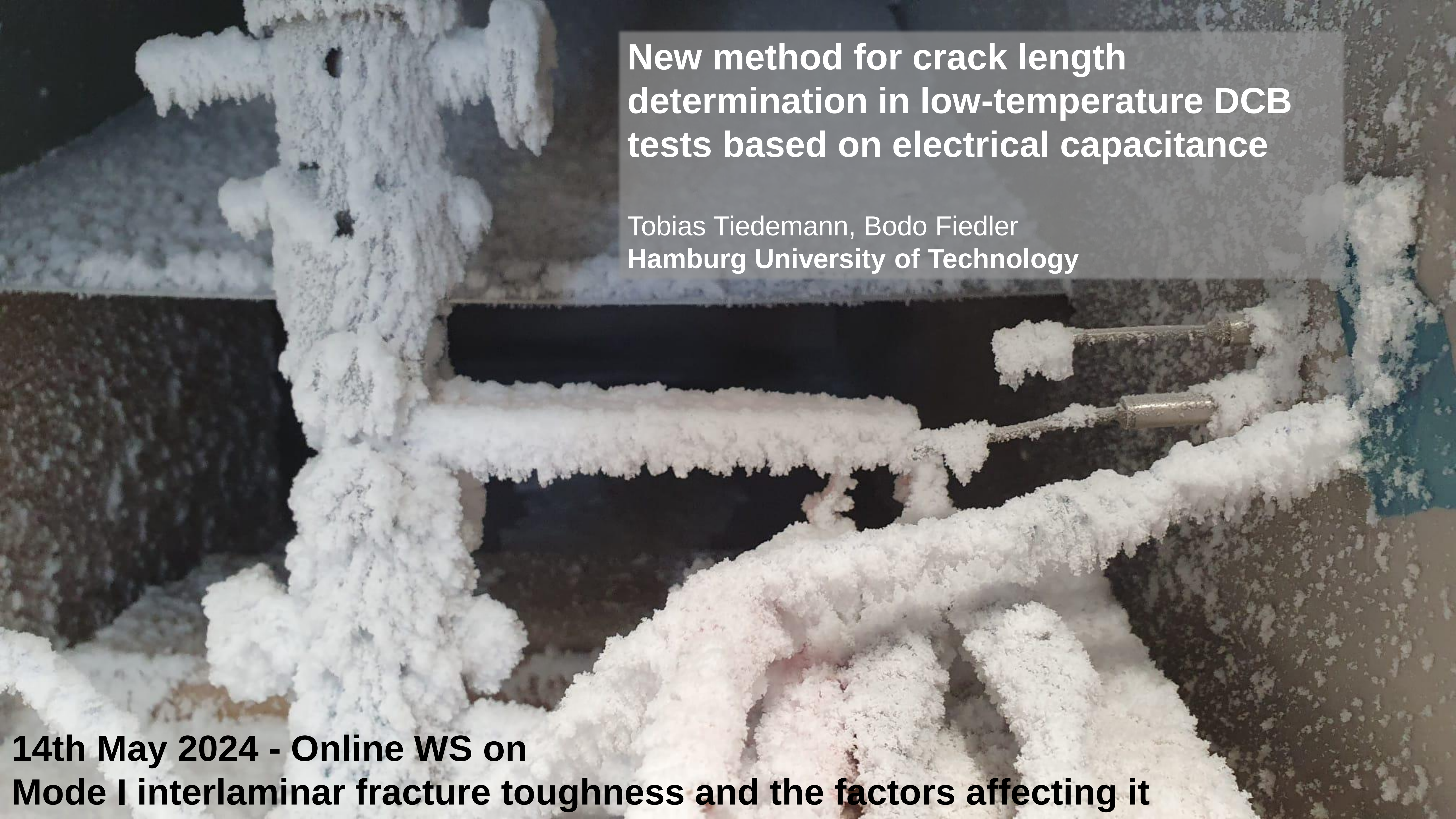

New method for crack length determination in low-temperature DCB tests based on electrical capacitance

