Polymer Composites

TUHH
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23rd International Conference on Composite Materials – ICCM23

CAPACITANCE MEASUREMENTS ON INTEGRATED CARBON FIBRE ROVINGS FOR STRUCTURAL HEALTH MONITORING IN GFRP

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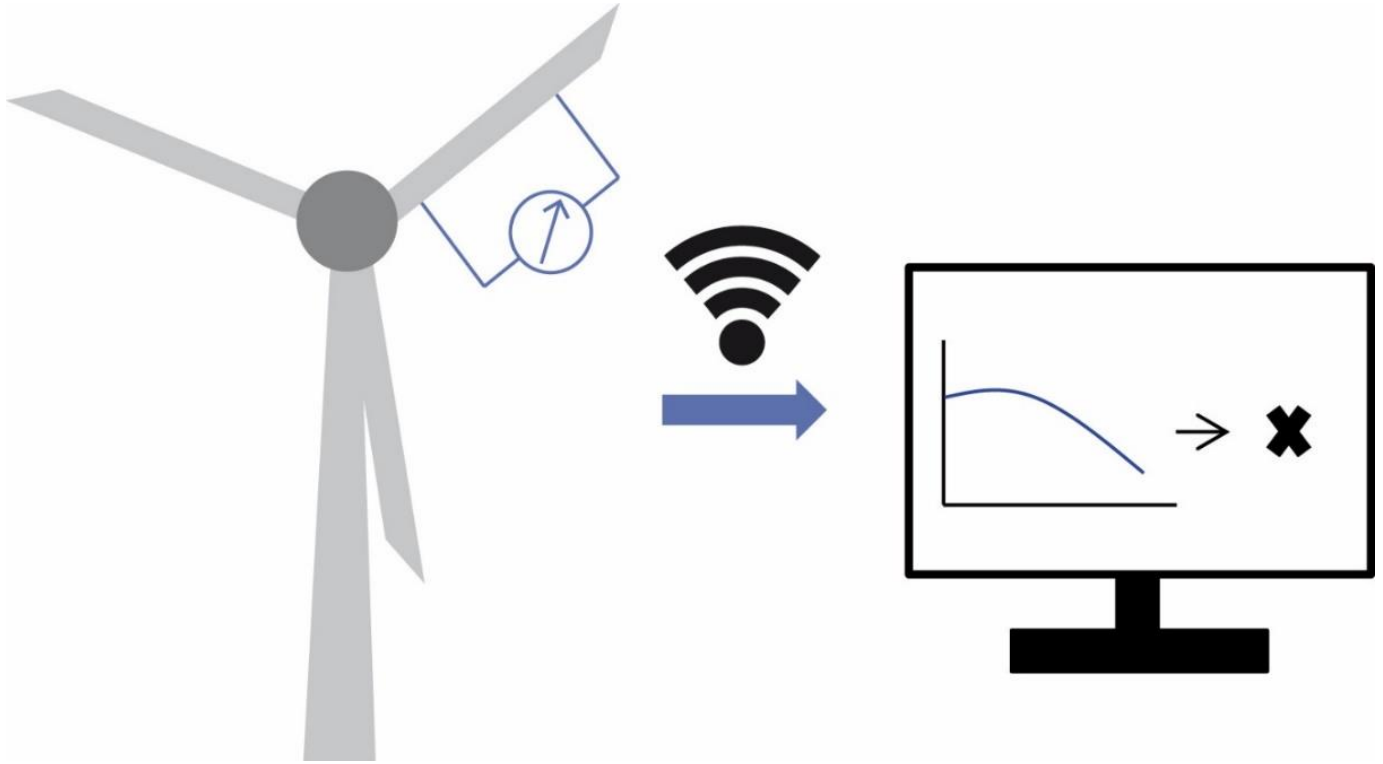
Belfast, 04.08.2023

