Polymer Composites

TUHH Hamburg University of Technology

The 11th International Conference on Composite Testing and Model Identification (CompTest 2023)

# ADAPTED BUCKLING SUPPORT TO INVESTIGATE THE COMPRESSIVE PROPERTIES OF LONG AND THIN SPECIMEN

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# Materials and test setup

## Material

**Material:**
North Thin Ply Technology (NTPT, Switzerland)
T700S Carbon Fibres, Toray (Standard modulus)
Epoxy TP 402, NTPT (Toughened)

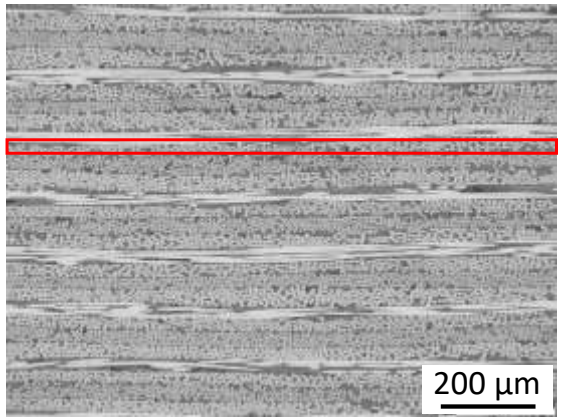
**Manufacturing:**
Hand layup
Autoclave: Curing at 160° C and 7 bar

## Test setup

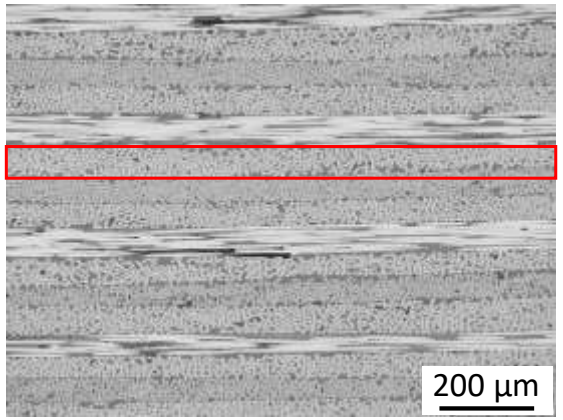
**Fibre area weight and layer thickness**
30 g/m² ≙ 28.7 µm
60 g/m² ≙ 55.2 µm
120 g/m² ≙ 114.0 µm
360 g/m² ≙ 340.0 µm