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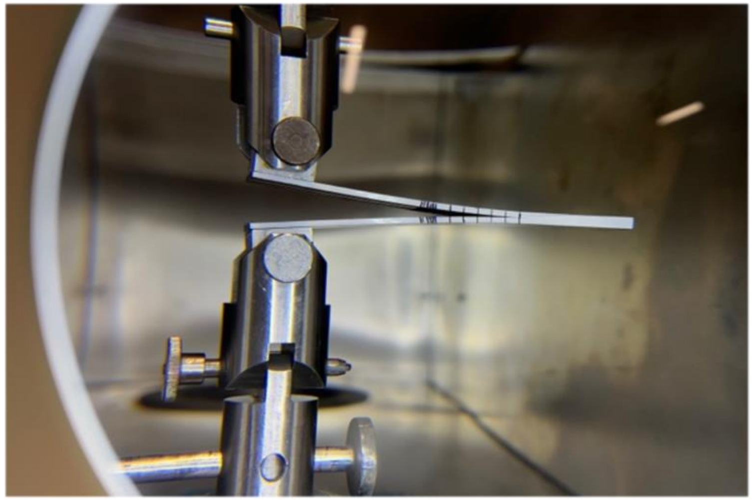
14th May 2024 - Online WS on
Mode I interlaminar fracture toughness and the factors affecting it

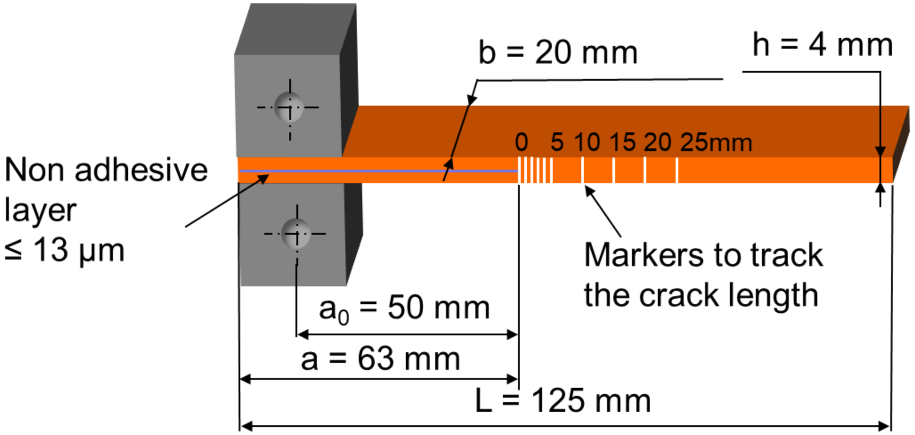
Mode I Fracture Toughness Test

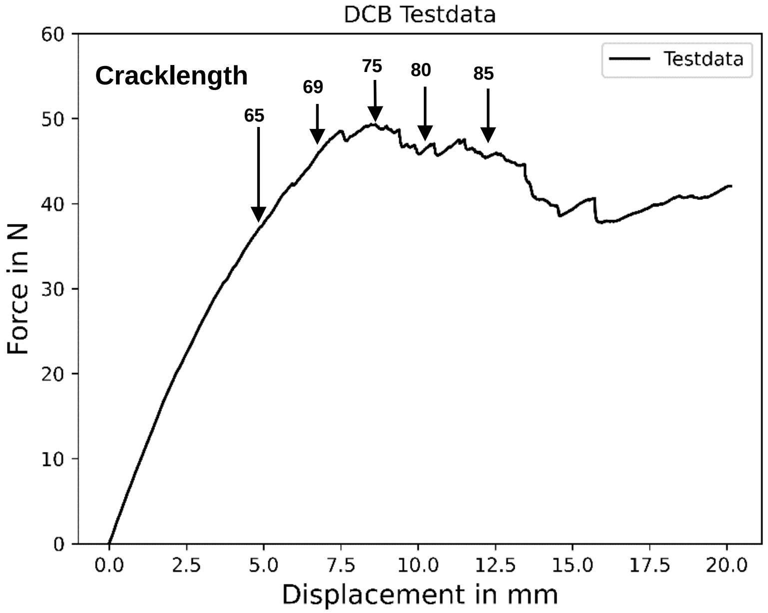
State of the art:

Double cantilever beam test (ASTM 5528)

- Pre-cracked specimen
- Crack initiation detection
- Crack propagation measurement