Motivation



Electrical SHM method for detection and evaluation of damages in GFRP

Local fibre replacement

- Fully-integrated, conductive carbon fibre bundles

→ Capacitance measurements for damage sensing

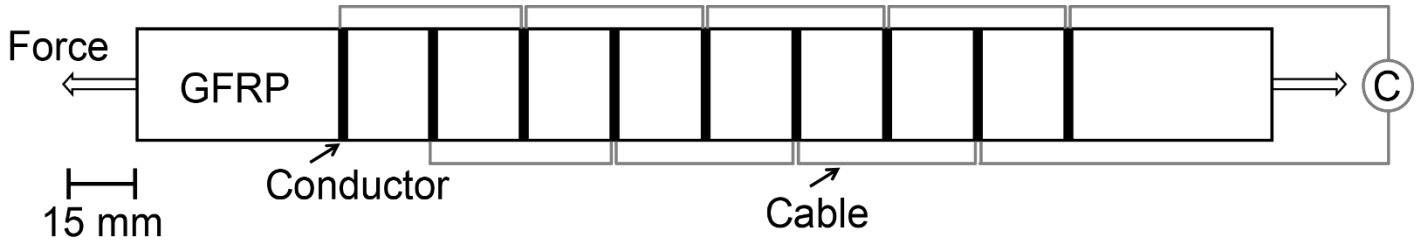
Manufacturing Bundle Specimens

Bundle Replacement → **RTM-Process** → **Specimen Preparation**

- Gurit non-crimp E-glass fabric UT-E250
- CF rovings FT300B 6000-50B

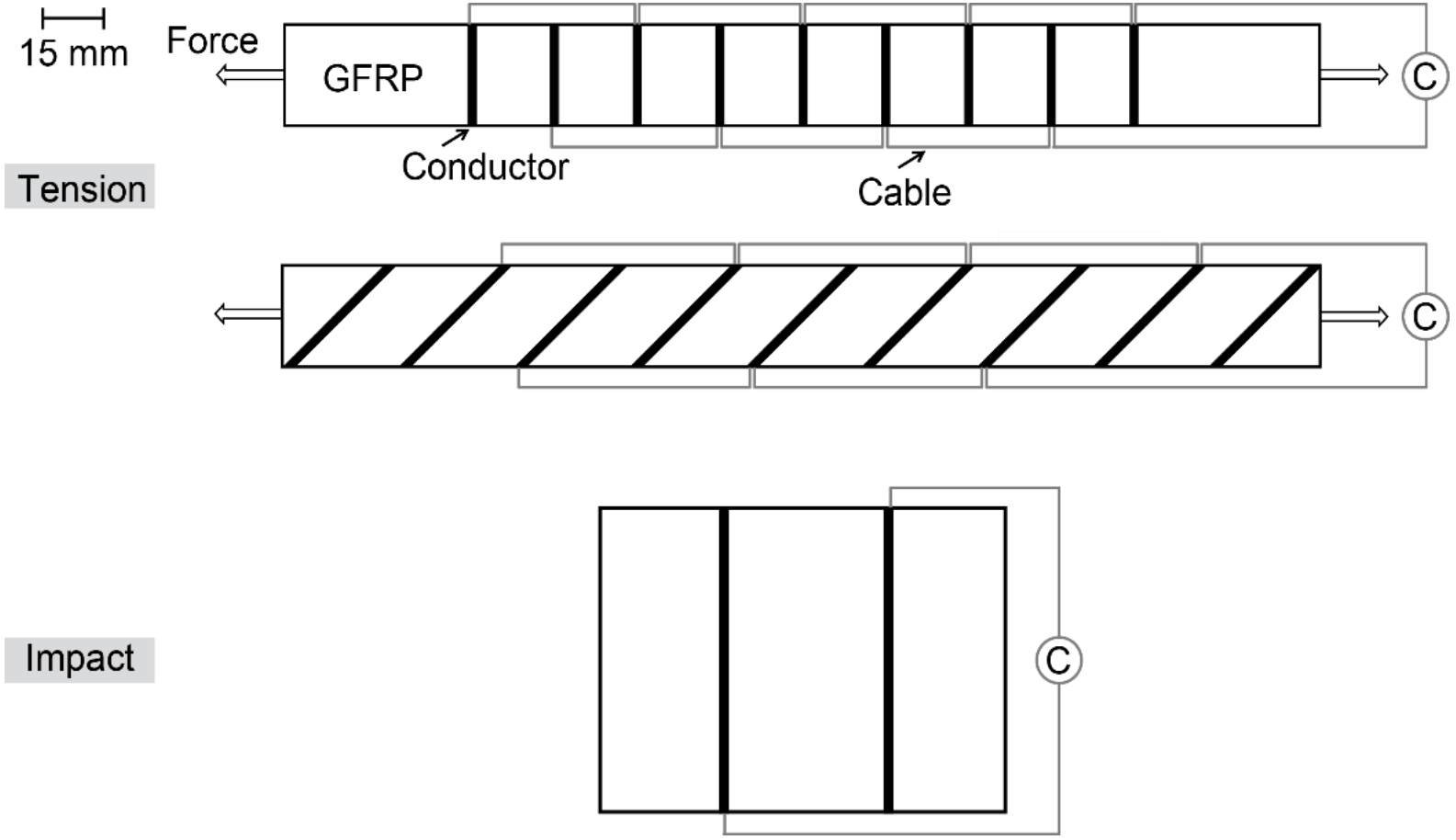
- Epoxy system: Hexion RIMR 135 & RIMH 137
- Heat press 16 h @ 50 °C
- Post-curing 16 h @ 80 °C

