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SUSTAINABLE & COST EFFICIENT
HIGH-PERFORMANCE COMPOSITE STRUCTURES
DEMANDING TEMPERATURE
AND FIRE RESISTANCE

THERMOMECHANICAL TESTING OF CFRP STRUCTURES UNDER VARYING THERMAL CONDITIONS

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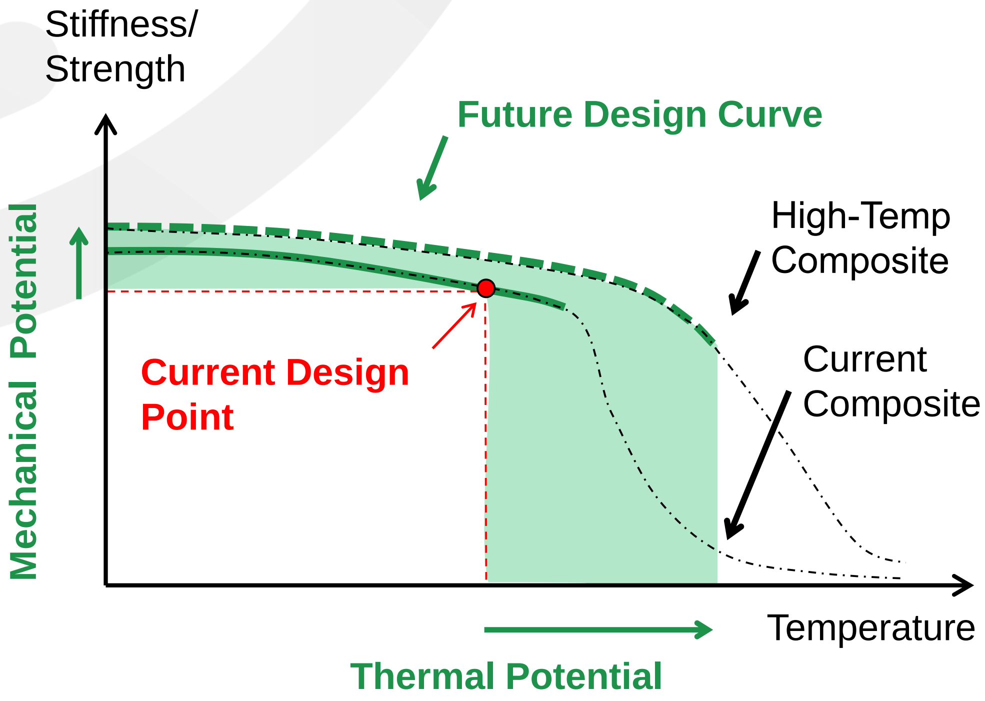
SAMPE Europe, 29 September, Baden

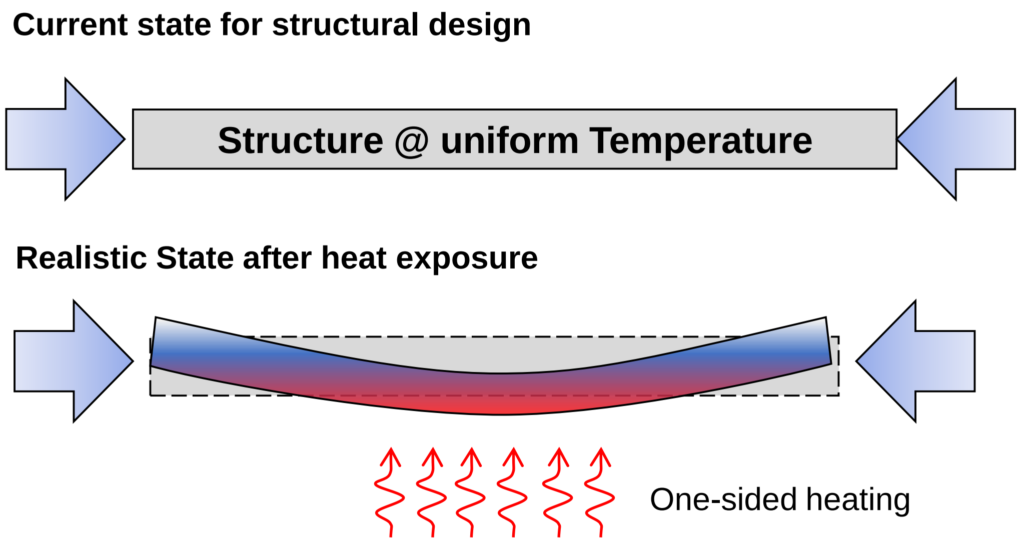
SuCoHS project, Grant Agreement N° 769118

Motivation

Potentials obtained from material behavior !!!



