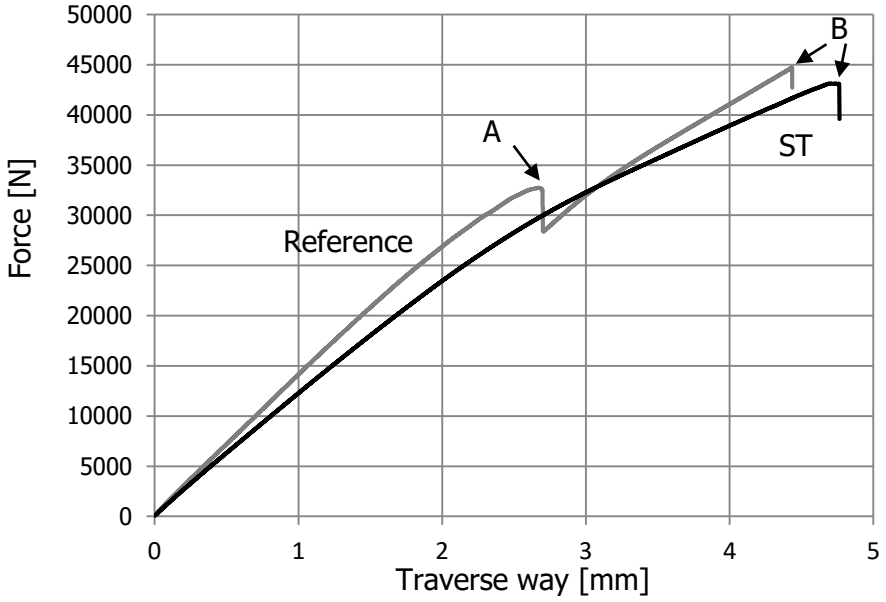


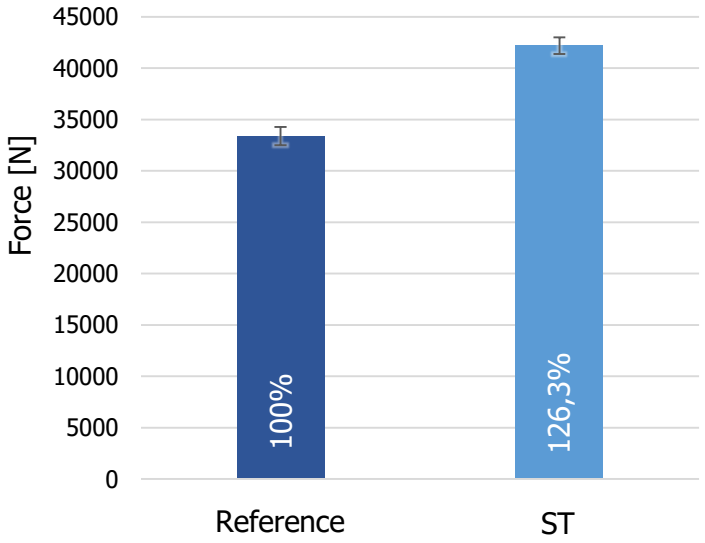
Residual strength of the CLS specimens

Reference: Cohesive failure (A)

ST: Substrate breakage (B)







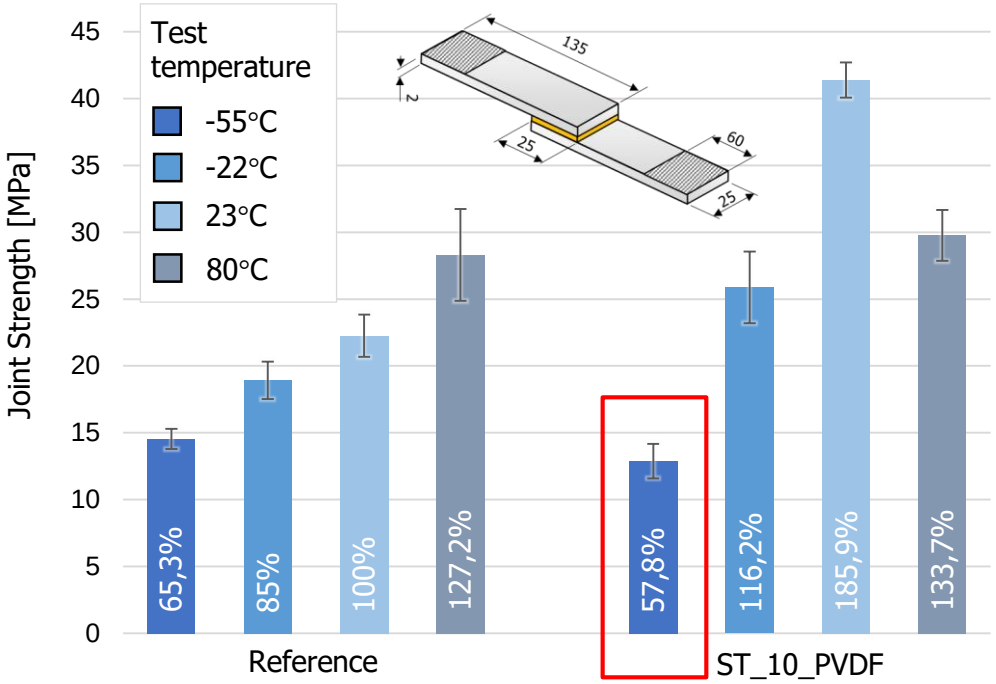
Local surface toughening stops cracks and increases the joint strength!