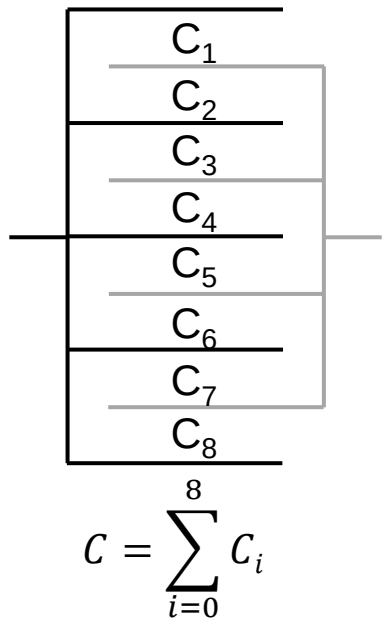
- Cutting using a precision saw
- Contacting using silver conductive paint



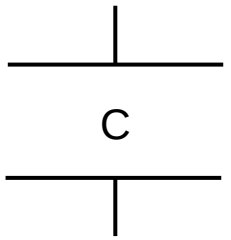
Specimen Geometries including CF Bundles

Coupon specimens	Lay-up	Bundle Distance
Tension	$[0/\mathbf{90_4}]_s$	13 mm 18 mm
	$[\mathbf{90_2}/0/45_2]_s$ $[90_2/0/\mathbf{45_2}]_s$	18 mm
Impact	$[0/\mathbf{90_4}]_s$	39 mm