Sensitivity of thermal deformation to stability ???



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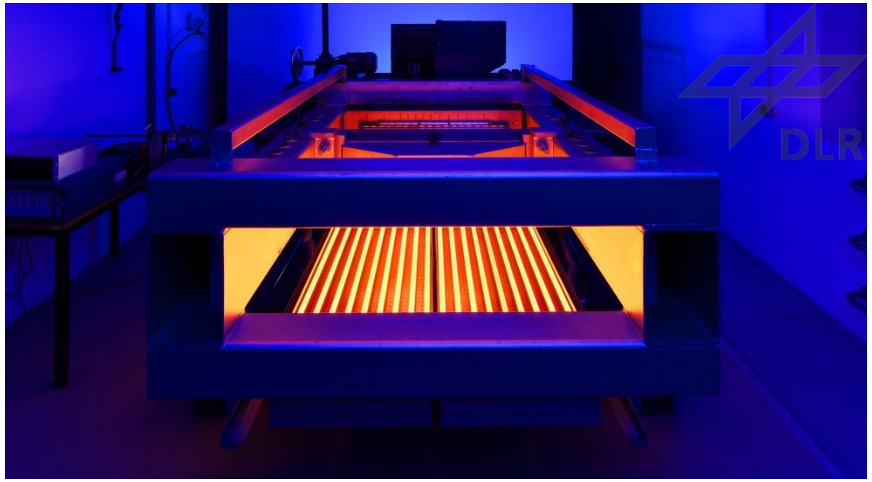
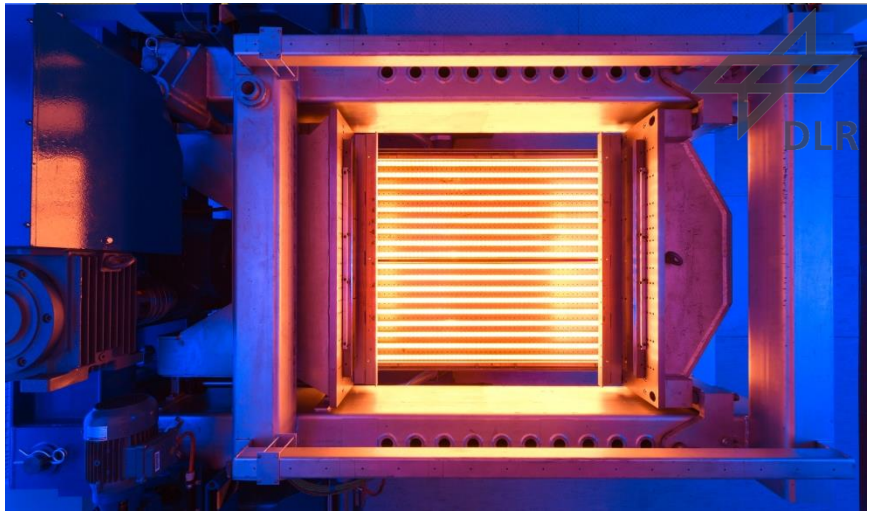
The Thermex test facility

- Coupled thermomechanical loading of structures up to component level
  - 1m * 0.8m
  - > 400 kN axial force
  - > 1200°C thermal loading
  - Active cooling possible
- Local or global heating to analyze heat transport mechanisms

- Curved or flat structures
- Stiffened structures, sandwich, composite structures, Assemblies, …