**Experimental work:**
Tension / Compression
Fatigue (R=0.1, -0.5, 10)
Fatigue after Impact (R=-0.5)

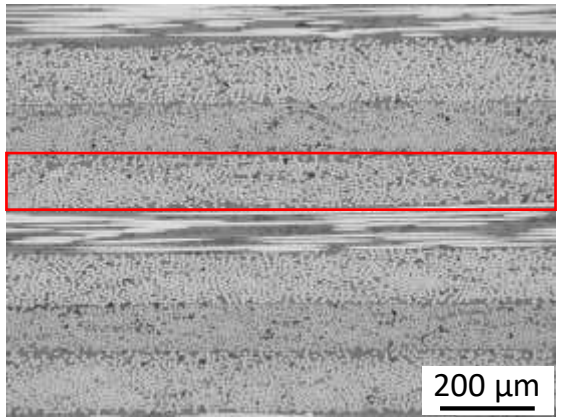
**Layup:**
$[45_m/90_m/-45_m/0_m]_{ns}$



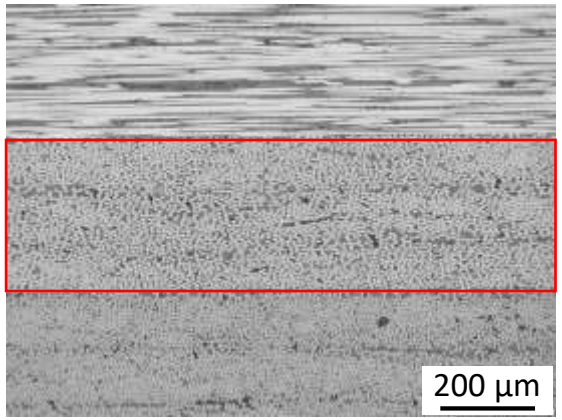
30 g/m²



60 g/m²

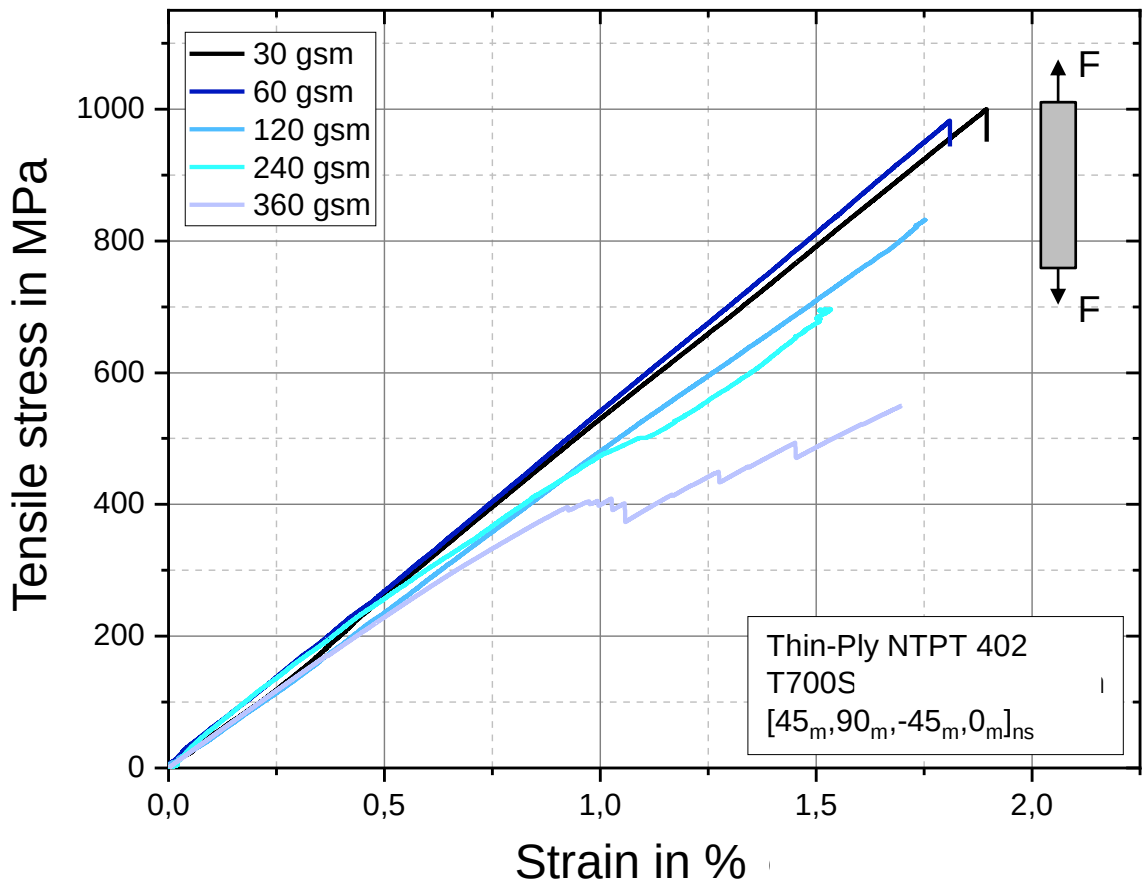


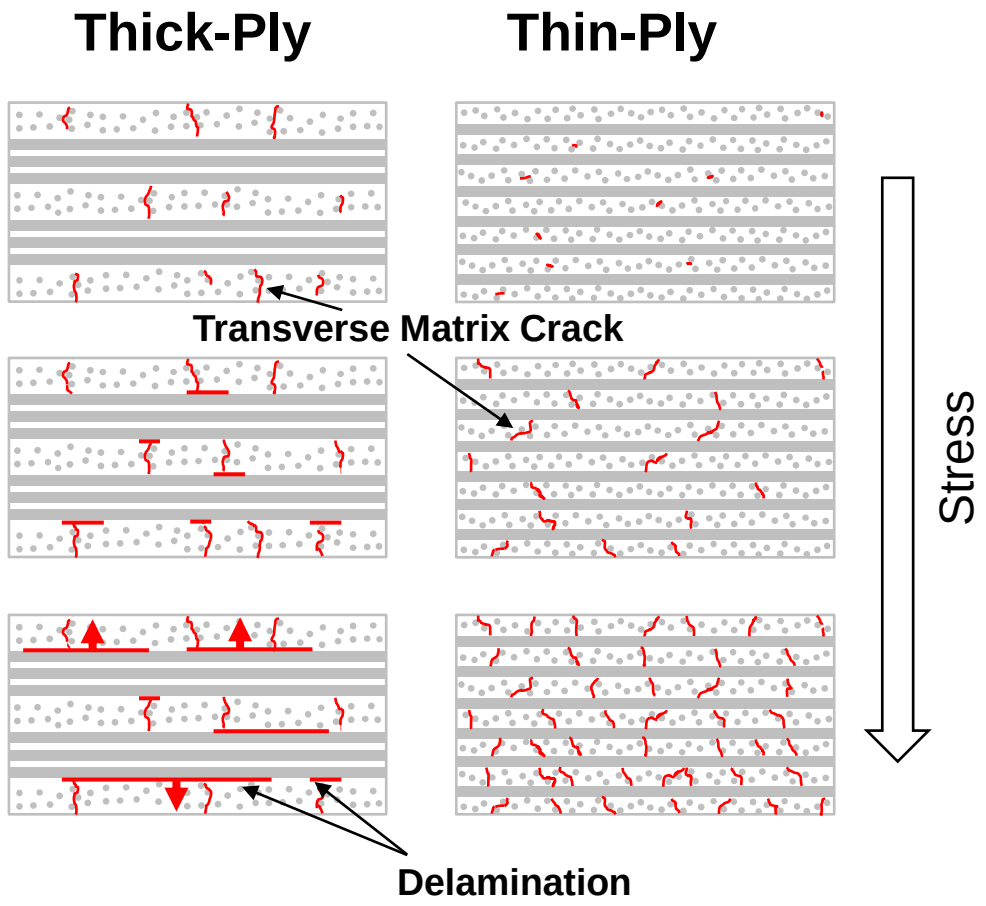
120 g/m²



360 g/m²

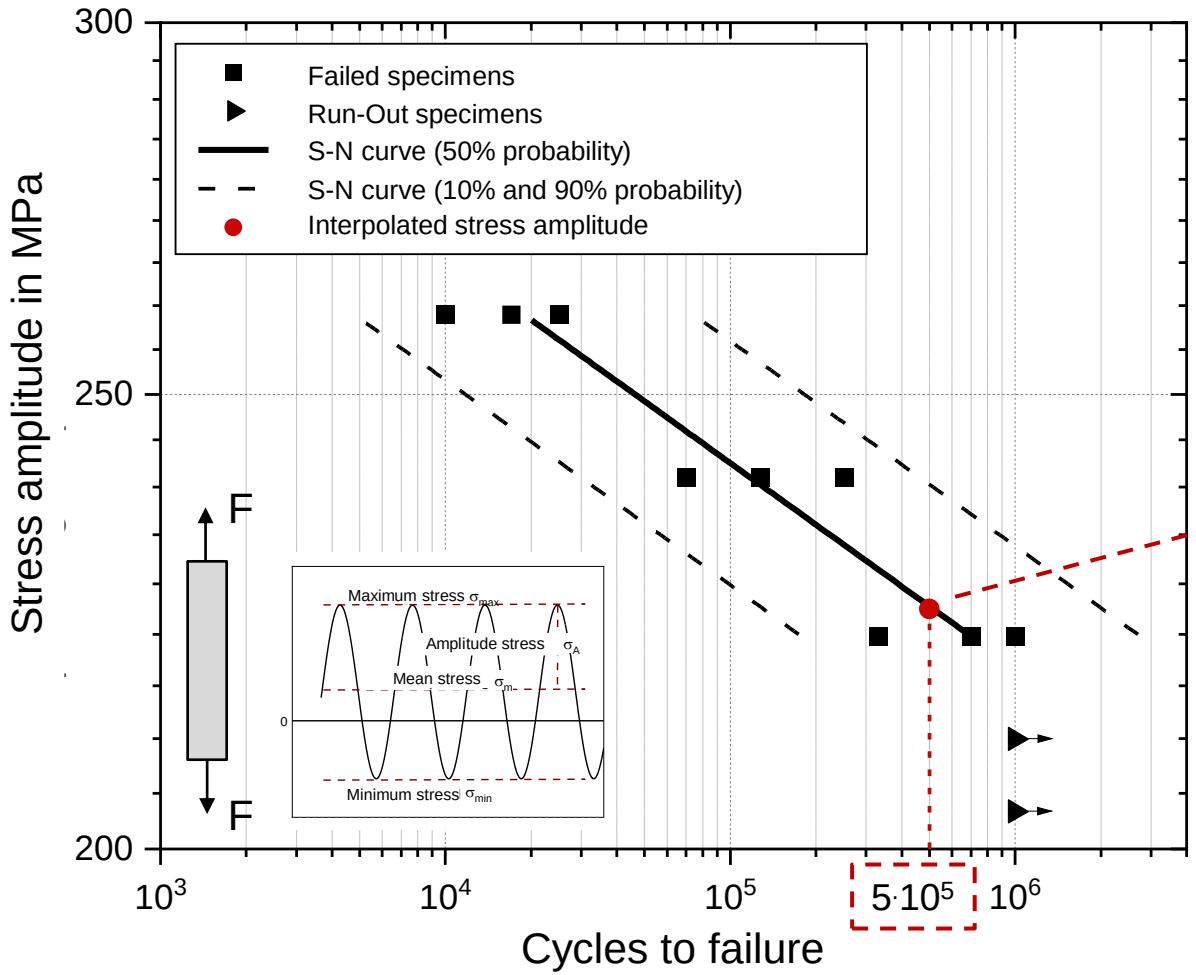
# Damage mechanisms - Thin-Ply

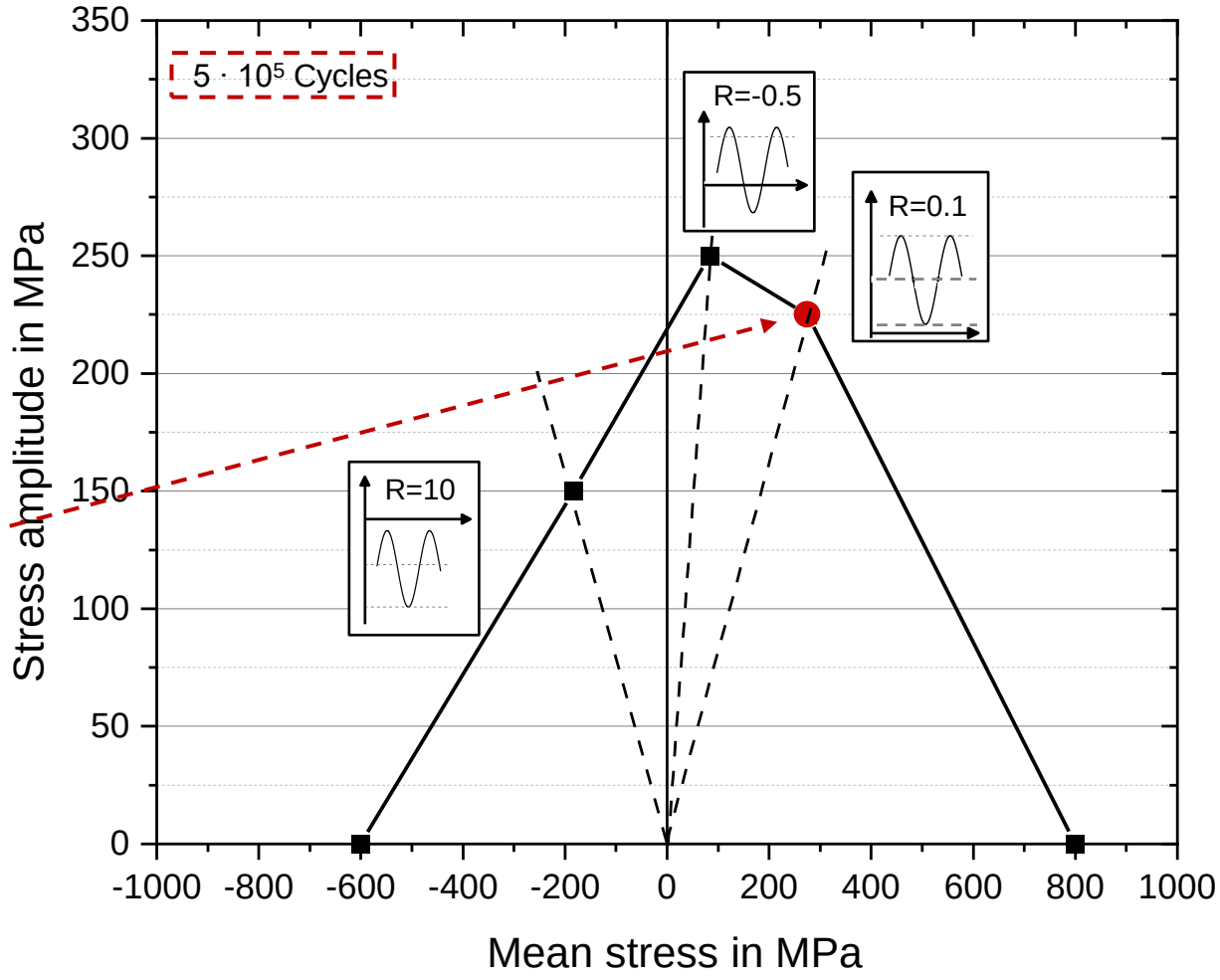


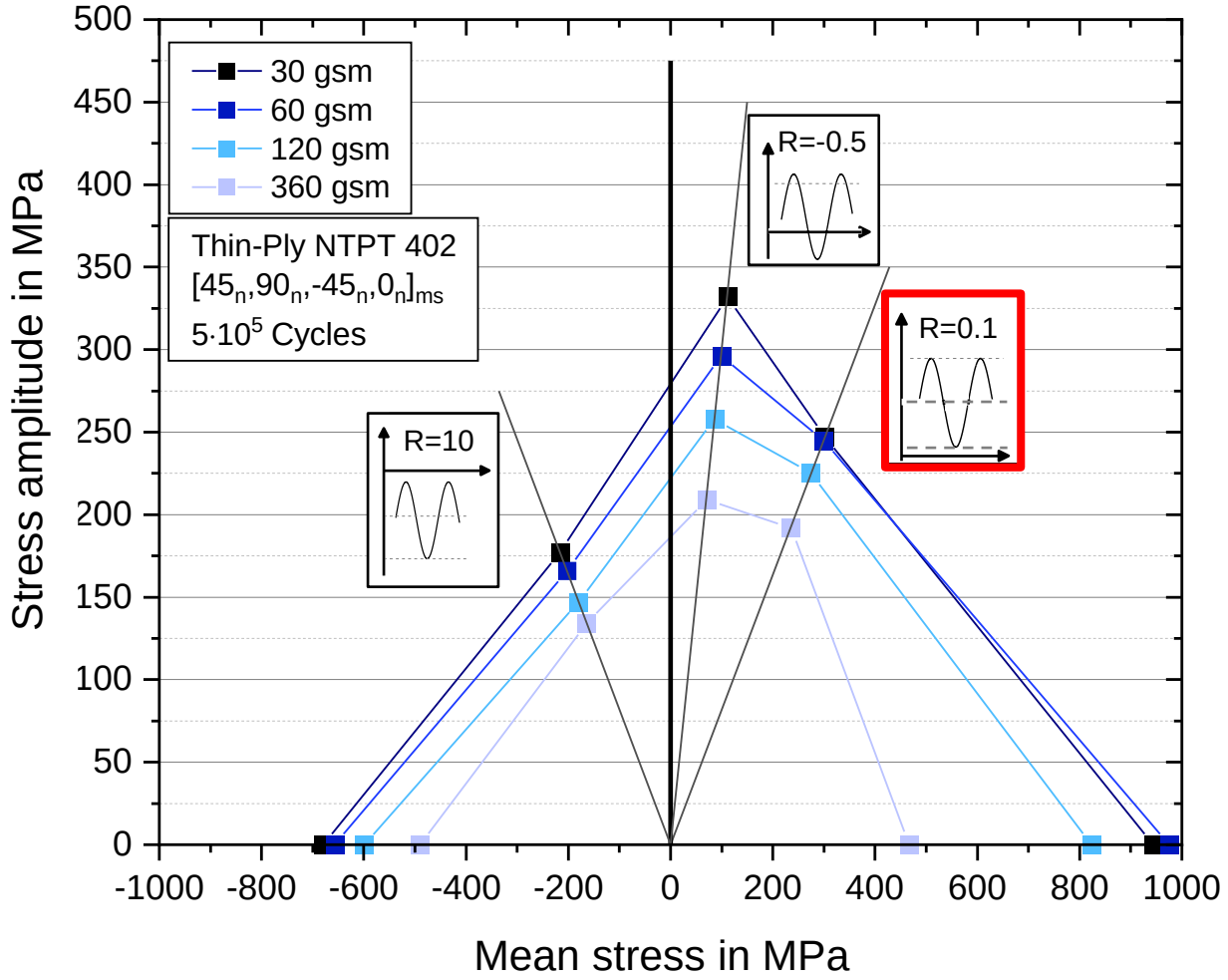