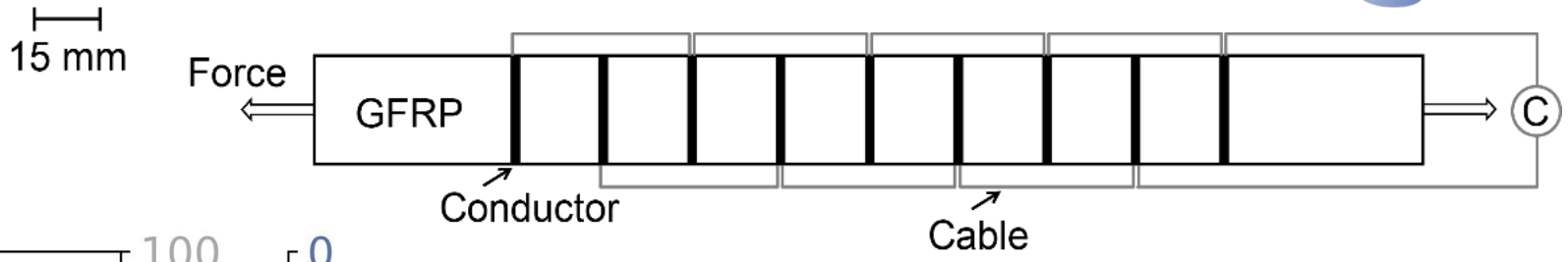
$$C = \sum_{i=0}^{8} C_i$$

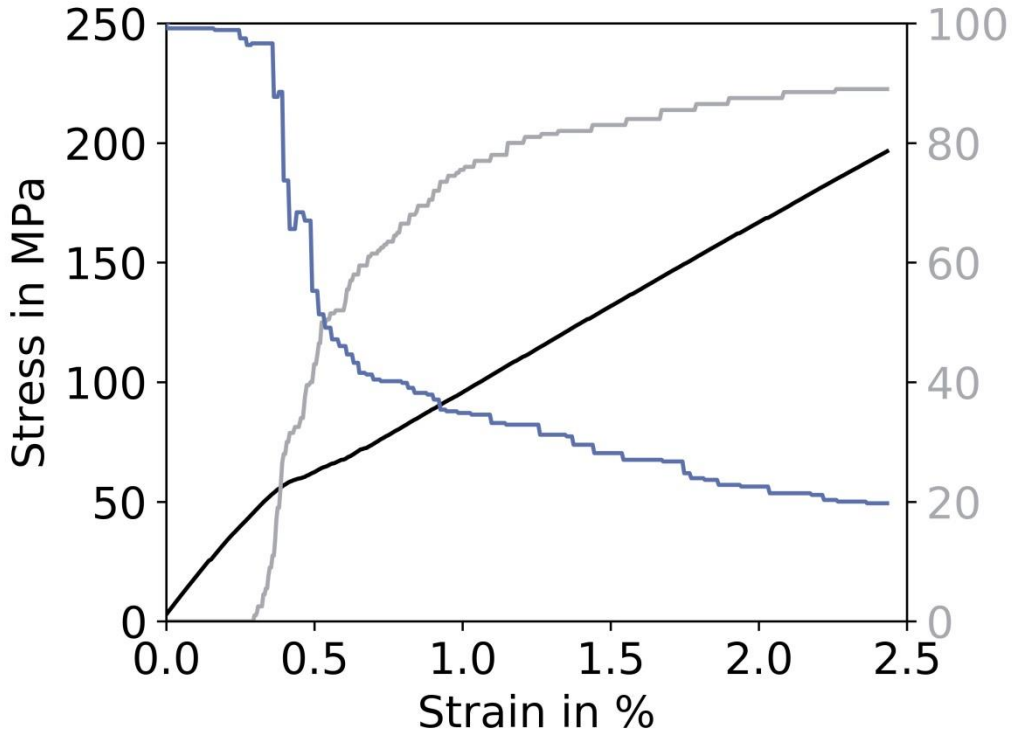


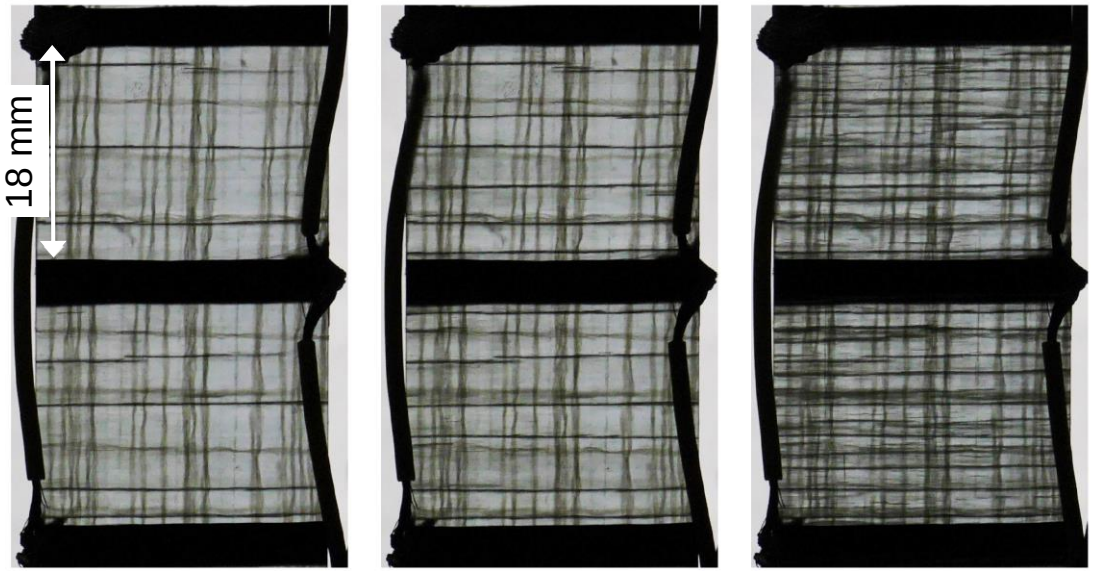
Capacitance-based Sensing

DIN EN ISO 527-4

$[0/\mathbf{90}_4]_s$







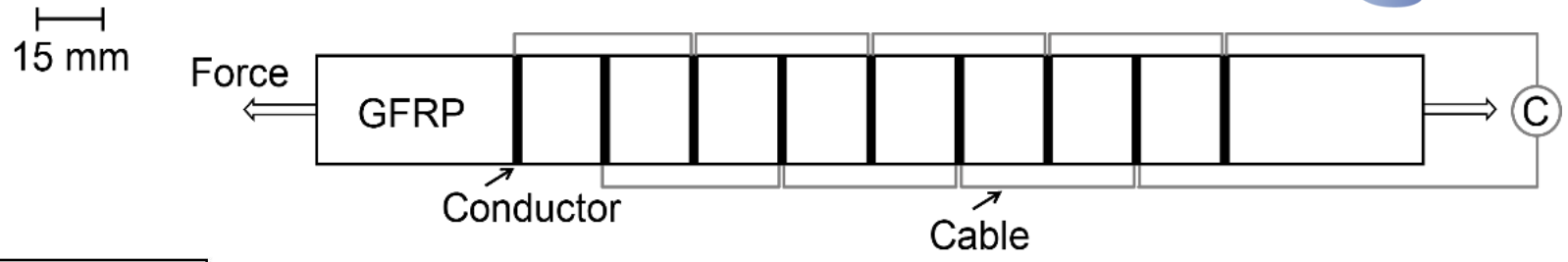
- Correlation of capacitance decrease and crack evolution
- Sensitivity sufficient → CF bundles suitable, material-conform electrodes