Thermex facility: Frontal view and top view

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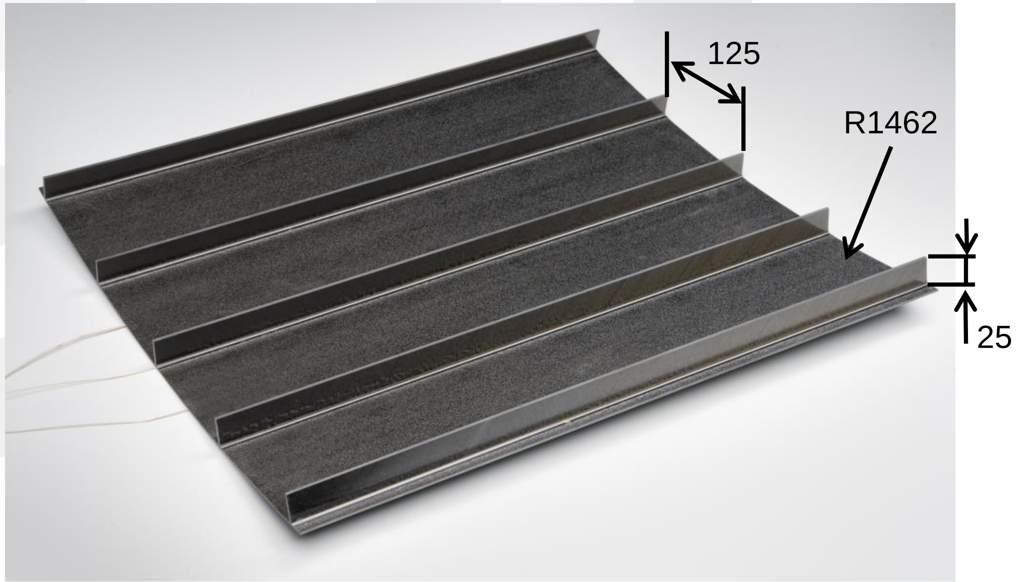
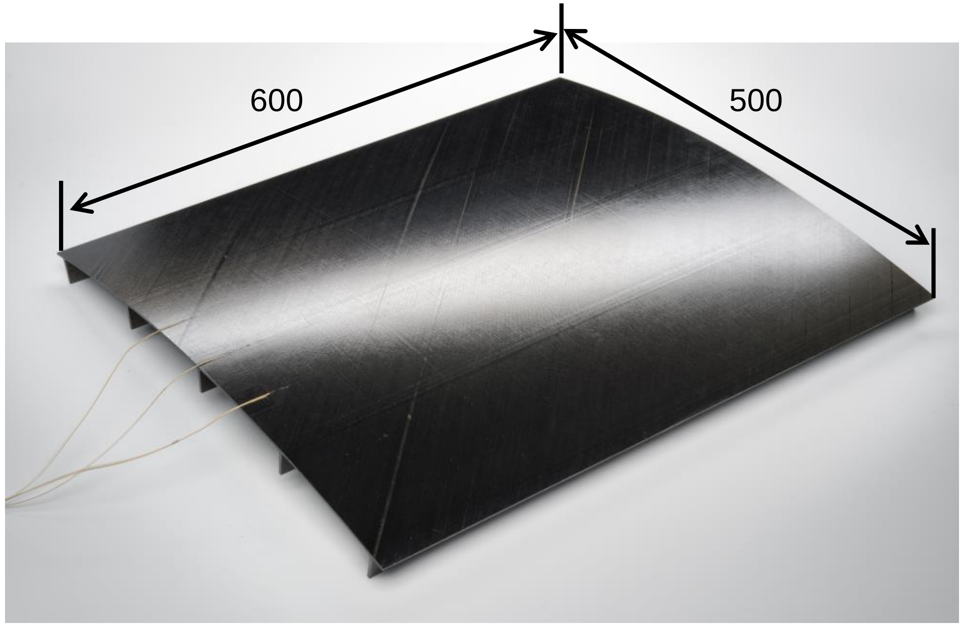
Test structure





Test structure manufactured at NLR

Region	Layup	Thickness
Skin	$[45/90/-45/0/0/-45/90/45]_4$	1.92mm
Stringer blade	$[45/90/-45/0/0/-45/90/45]_6$	2.88mm

Quasiisotropic laminate stacking

Tailcone panel (Aernnova Engineering)

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Applied sensor systems

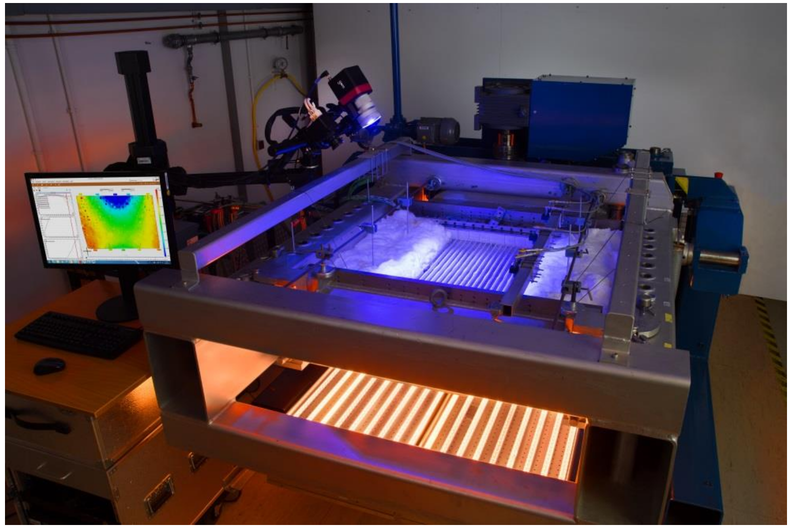
Global techniques

- Thermography (Temperature)
- Digital Image correlation (displacement, strain)