- Suppression of delaminations
- Failure behaviour changes from delamination-dominated (Thick) to brittle, fibre-dominated (Thin) behaviour
- **Significantly increased strength with decreasing layer thickness**

# Constant-Life-Diagram (CLD)



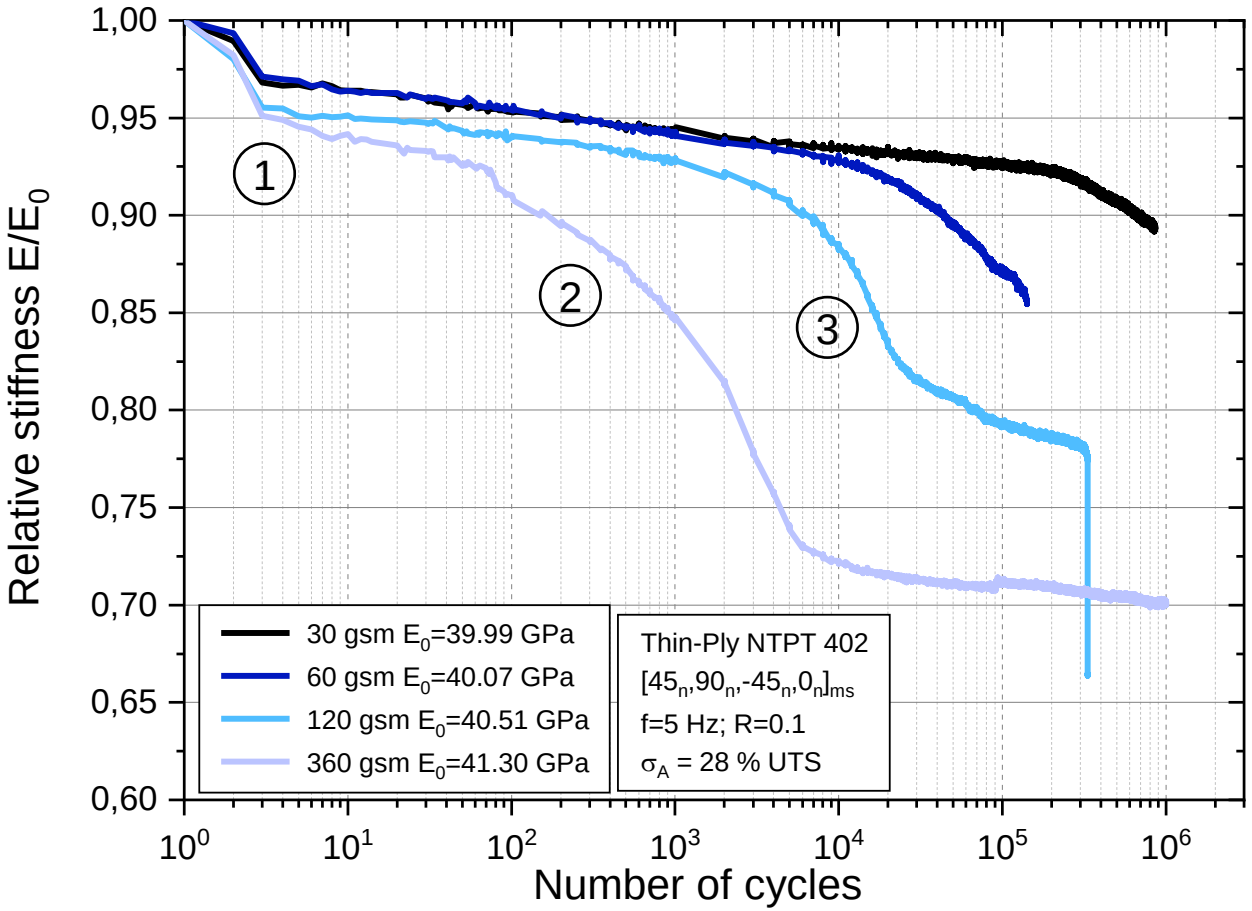



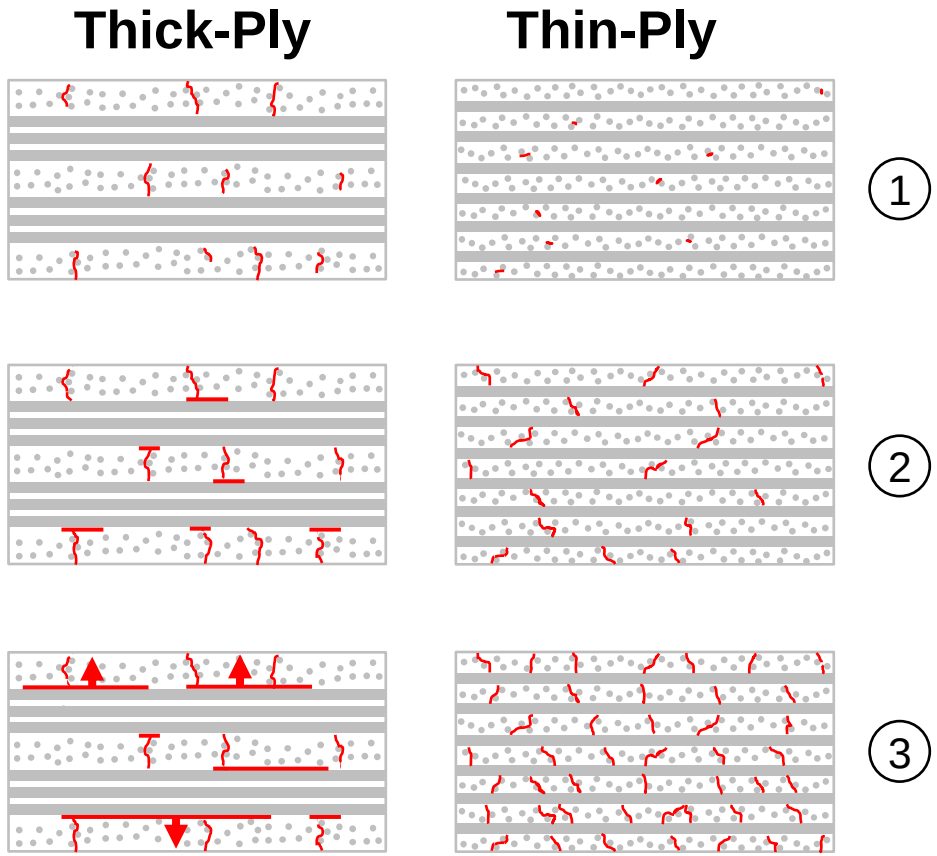
# Constant-Life-Diagram - Overview




- Superior static behaviour with decreasing layer thickness
- Superior fatigue behaviour with decreasing layer thickness independent of stress ratio