Capacity Measurement

Ideal capacitor

$$C_{el} = \epsilon_0 \cdot \epsilon_r \cdot \frac{A}{d}$$

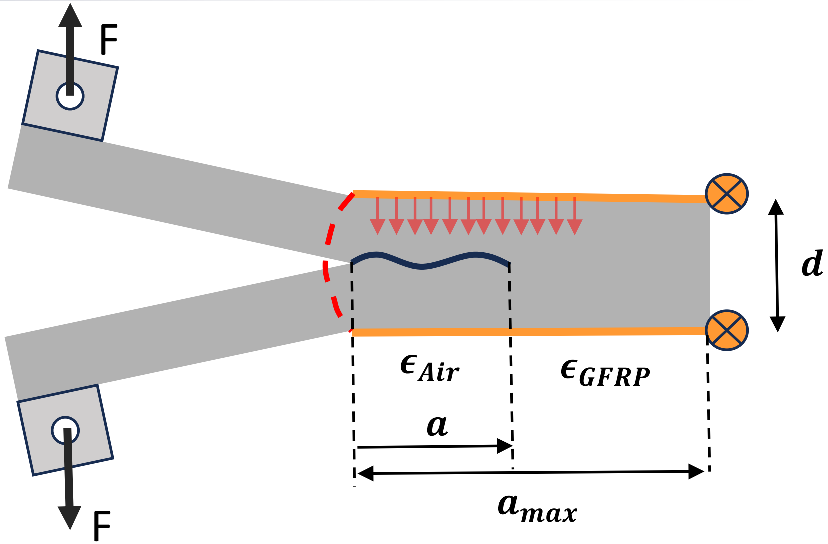
DCB Crack length determination

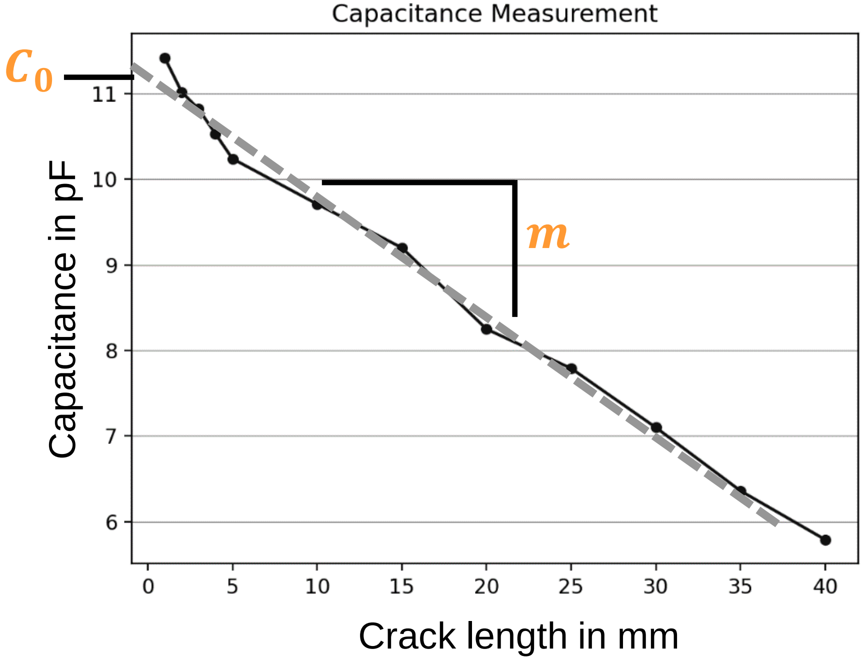
$$C_{el} = \epsilon_0 \cdot (\epsilon_{Air} \cdot a + \epsilon_{GFRP} \cdot (a_{max} - a)) \cdot \frac{b}{d}$$

C_{el} = electrical capacitance
A = capacitor area
d = distance
ϵ_0 = vacuum permittivity
ϵ_r = relative permittivity
$\epsilon_{r,Air}$ = 1
$\epsilon_{r,GFRP}$ = 5…8