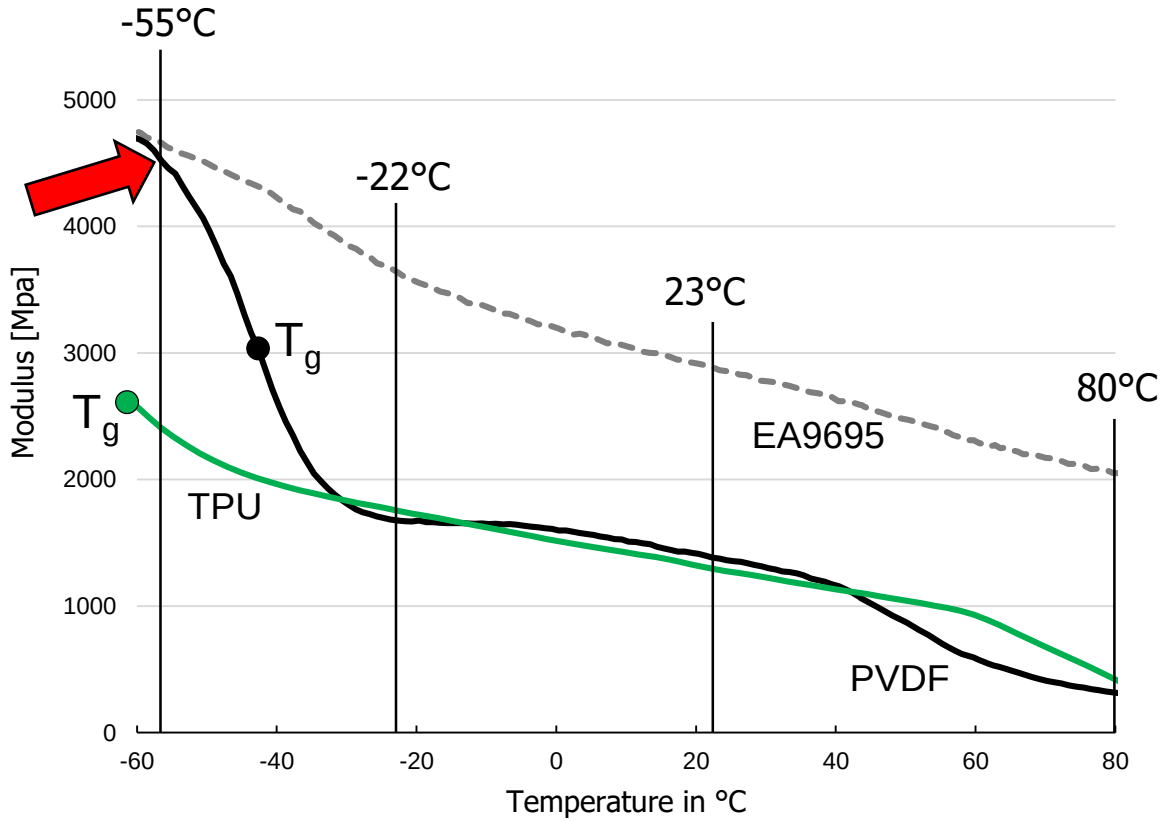
Conclusion and Outlook

- ...increases the joint strength by up to 84% or until the joint component breaks
- .... has a reliable crack-stopping effect beyond the operating load to 117% LL
- .... 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…

Conclusion and Outlook





→TPU for next trials!

Imprint

Topic: Local Surface Toughening – A boltless crack stopping technology for aerospace structures

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Institute: Institute of Lightweight Systems

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