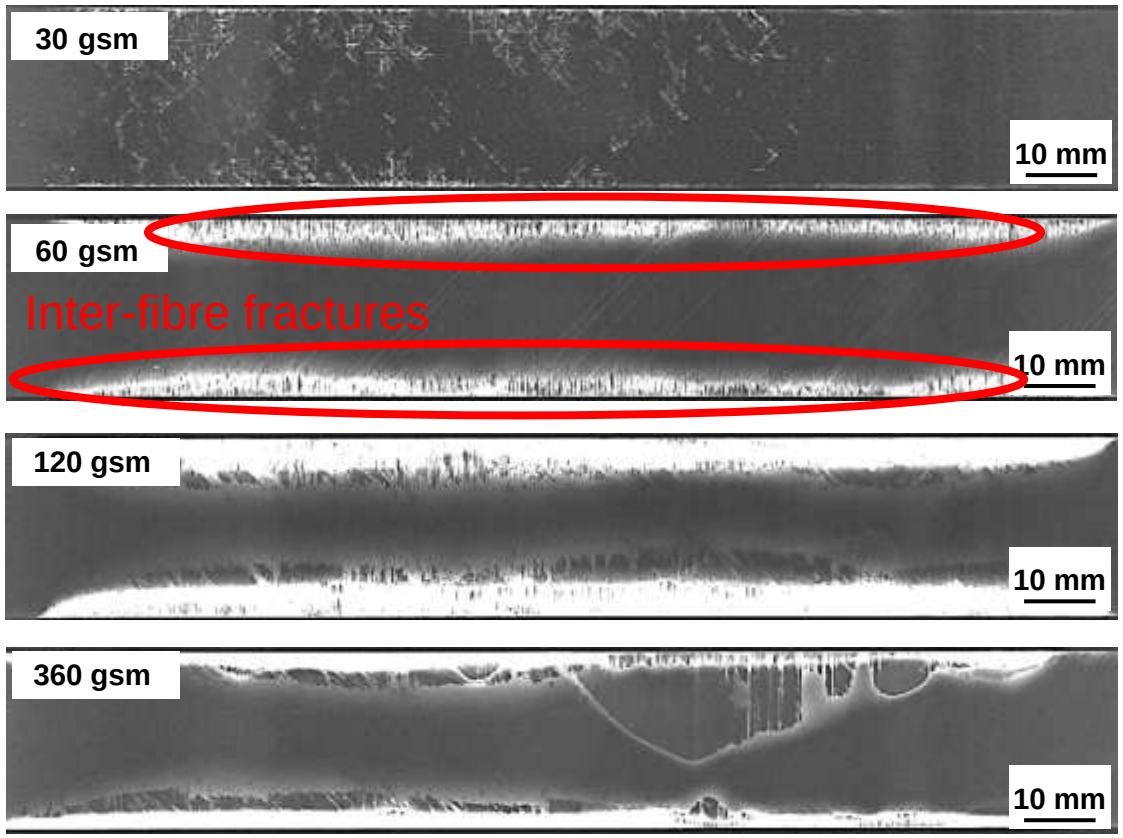
# Fatigue R = 0.1 (Tension – Tension)