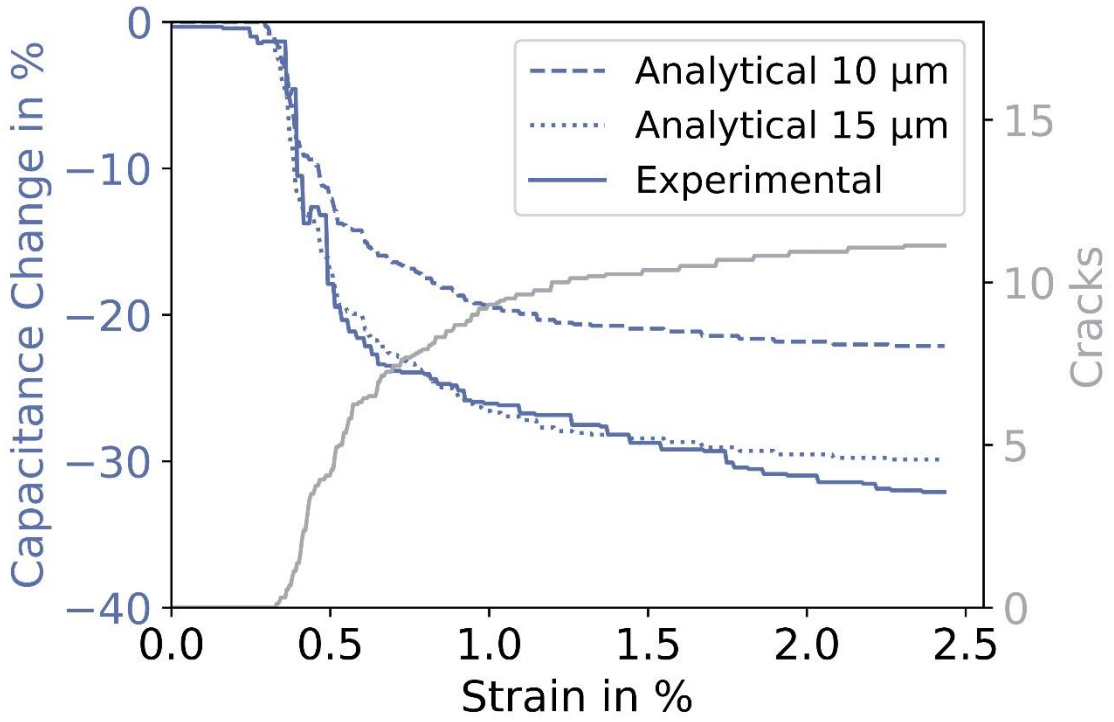
More information:
[Bug2021]