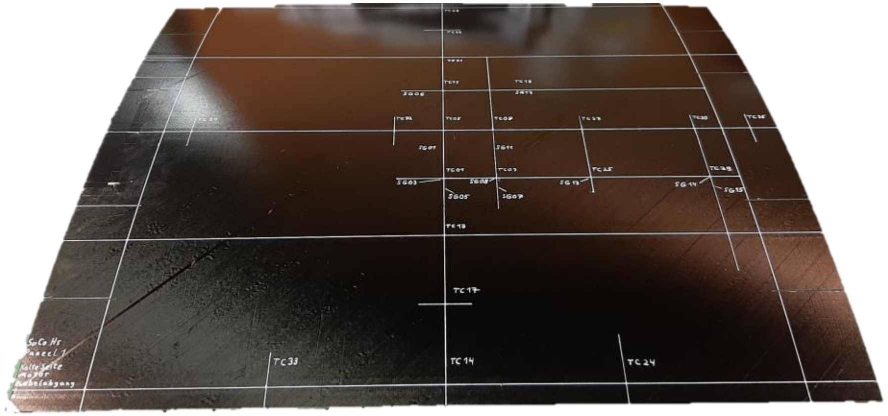
Local measurement

- Fibre bragg grating (strain)
- Strain gauge (strain)
- Thermocouples (temperature)
- Heat flux sensor (heat flux)
- Displacement sensors
- Axial force

(Strain gauge and Thermocouples:) Applied using PI32 (usable until 350°C)



Global optical measurement within an earlier test campaign



Local sensor positions prior to application

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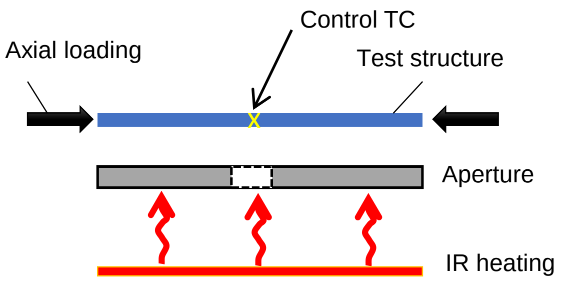
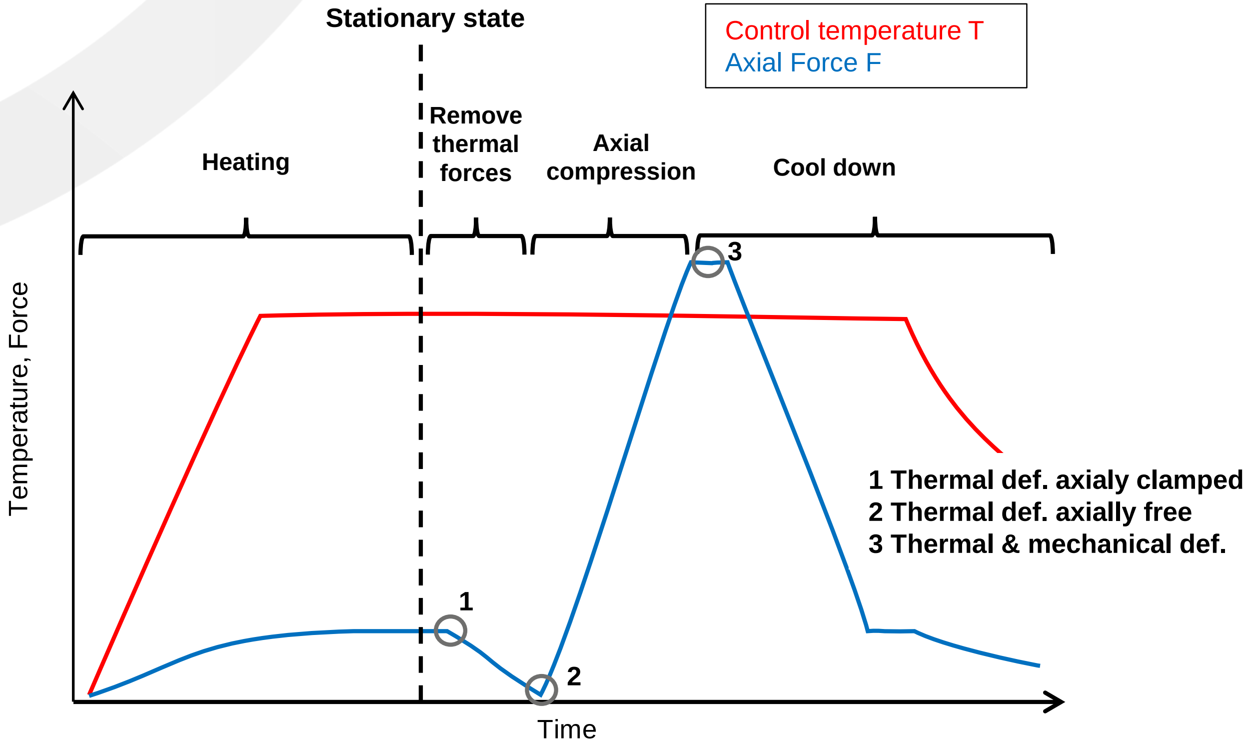
Test procedure and boundary conditions