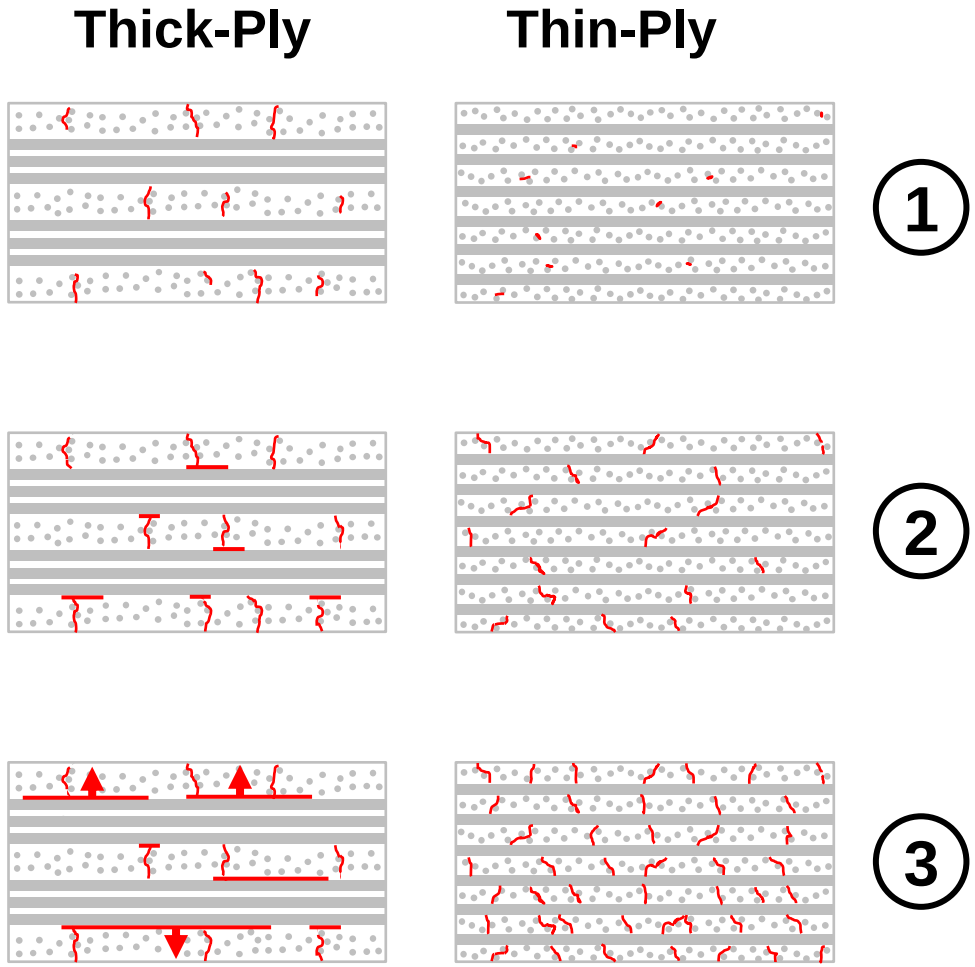



- Linear degradation until final failure
- No delaminations for the Thin-Ply

# Fatigue R = 0.1 (Tension – Tension)

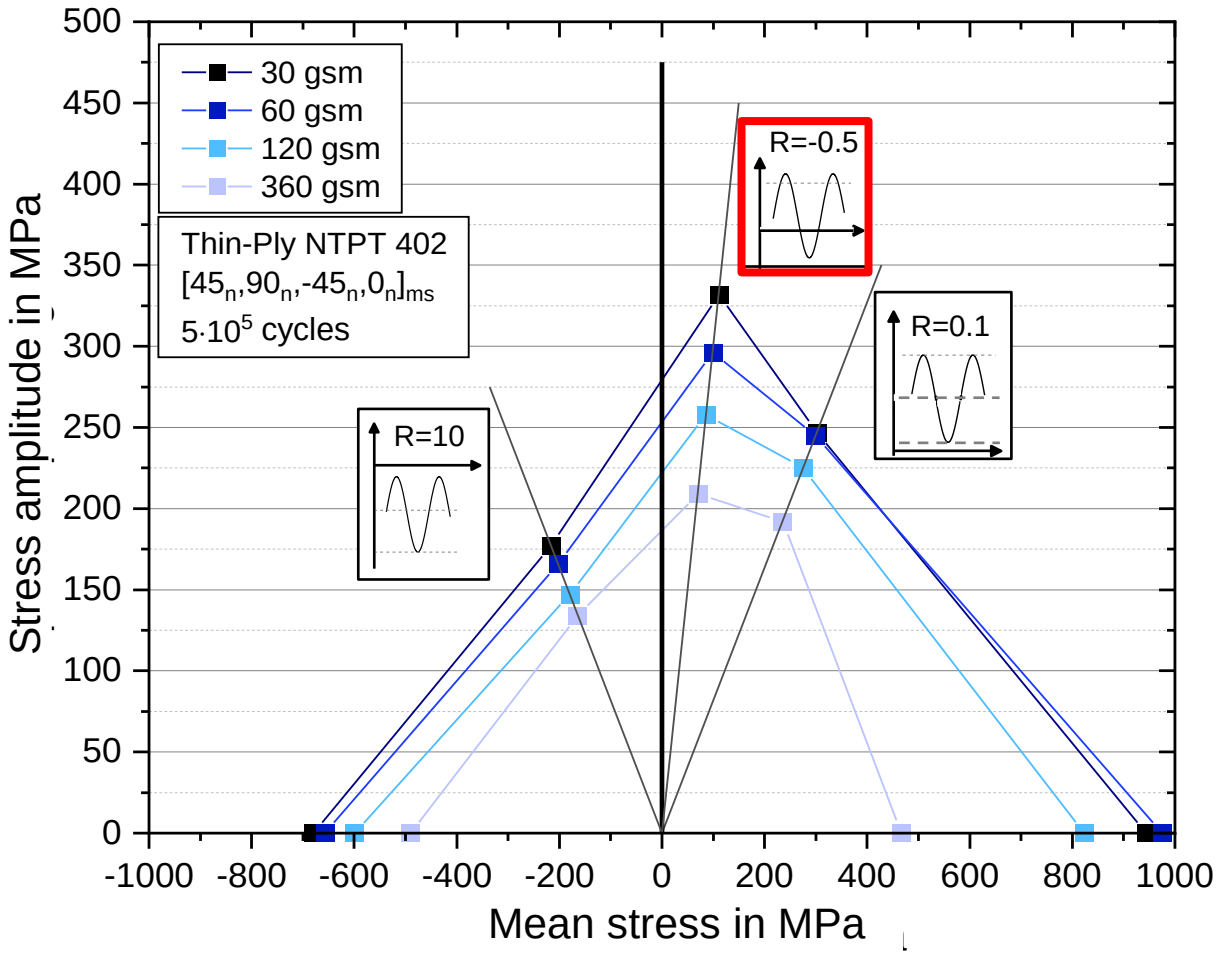


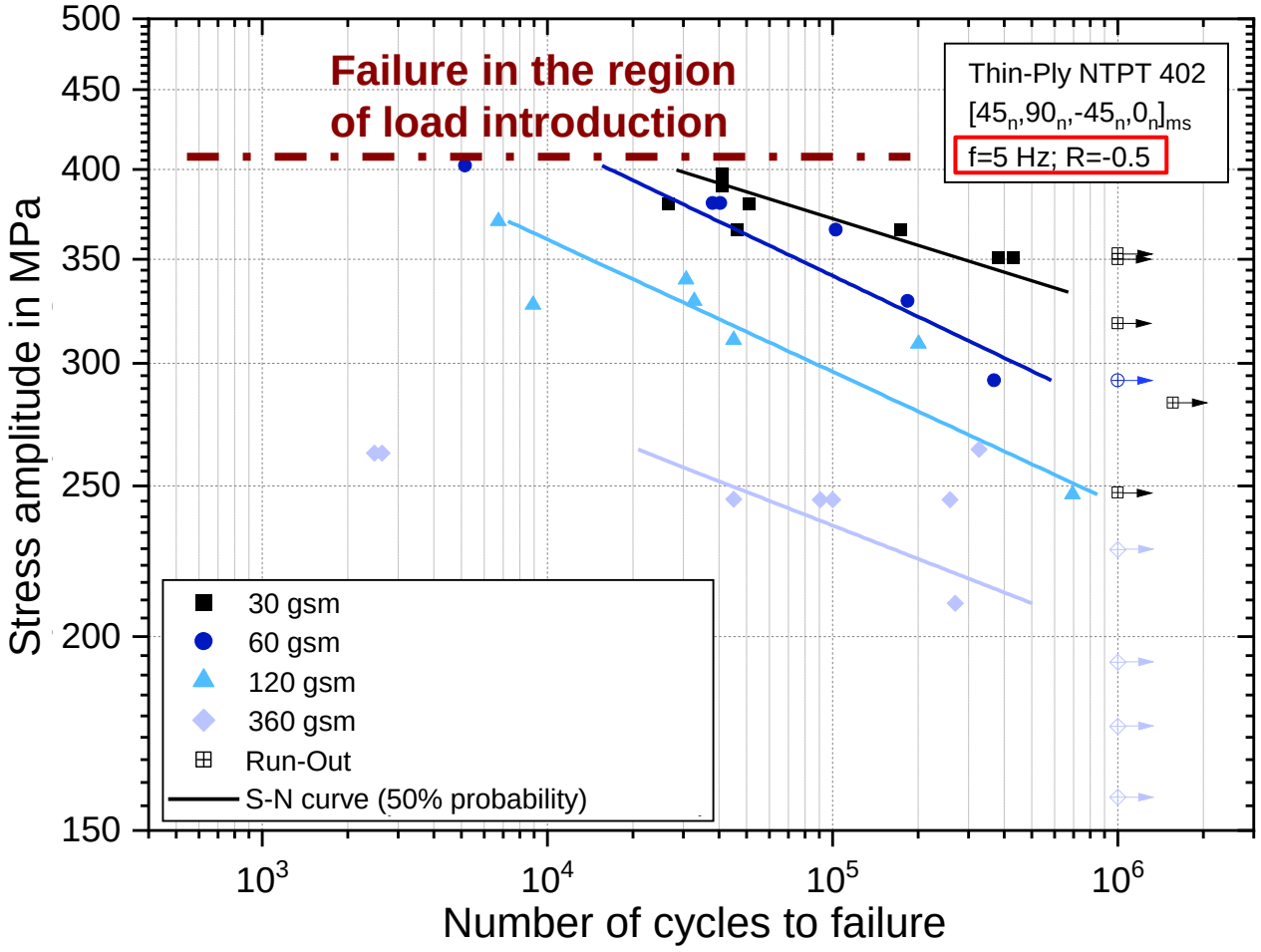




X-Ray images of 20.000 cycles with amplitude stress of $\sigma_A$ = 67 % UTS

- No Delaminations occur in the case of the 30 gsm and 60 gsm
- 60 gsm samples exhibit a high number of inter-fibre fractures

# Fatigue R = − 0.5 (Tension – Compression)

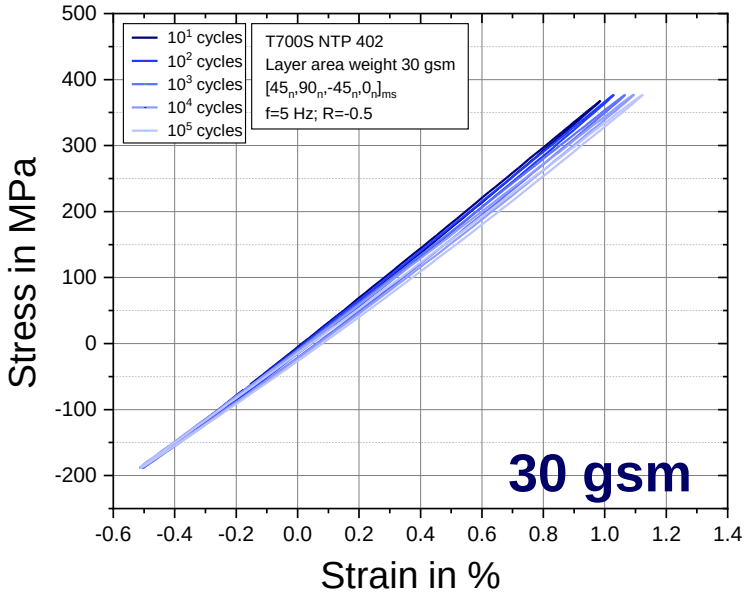


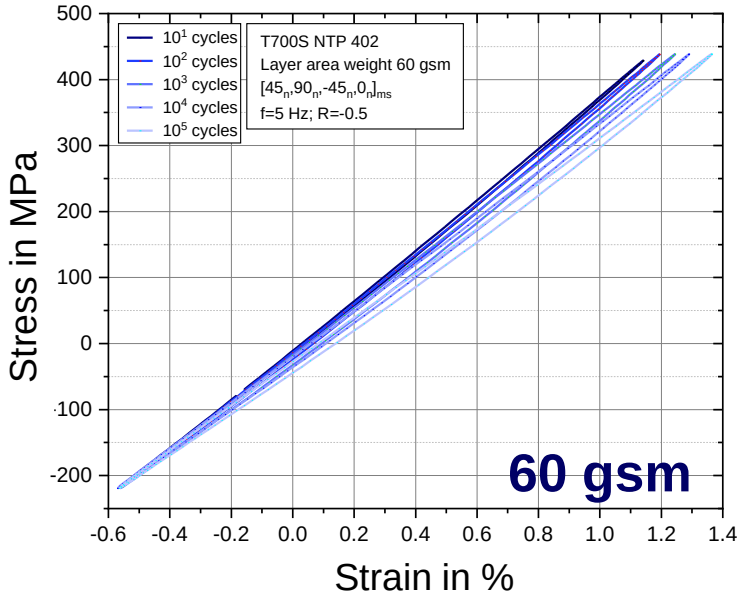



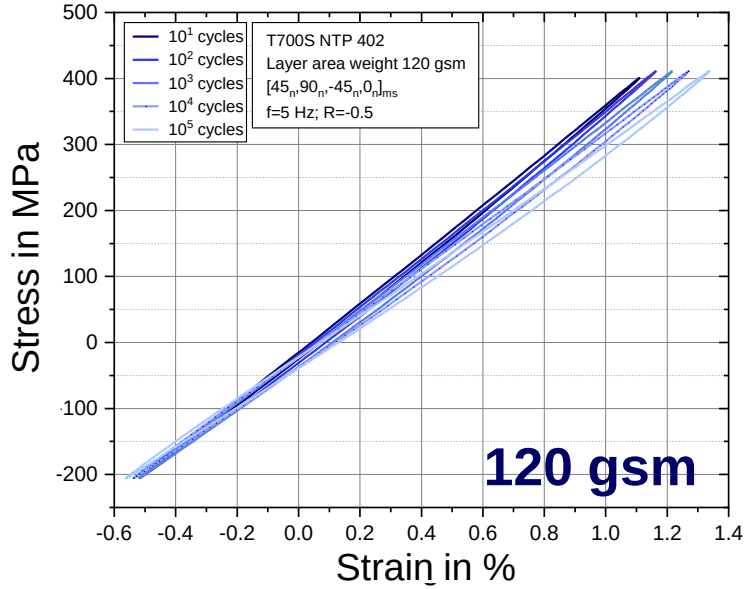

Thin-Ply:

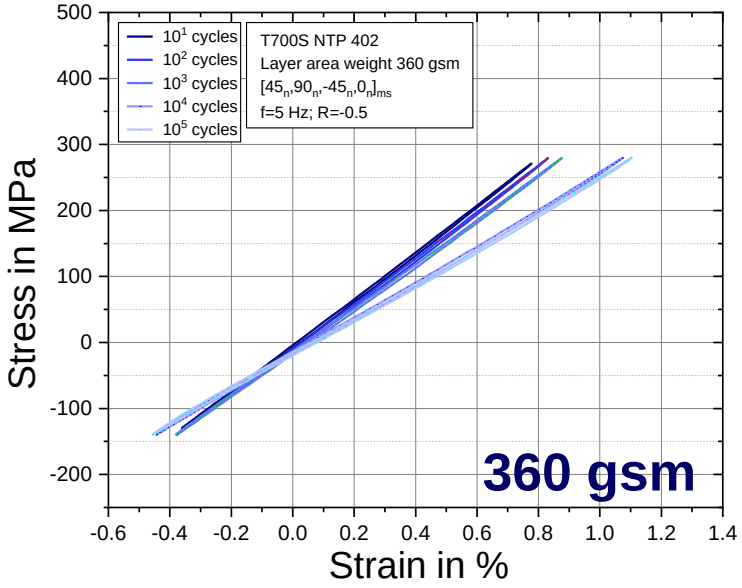
- High stresses → Failure in the region of load introduction due to high-stress concentrations
- High cycles → Less degradation → Higher fatigue performance