Linear Relationship

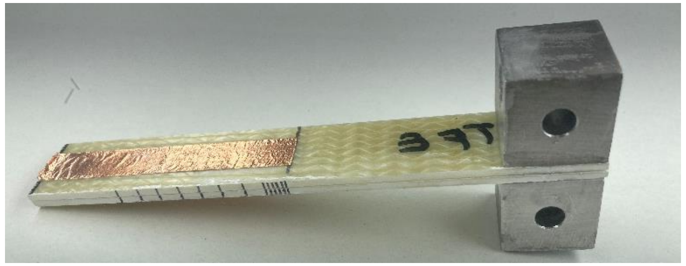
$$a = \frac{C_{el} - C_0}{m}$$





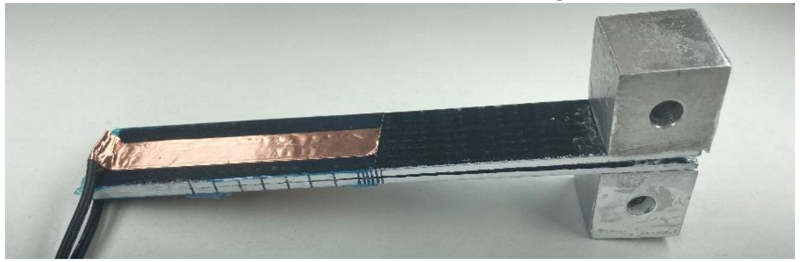
Materials

GFRP

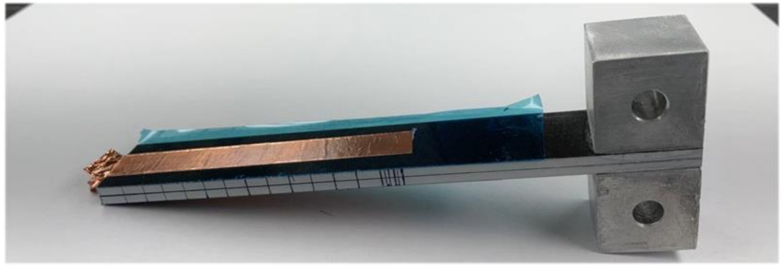


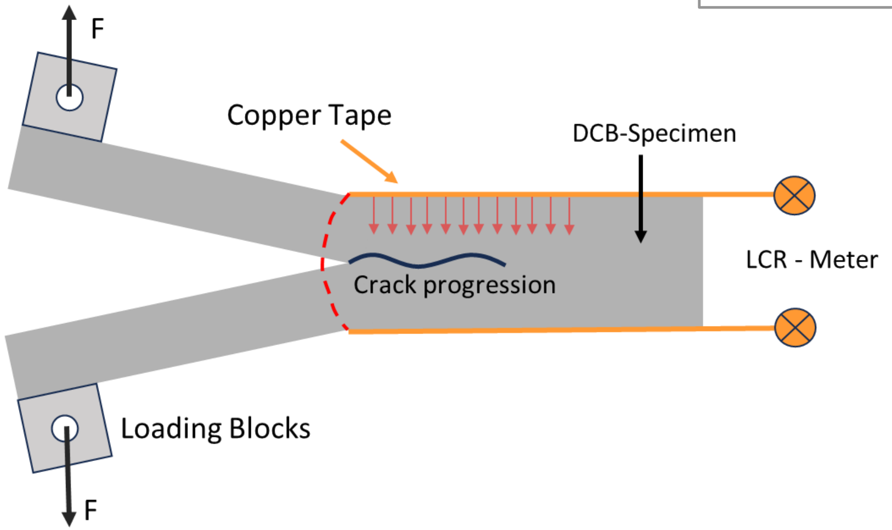
Conductive Materials

GFRP + Carbon Nanoparticles

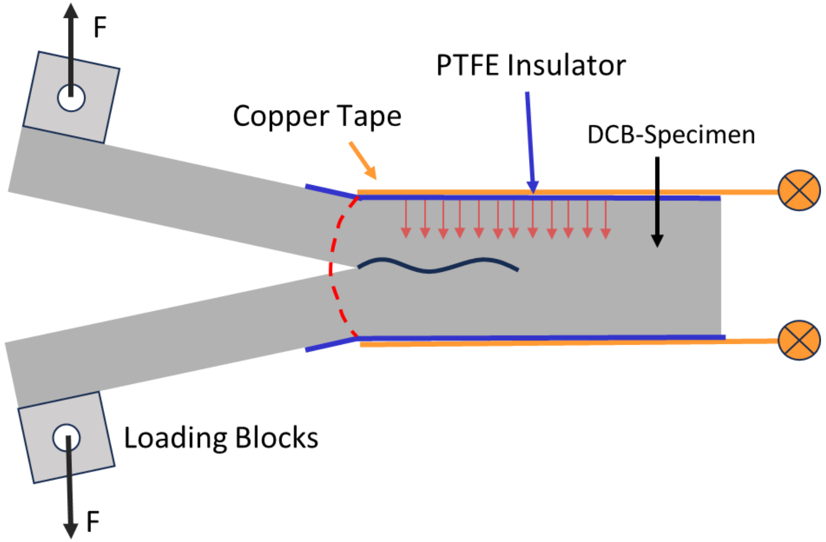


CFRP





$$C_{el} = \epsilon_0 \cdot (\epsilon_{Air} \cdot a + \epsilon_{GFRP} \cdot (a_{max} - a)) \cdot \frac{b}{d}$$