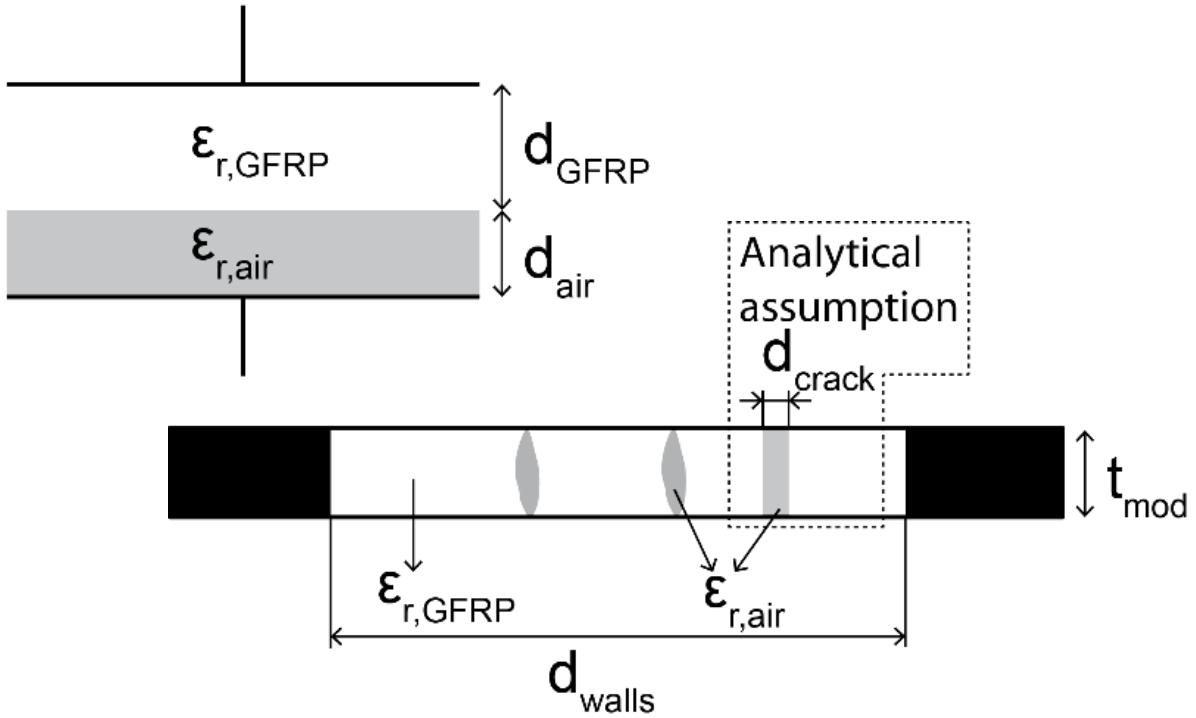
Analytical Modelling

DIN EN ISO 527-4

$[0/\mathbf{90}_4]_s$







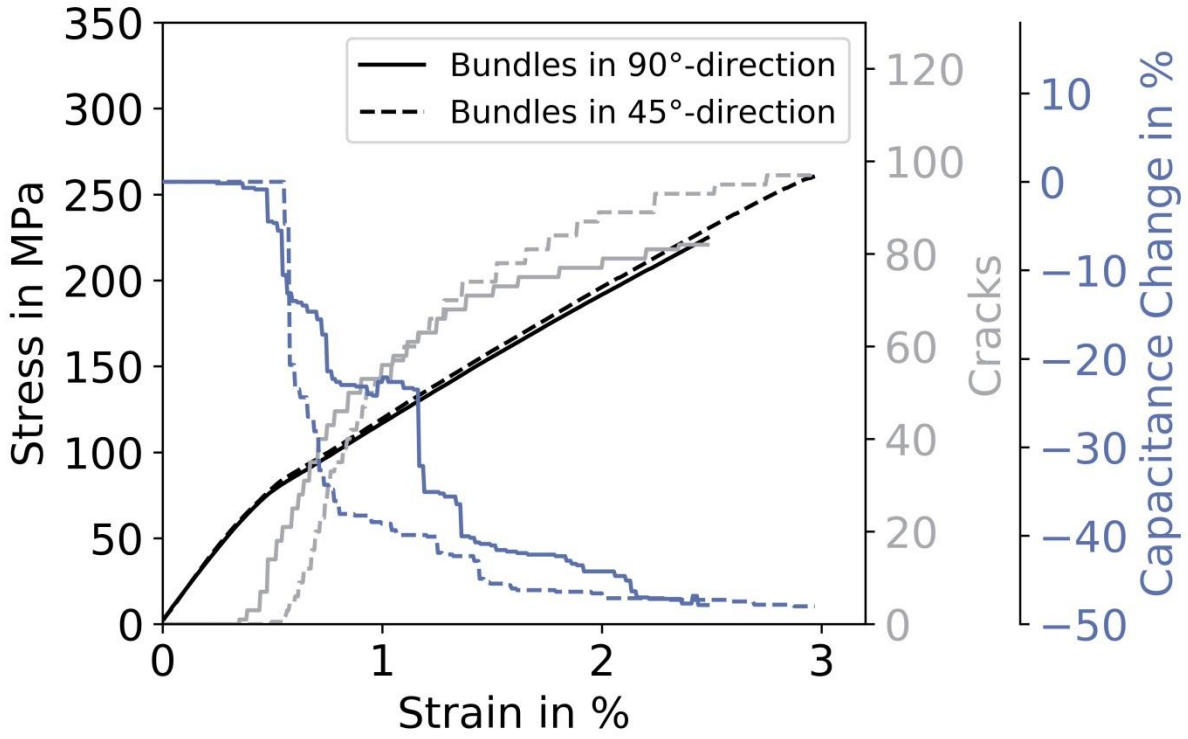
- Analytical modelling confirms cracks