# Fatigue R = – 0.5 (Tension – Compression)



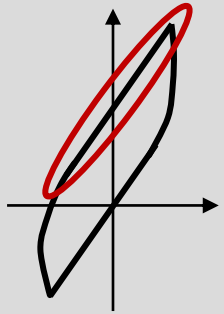



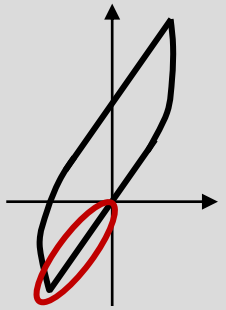

**Thin-Ply:**

- Failure under tensile stress
  - Fibre fracture



**Thick-Ply:**

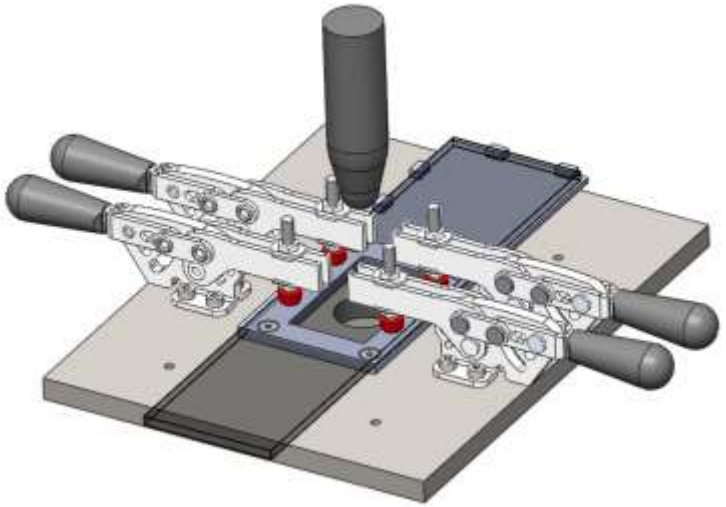
- Failure under compressive stress
  - Delaminations

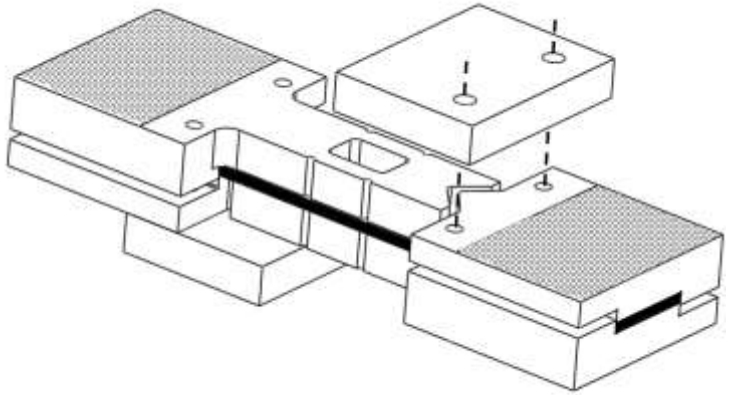


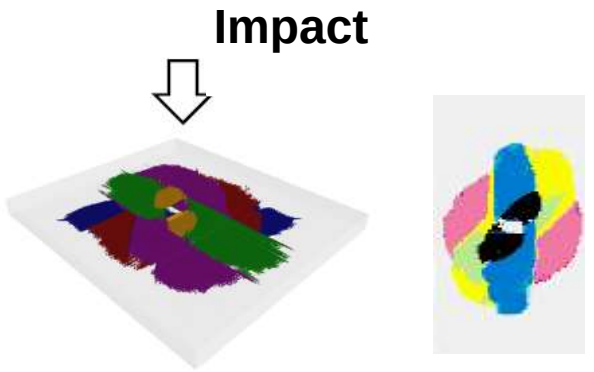
# Fatigue after impact

**Impact**

**Fatigue tests**





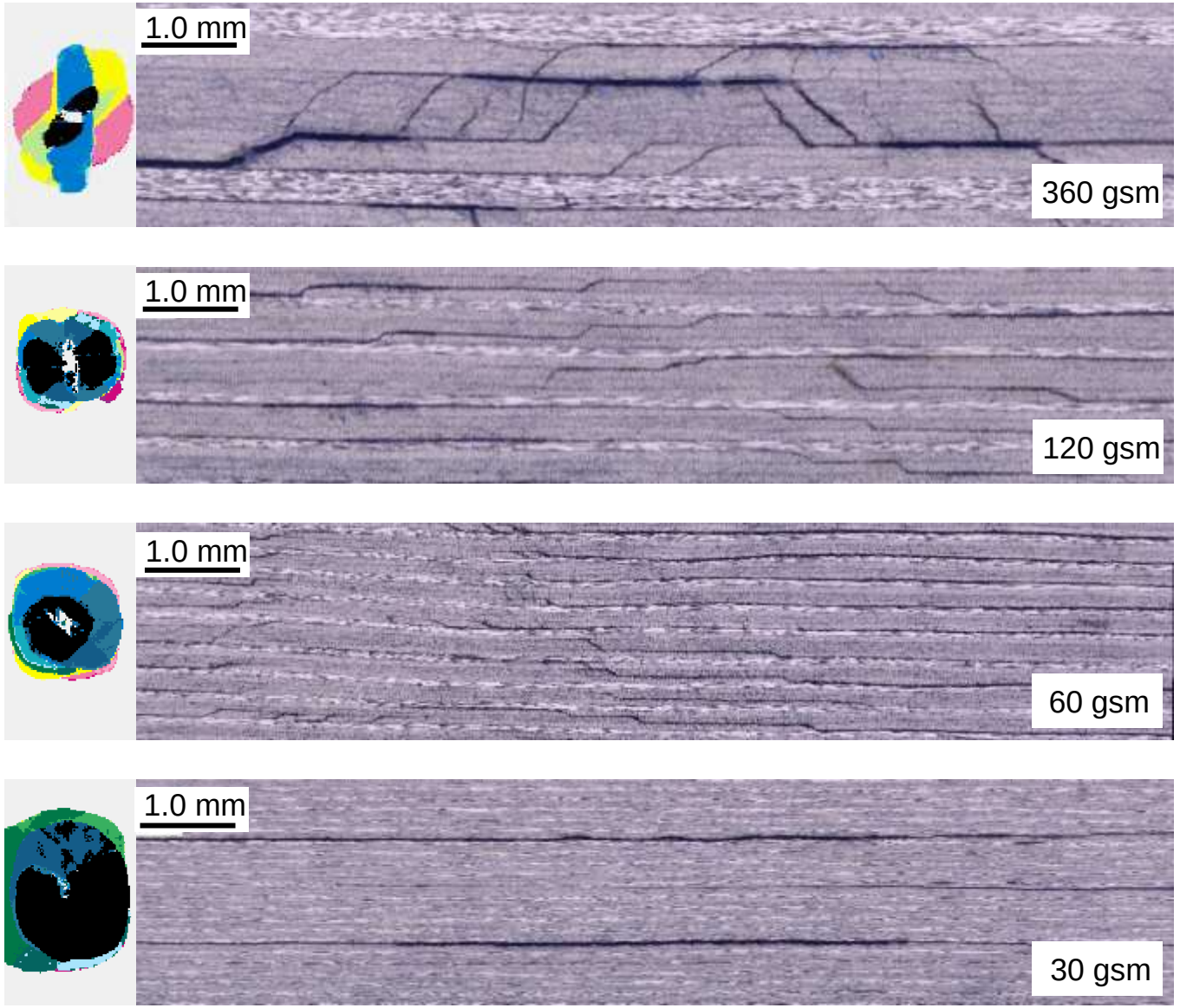



- Impact energy: 8J
- No edge delamination
- No fibre fracture
- Clamping in accordance with ASTM D-7136-5

- Anti-buckling support in accordance with ASTM D-6484
- Free transversal contraction
  - ➢ Less edge delamination
- Stress ratio R = -0.5

- Fatigue tests
- Stepwise fatigue tests
  - Ultrasonic scans
  - Computer tomography
  - Microsections