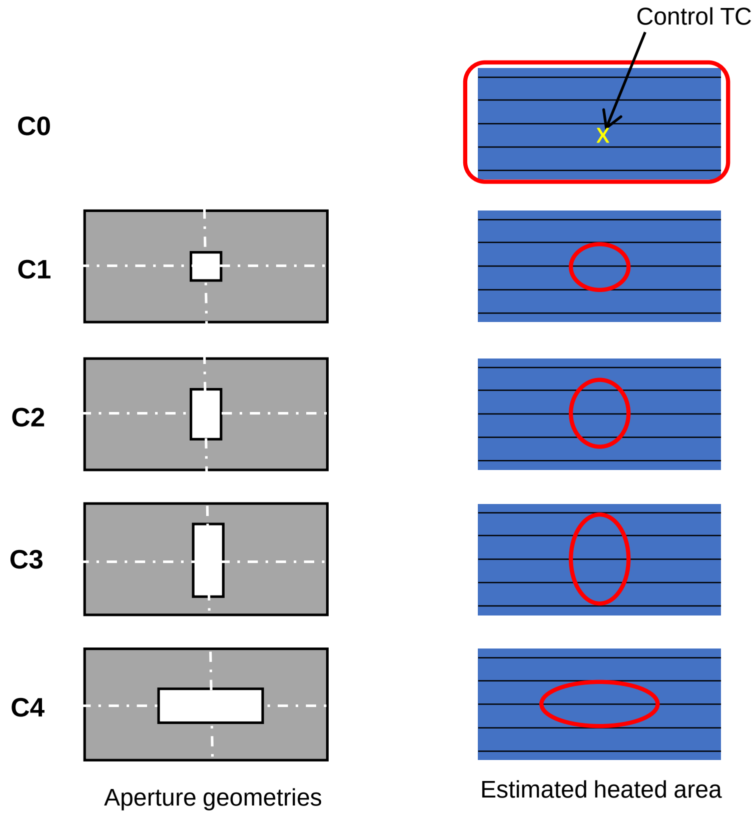
Test setup

- Thermal state controlled by a thermocouple

∑43 tests
- 5 different thermal boundary conditions applied by
- 5 target temperatures applied: 23°C, 100°C, 150°C, 200°C, 250°C