as main effect for capacitance decrease
- Assumptions regarding air as second medium and rectangular cracks sufficient

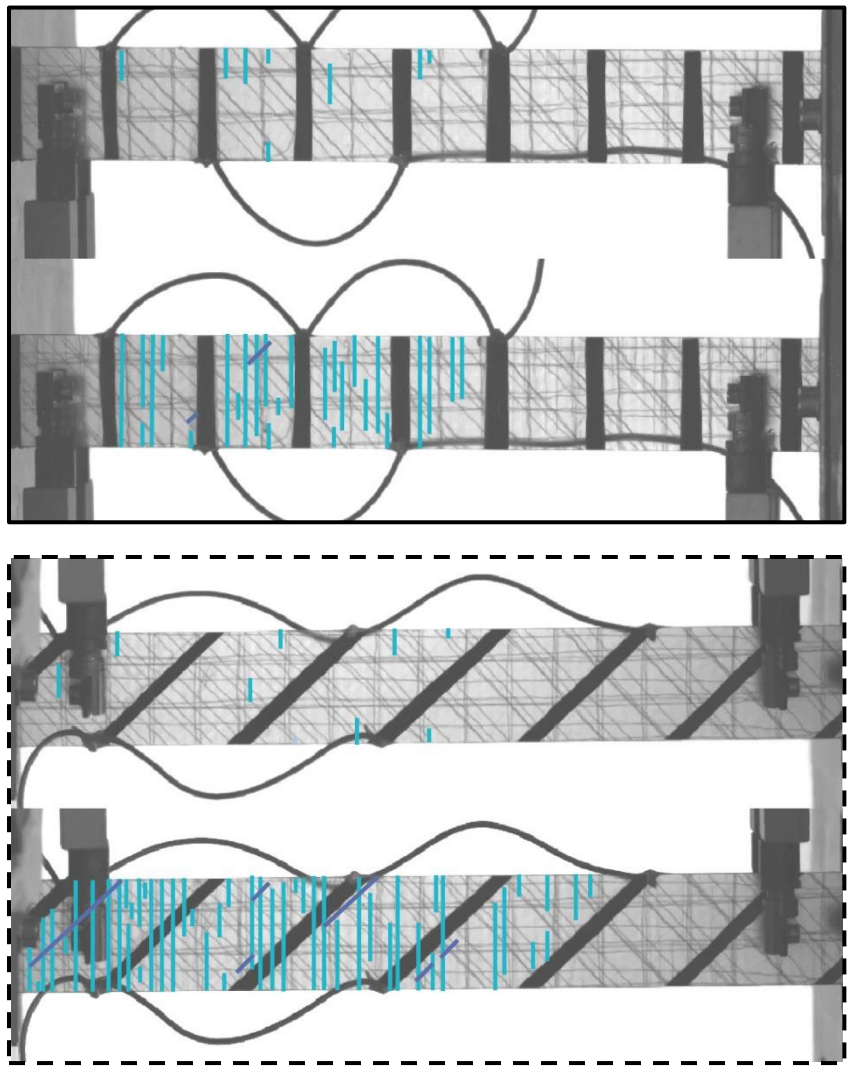
More information:
[Bug2021]