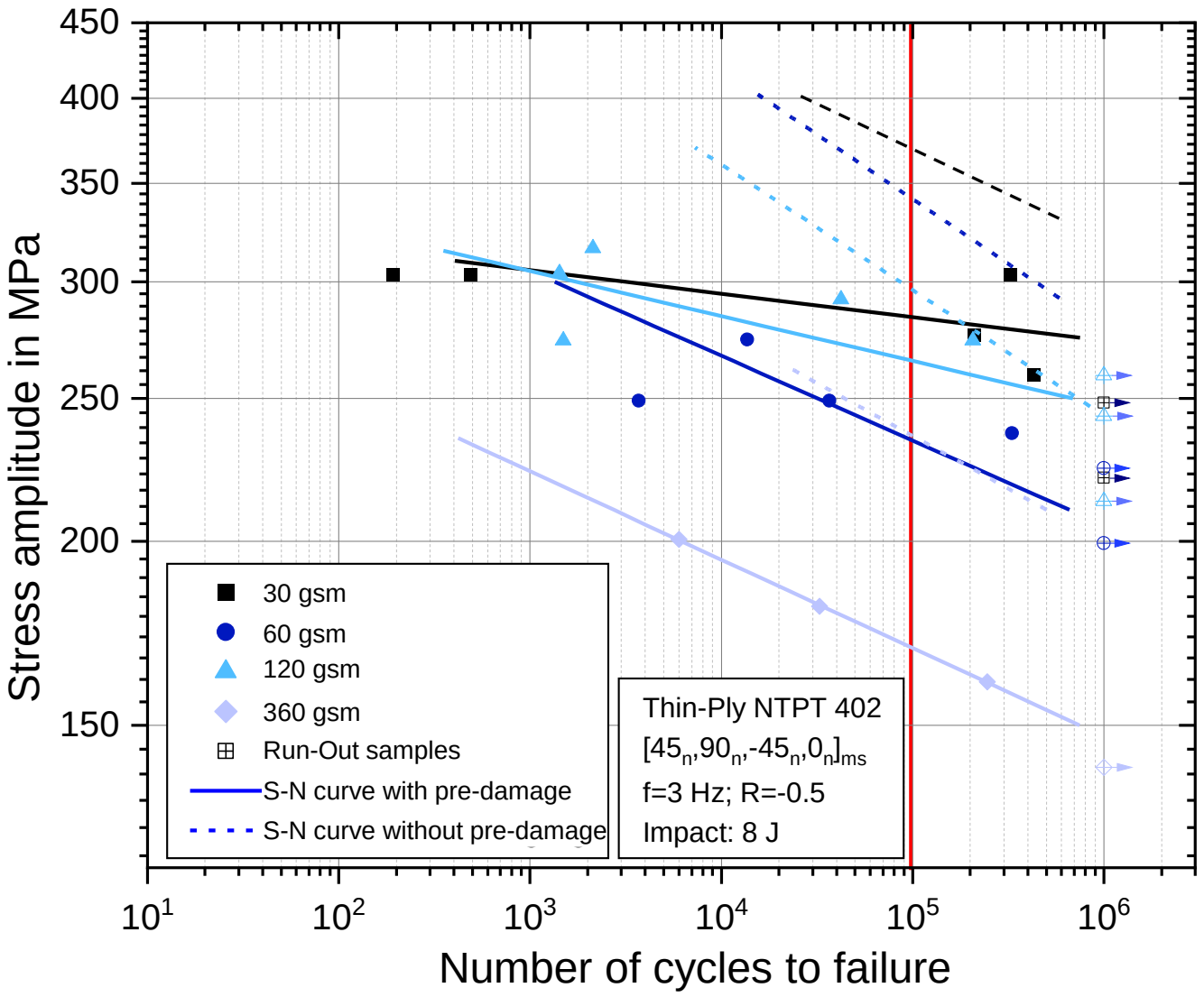
# Impact




With **decreasing** layer thickness:

- Larger projected delamination area
- Less indent deformations
- Suppression of inter-fibre fracture
- Shape of delamination change from a peanut shape to a circular shape
- Only 3 delaminations yield to sublaminates (30gsm)

# S-N curve R = − 0.5 (Tension – Compression)

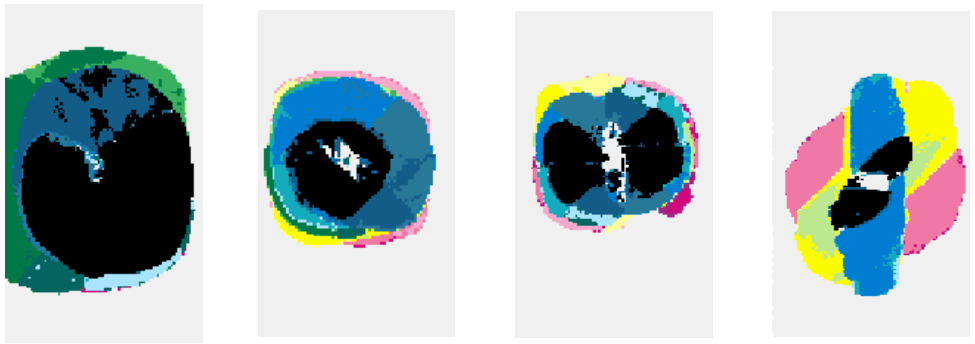



Failure at $10^5$ cycles:

30 gsm: 283 MPa → -20%
60 gsm: 234 MPa → -31%
120 gsm: 265 MPa → -10%
360 gsm: 169 MPa → -28%

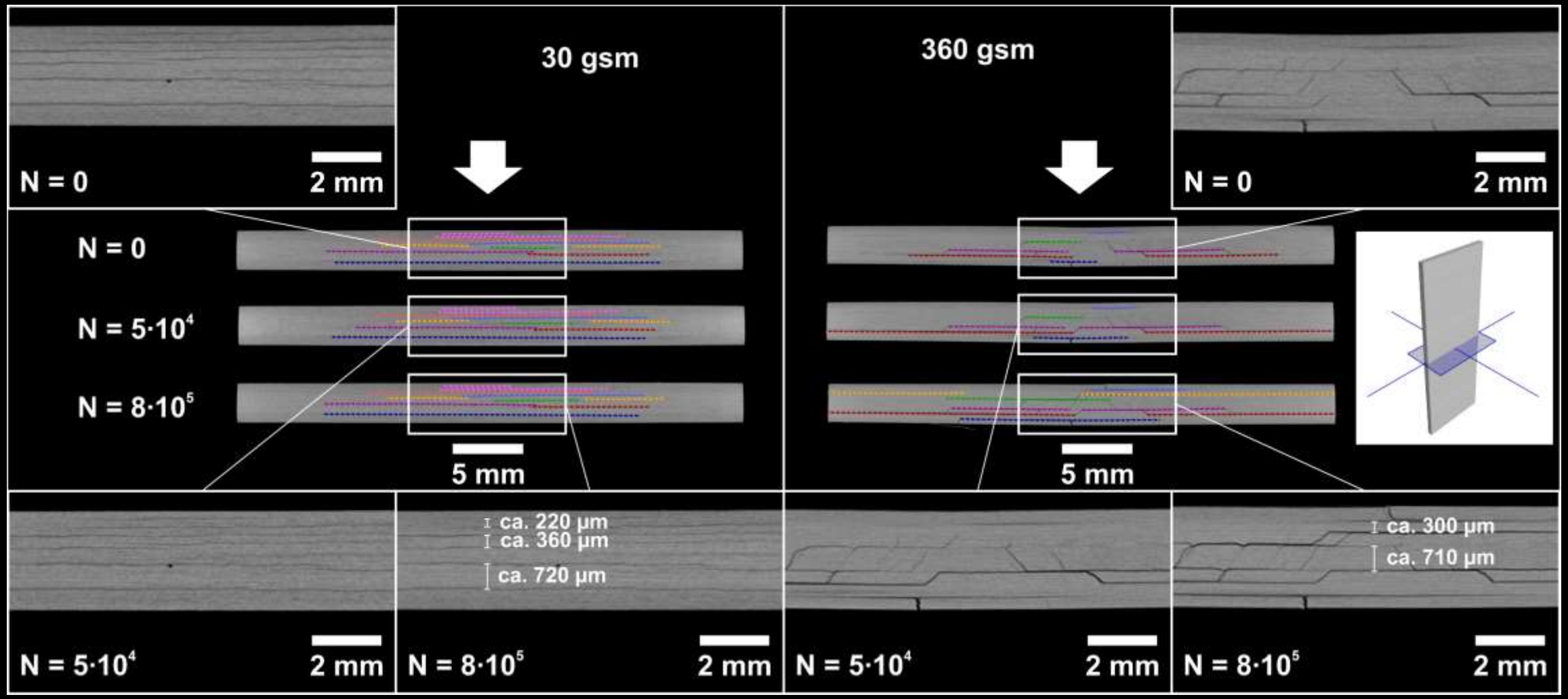
Main influence factors:

- Residual stiffness of the sublaminates
- Shape of delaminations
  - Thinner layers: circular
  - Thicker layers: peanut shape



30 gsm | 60 gsm | 120 gsm | 360 gsm

# Fatigue after impact– CT images




- Less damage growth due to lower interlaminar shear stresses
- Sublaminates exhibit a positive influence on the fatigue performance under compressive stresses

# Conclusion

## Reminder Thin-Ply:

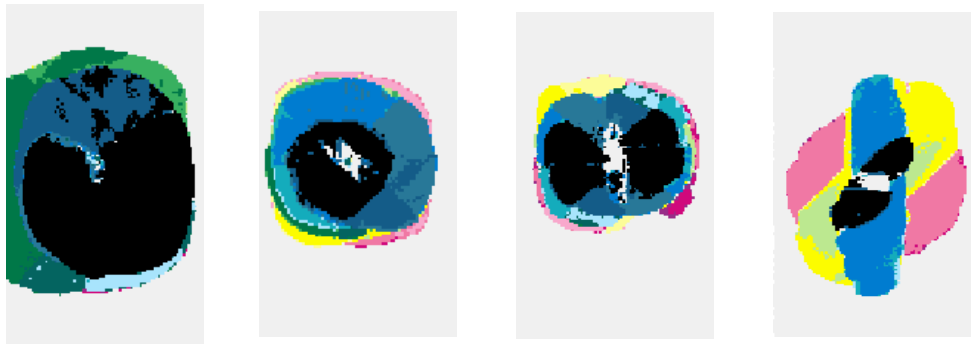
- Higher static tensile and compressive strength with decreasing layer thickness
- Failure behaviour changes from delamination-dominated (Thick) to fibre-dominated (Thin) behaviour