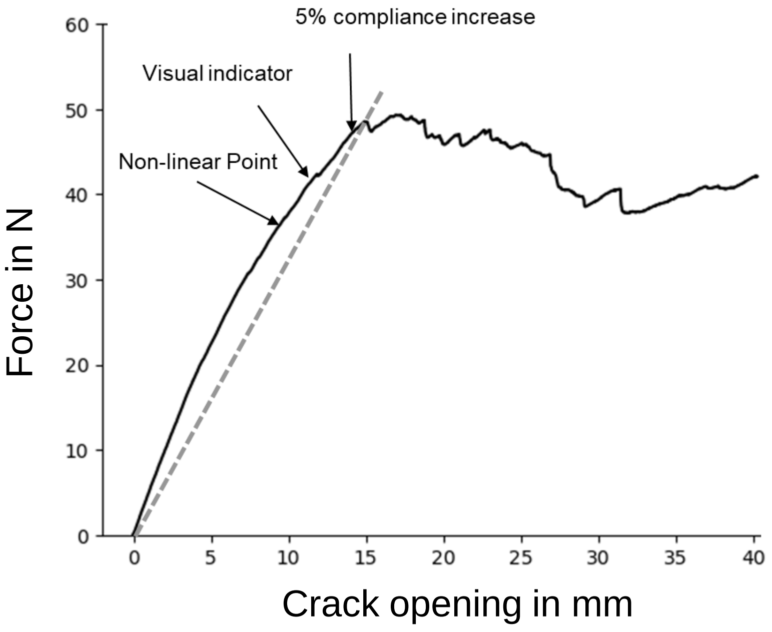
$$C_{el} = \epsilon_0 \cdot (\epsilon_{Air} \cdot a + \epsilon_{GFRP} \cdot (a_{max} - a) + \epsilon_{PTFE} \cdot a_{max}) \cdot \frac{b}{d}$$

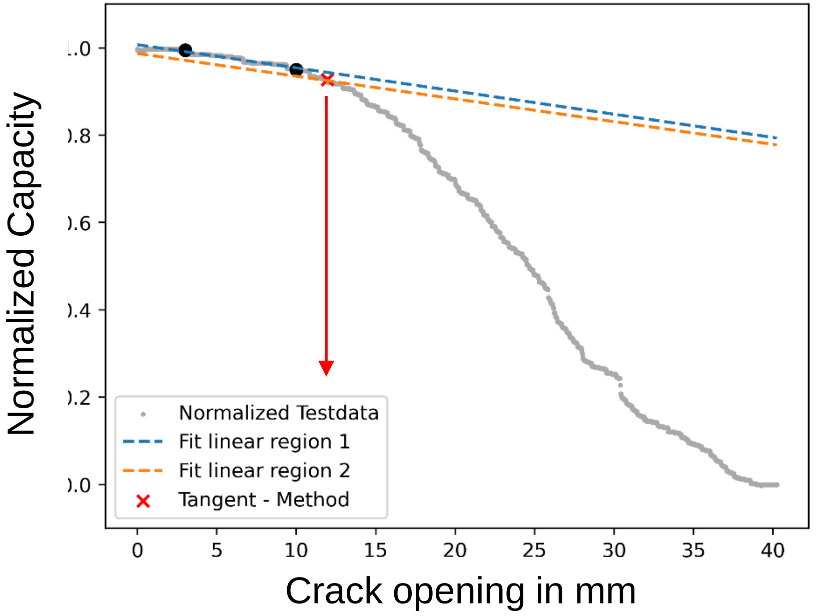
Evaluation Method – Initiation Point

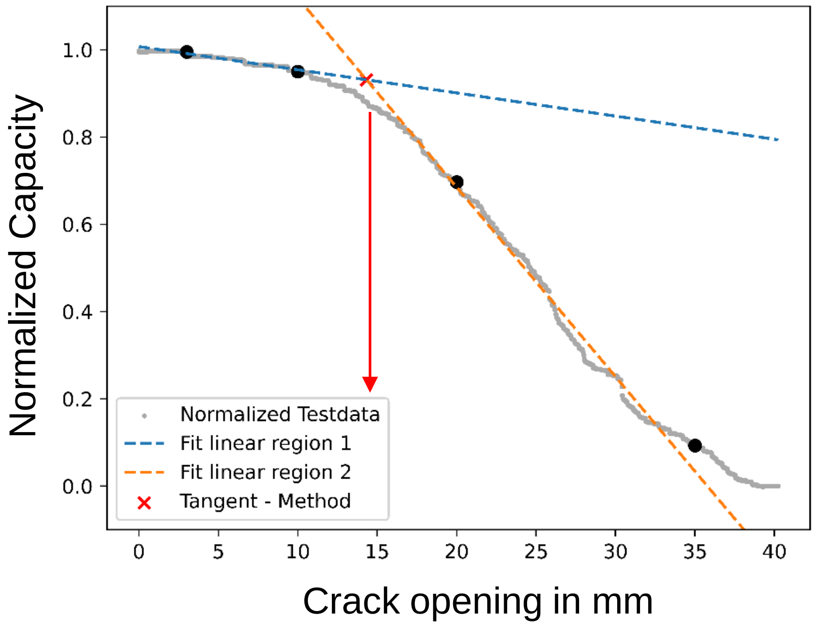
Determination of the critical energy release rate G_{Ic} based on electrical capacitance