Typical test scenario



Variation of thermal load conditions

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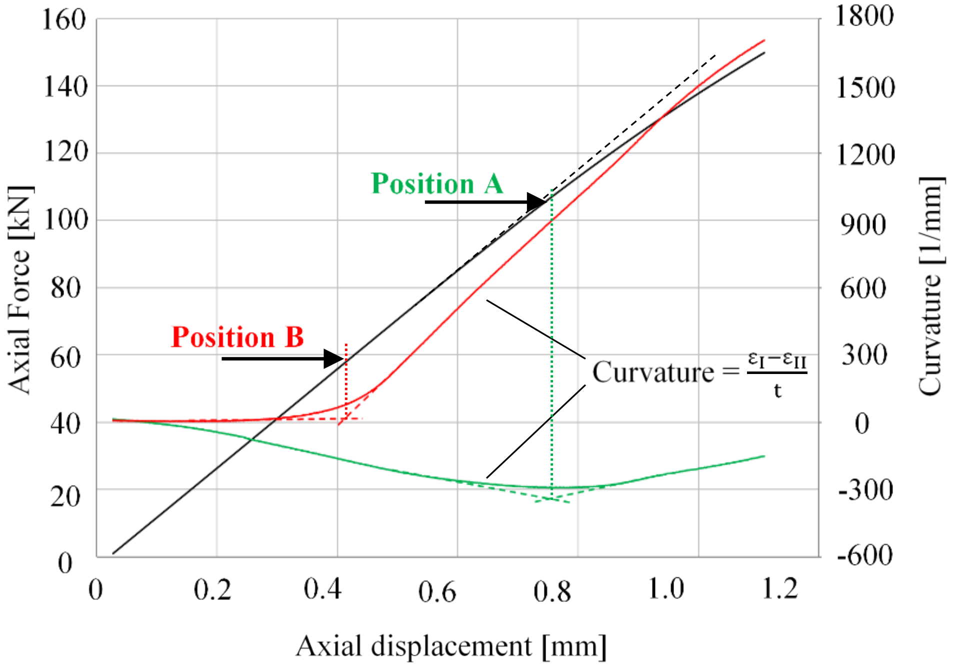
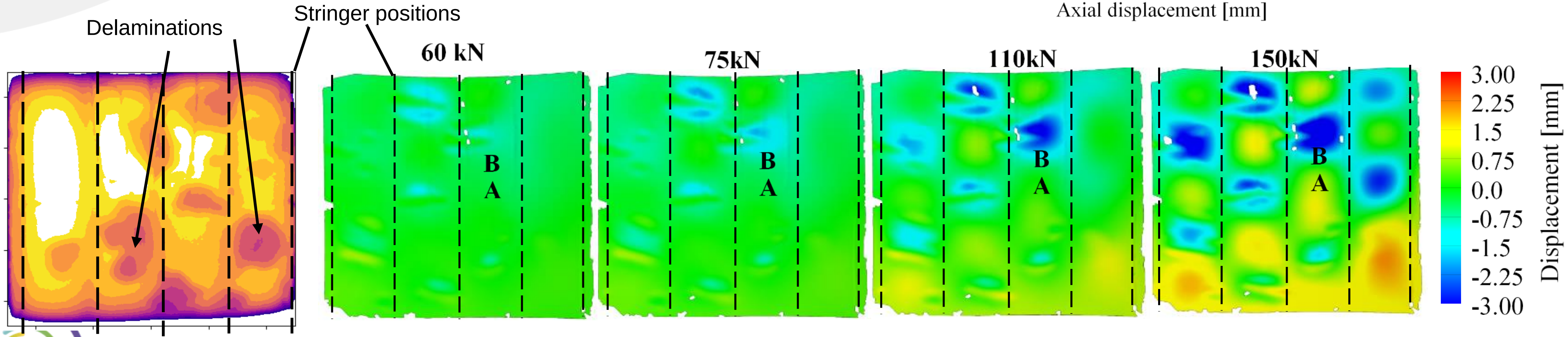
Results: RT behavior

- Local delamination produced within the final strain gauge adhesive cure
- Measurement affected, especially local sensors
- Buckling behavior affected
  - FEA prediction: F_{LB}=113kN
  - Initial buckling development in upper part
  - Sublaminate buckling due to delamination





Thermography image of C0 test showing local delamination (left) and out-of plane deformations within RT test

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Results: Test campaign overview

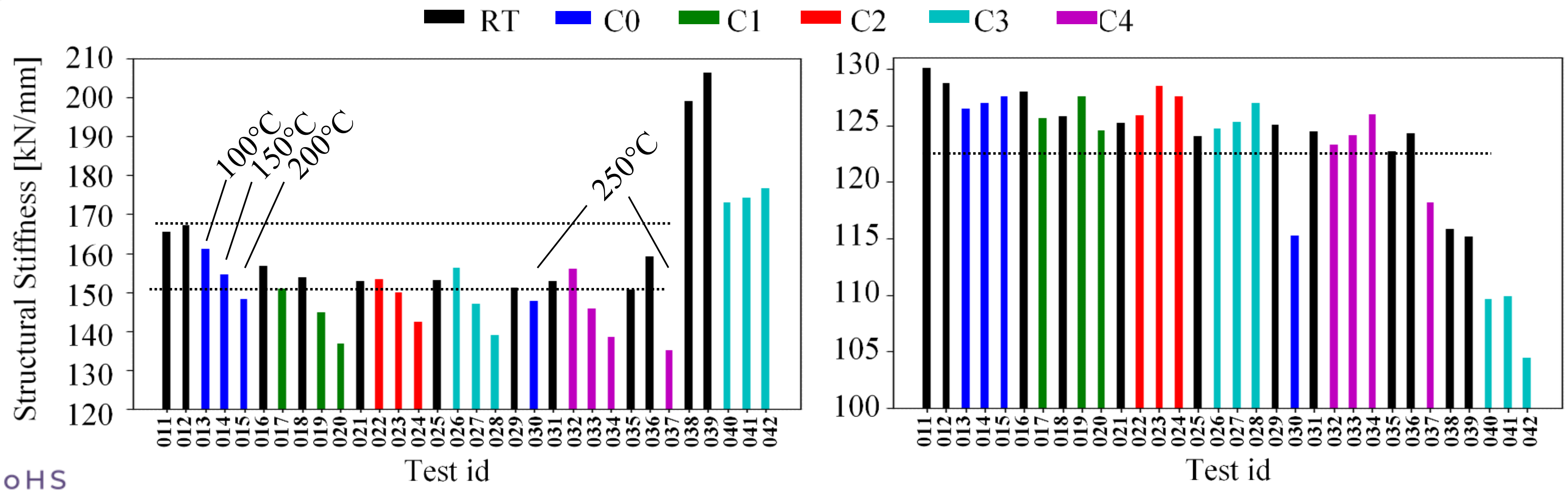
Stiffness development: Testing performed up to 150KN