Capacitance-based Sensing

DIN EN ISO 527-4

$[\mathbf{90_2}/0/45_2]_s$
$[90_2/0/\mathbf{45_2}]_s$





55 MPa
~ 0.32% strain

80 MPa
~ 0.47% strain

56 MPa
~ 0.32% strain

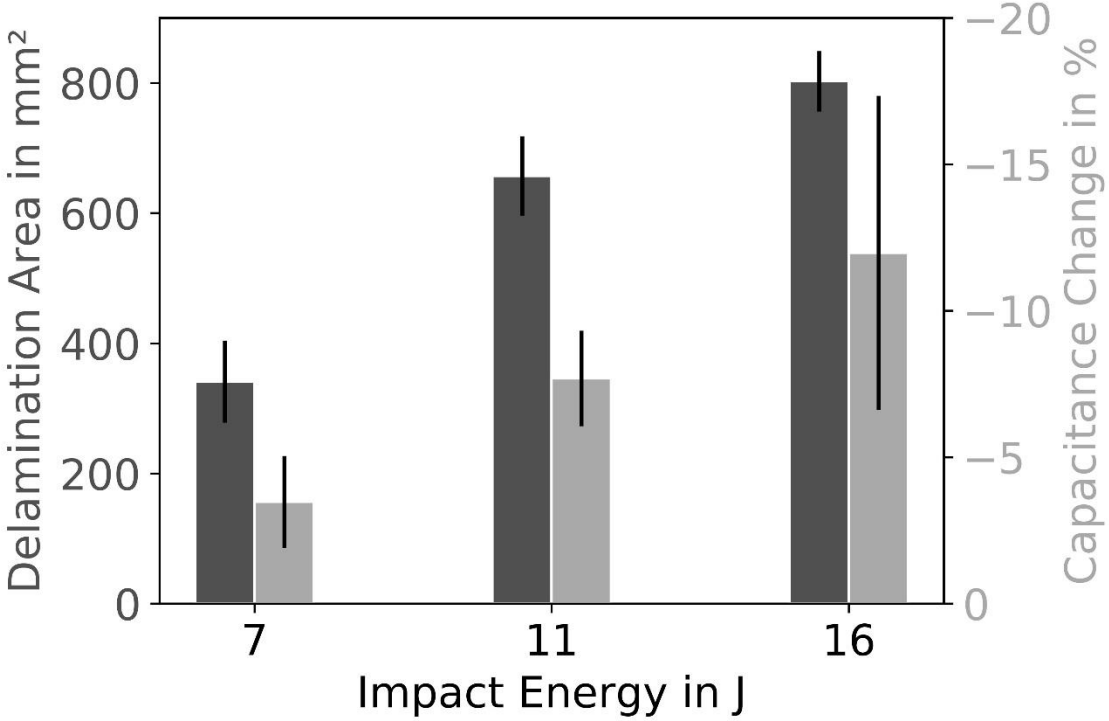
80 MPa
~ 0.51% strain

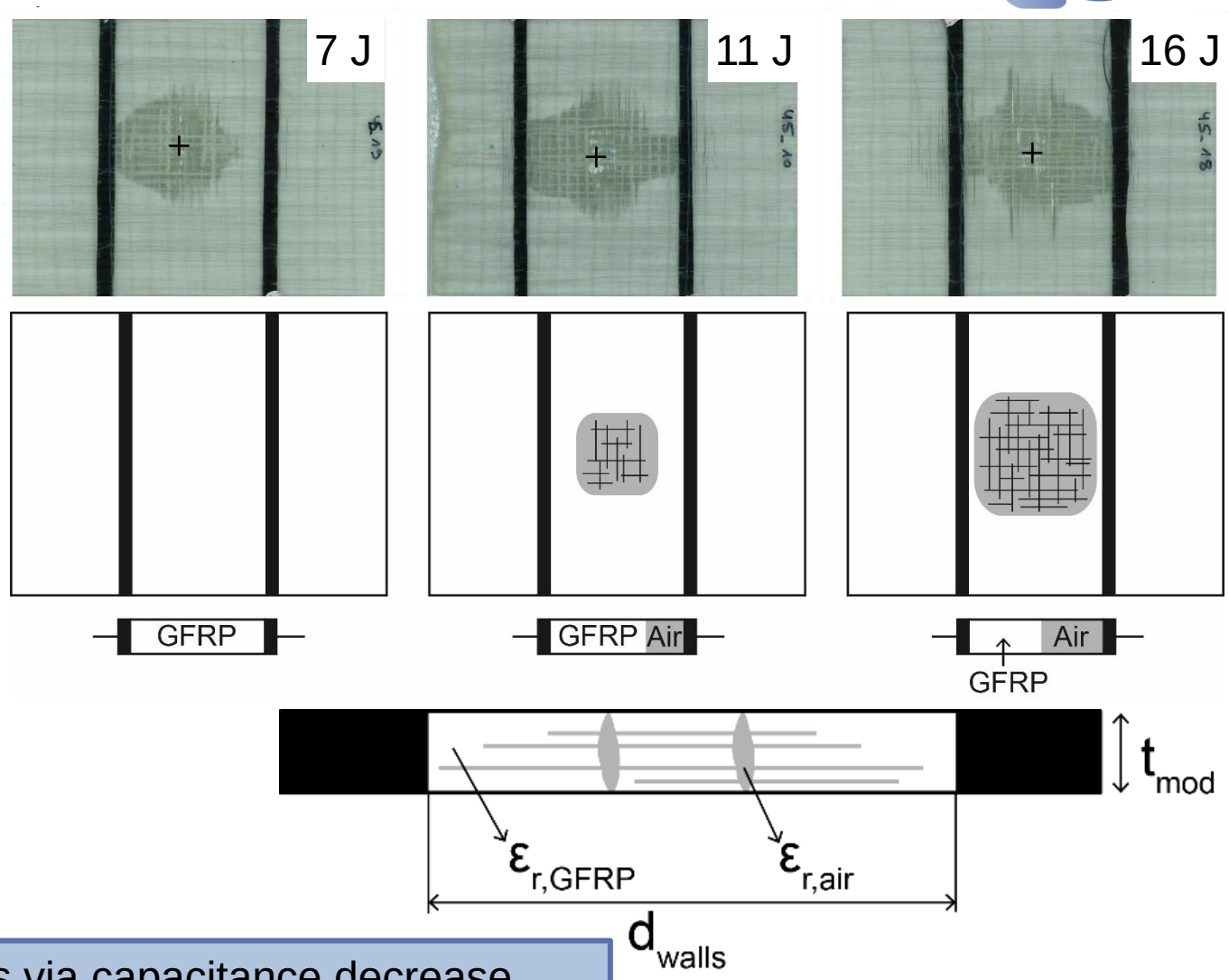
- Suitable bundle configurations allow detection of damages in different composite layers

More information:
[Bug2022]

Detection of Impacts

$[0/\mathbf{90}_4]_s$





- Detection and size estimation of impact damages via capacitance decrease
- Smart sensor layout and contacting enables damage localisation

More information:
[Bug2022b]

Conclusion

Fully-integrated, conductive carbon fibre bundles for damage sensing in GFRP

- No significant reduction of strength and modulus
- Detection of matrix cracks and impact damages via capacitance decrease
- Suitable sensor design and contacting enables damage localisation

Thank you for your attention!

Funded by
DFG Deutsche Forschungsgemeinschaft
German Research Foundation

TUHH
Hamburg
University of
Technology

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[Bug2021] C. Buggisch, A. Gagani, and B. Fiedler. (2021). Capacitance measurements on integrated conductors for detection of matrix cracks in GFRP. *Functional Composite Materials*. **2**, 2. https://doi.org/10.1186/s42252-020-00013-x

[Bug2022] C. Buggisch. (2022). Structurally compatible embedded sensors for damage detection in glass fibre reinforced polymers. *Technisch-wissenschaftliche Schriftenreihe/ TUHH Polymer Composites*. **42**, https://doi.org/10.15480/882.4557

[Bug2022b] C. Buggisch, D. Gibhardt, M. Kern, and B. Fiedler. (2022). Impact damage detection in glass fibre reinforced polymers via electrical capacitance measurements on integrated carbon fibre bundles. *Composites Communications*. **30,** 101090. https://doi.org/10.1016/j.coco.2022.101090