1. Determine initiation point

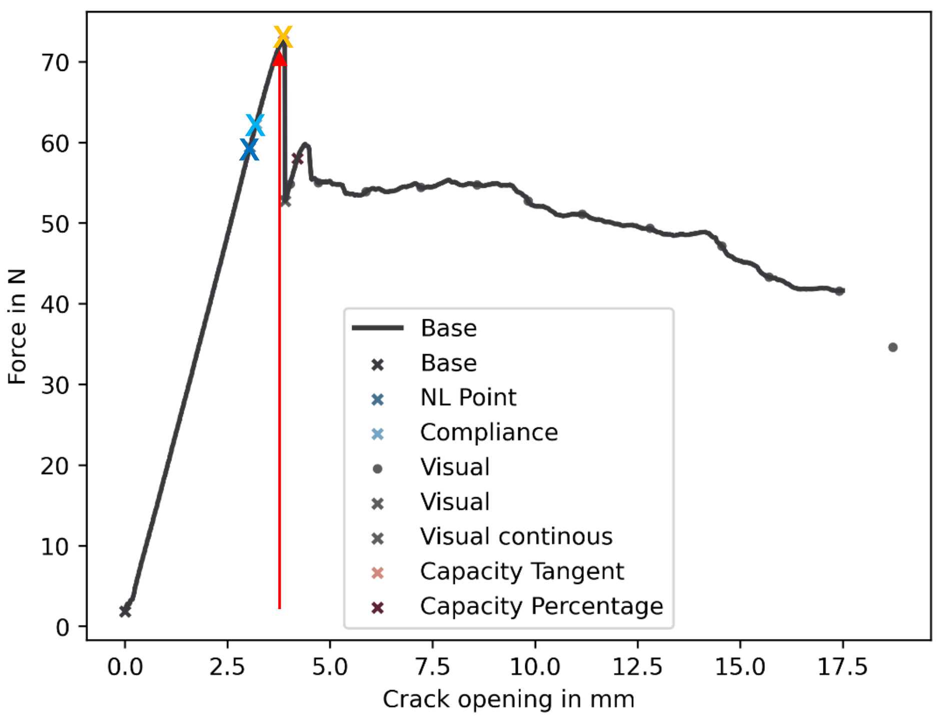
- Visual inspection
- Non- linear Point
- 5% Compliance increase
- 5% Capacity decrease
- Capacity tangent