## Fatigue behaviour:

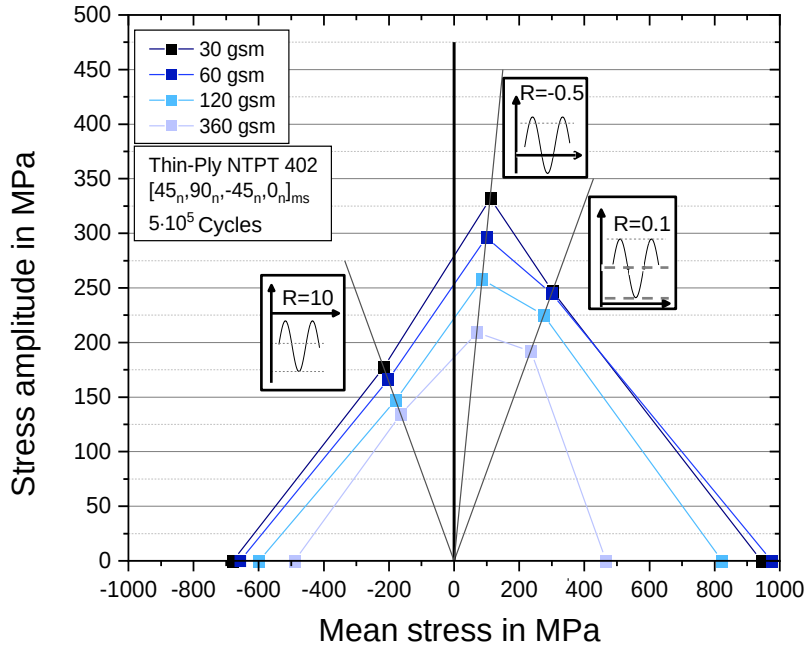
- Thin-Ply composites exhibit a superior fatigue performance independent of the stress ratio
- Fatigue behaviour under tensile-compressive stresses
  - Thin-Ply: Failed under tensile stress → Fibre fracture
  - Thick-Ply: Failed under compressive stress → Delaminations

## Fatigue after impact:

- Thin-Ply:
  - Larger delaminated areas projected
  - Superior fatigue behaviour → Less damage growth



30 gsm 60 gsm 120 gsm 360 gsm



# Acknowledgements

# Thin-Ply: Lightweight potential

Thin-Ply

- Layer thickness below 100 µm, down to 18 µm
- Tow spreading process to spread 24k tows
- Higher laminate qualities
  - More homogeneous fibre distribution
  - Less and smaller resin-rich areas

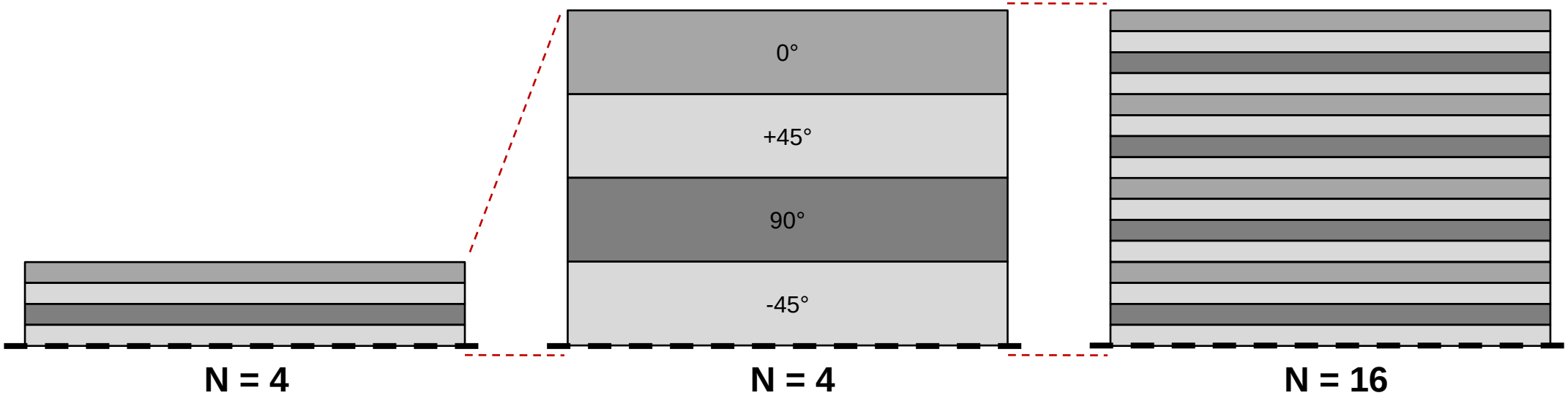
More degrees of freedom in design:

- Possibilities to optimize the laminate
- Low influence of design-rules

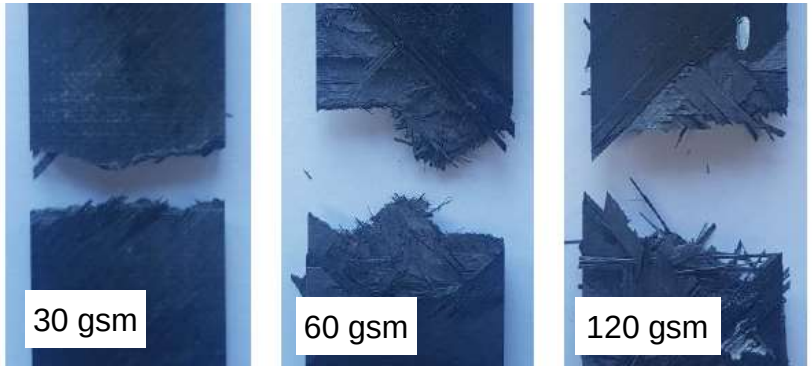
Significantly higher strength:

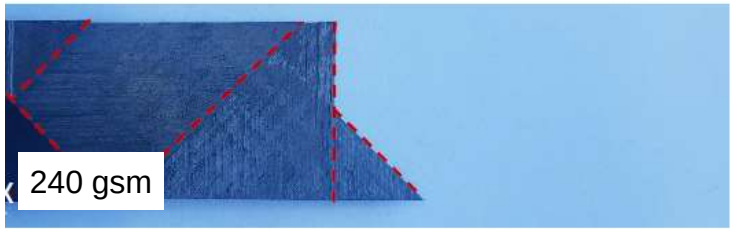
- Tensile tests of quasi-isotropic laminates:
  - Improved onset of damage (+230%)
  - Improved ultimate strength (+41%)

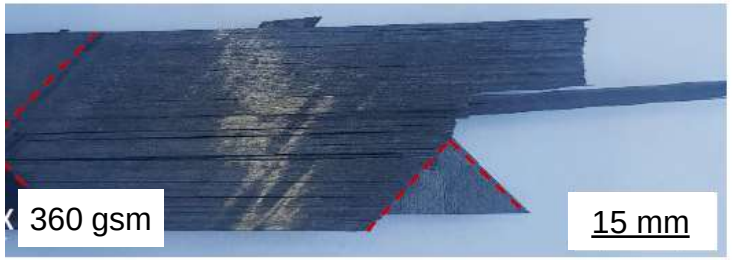
[Amacher 2014]

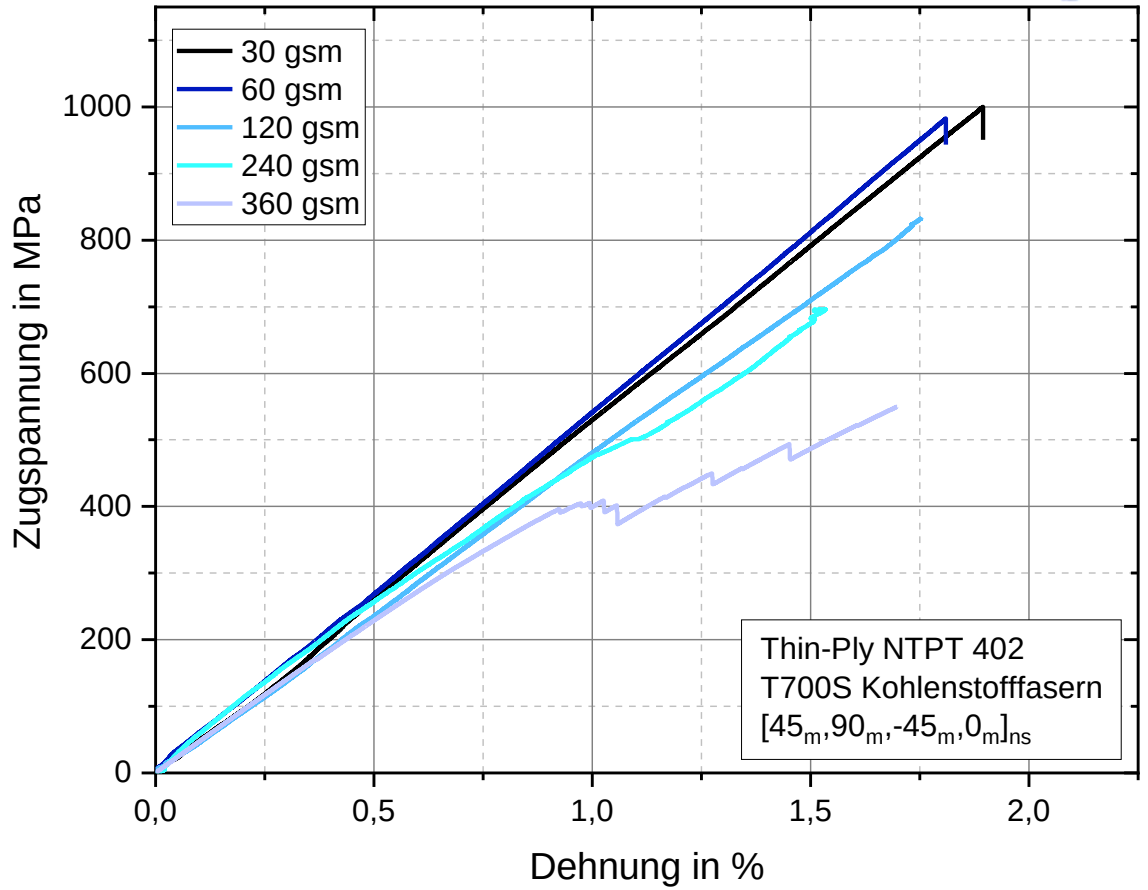


# Zugversuche - Bruchbilder




- Zunehmende Zug- und Druckfestigkeit mit abnehmender Schichtdicke
  - Spröderes Versagensverhalten
  - Keine bzw. geringe Vorschädigungen
- Gleiche Festigkeiten von 30 und 60 gsm Proben

# Zugversuche – AE Untersuchungen