- Settlement within clamping between test 012-015
  → Stiffness reduction: -1.5% prebuck., -0.7% postbuck.
- Damage progression, Increasing delamination from 036 onwards
- Good repeatability of stiffness with relatively low scatter

Test 011-036	Structural stiffness
Prebuckling	156.3±5.6kN/mm (±3.6%)
Postbuckling	125.8±2.2kN/mm (±1.8%).

Structural Stiffness Scatter evaluated from repeated RT tests

Prebuckling Stiffness **Postbuckling Stiffness**



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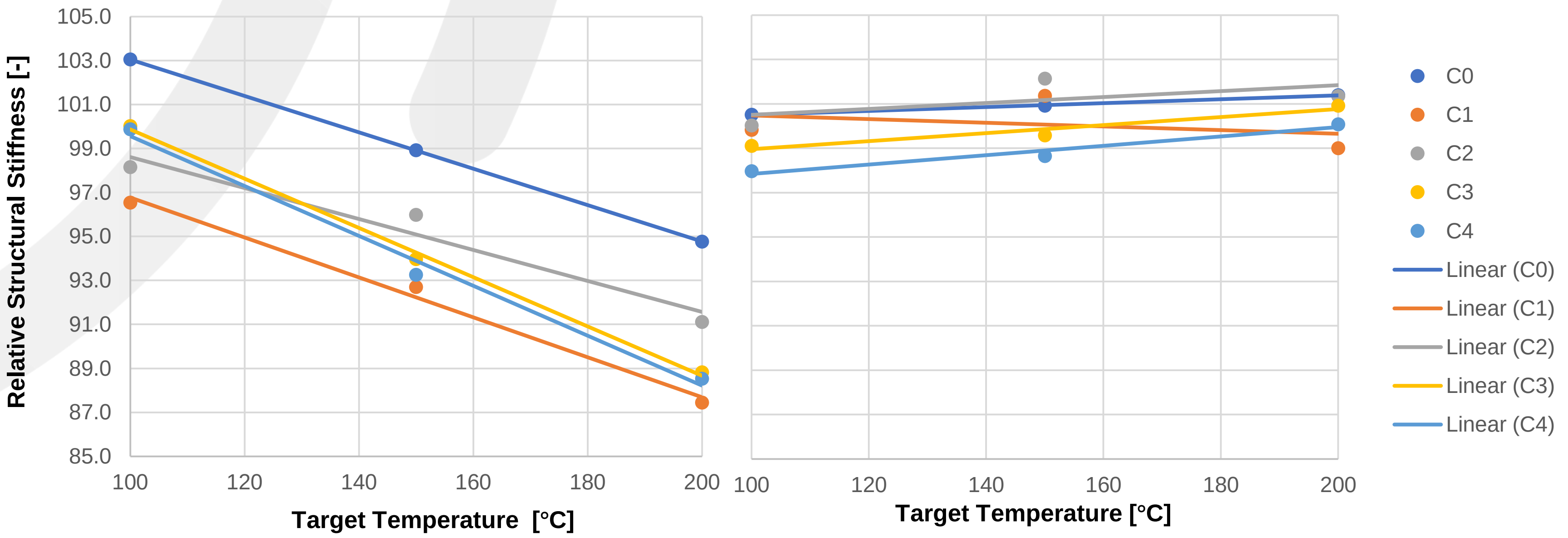
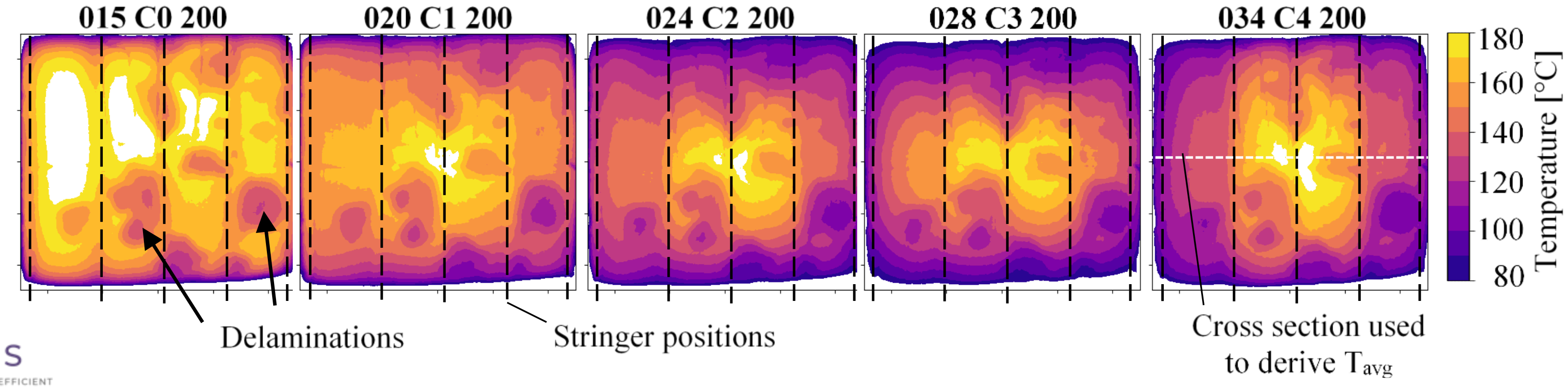
Results: Variation of thermal boundary condition