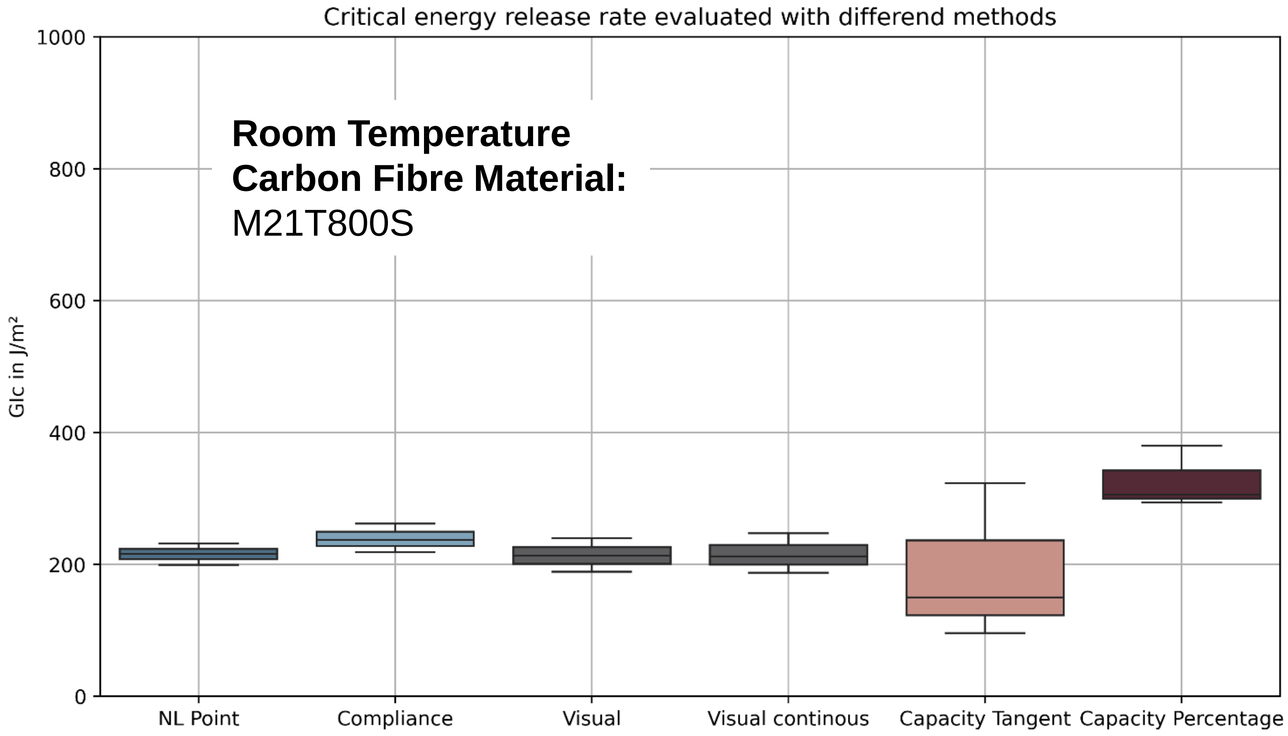






Conclusion – Critical energy release rate

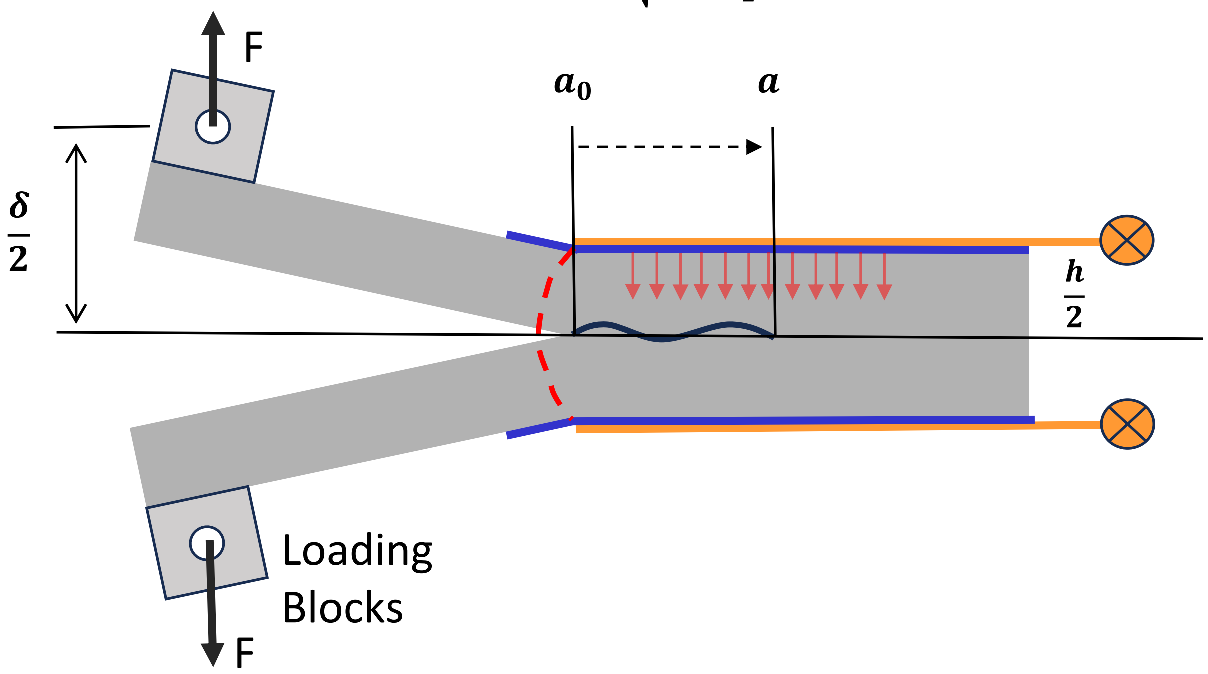


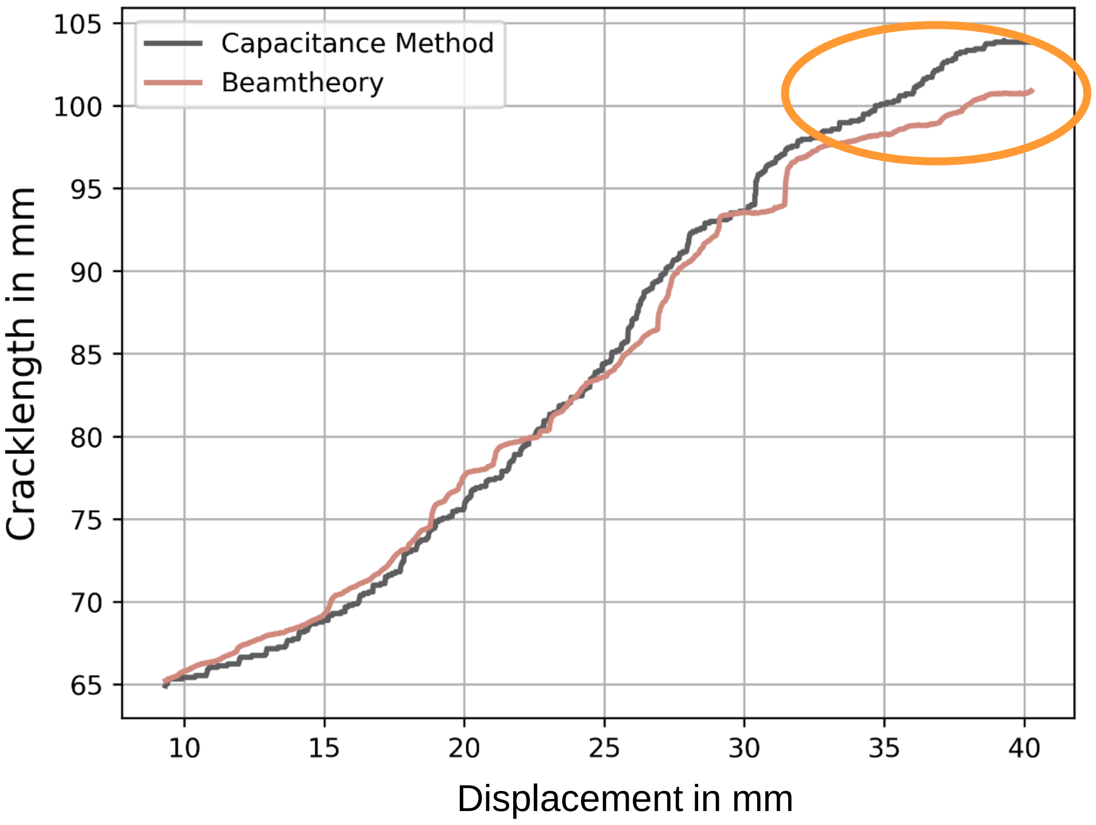


Validation with Beam Theory

$$\delta = \frac{F \cdot a^3}{3 \cdot E \cdot I} \qquad I = \frac{b \cdot h^3}{12}$$

$$a = \sqrt[3]{\frac{\frac{\delta}{2} \cdot 3 \cdot E \cdot I}{F}}$$

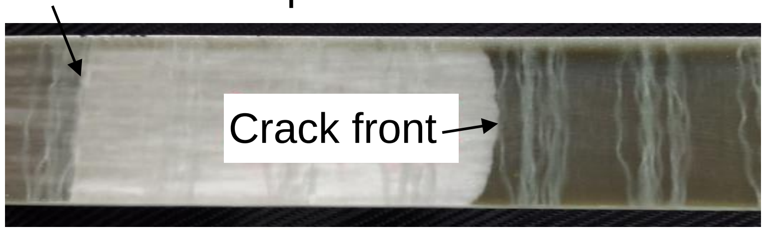


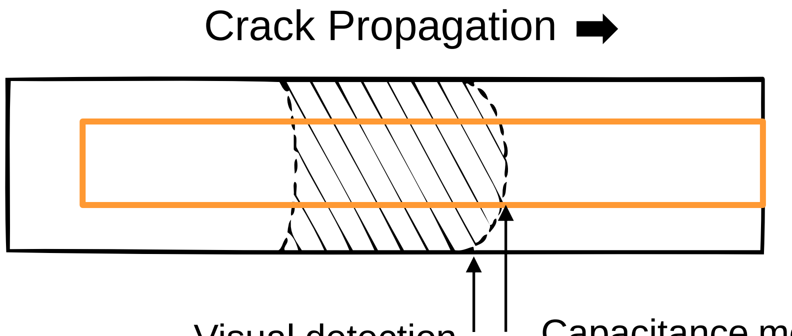


Summary

- Reliable R-Curve determination even with no visual markings
- Method can be used with different materials - conductive and non conductive
- Possibility of using DCB in closed test environment

- Crack front detection in the middle of the specimen
- Start of crack propagation
- Large bending has no impact (beam theory)





B. D. Davidson, „An Analytical Investigation of Delamination Front Curvature in Double Cantilever Beam Specimens“, *Journal of Composite Materials*, Bd. 24, Nr. 11, S. 1124–1137, Nov. 1990

Acknowledgement