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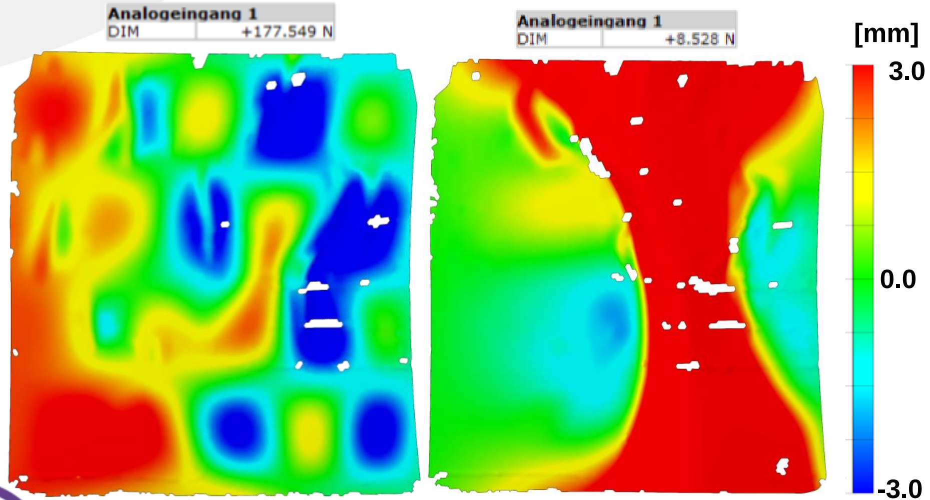
Results: Structural collapse

- Testing at 23°C until 178kN
- Progressing delamination from previous tests
- Noises >170kN → crack progressing, delamination propagates between central skin fields



Out-of-plane displacements before and after collapse

Destroyed test structure after removing axial displacement

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Conclusion and outlook

- Due to process-induced delamination, buckling developed smoothly
- Influence of material property temperature dependency could be reproduced as well as the dominance of properties in fiber direction
- Validation of numerical analyses is ongoing
- A second test is to be performed

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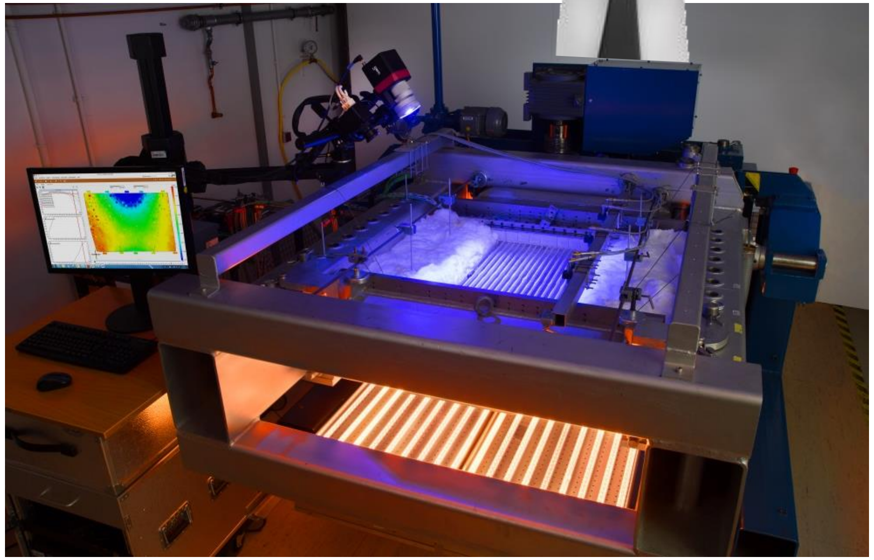

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