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KU LEUVEN

Measuring UD fibre direction compressive strength and the factors affecting it

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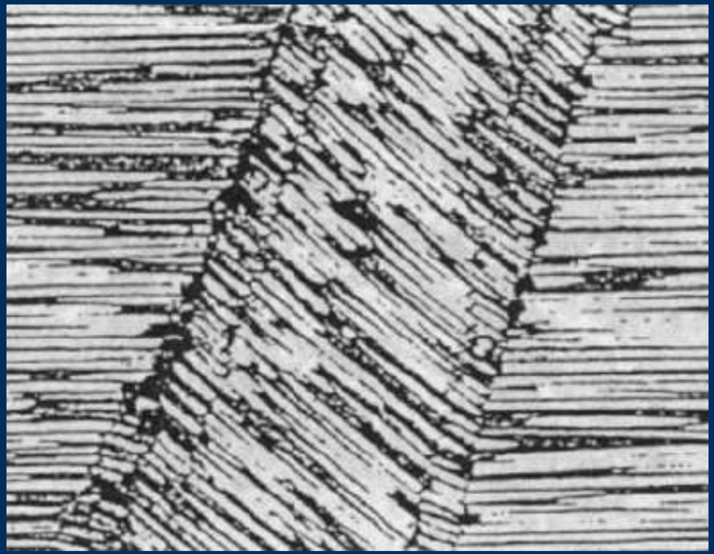
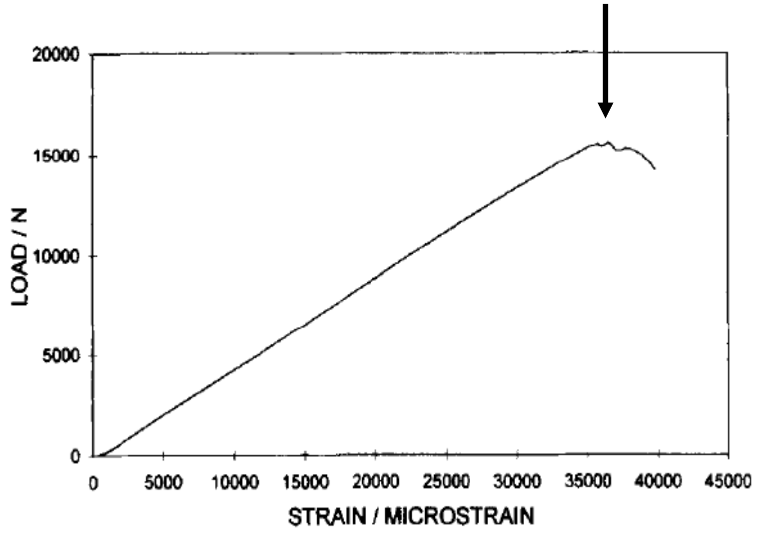


Definition of strength

At a previous workshop, the following definition was proposed:

The strength of a unidirectional composite is the maximum stress that the material can sustain under uniform uniaxial loading

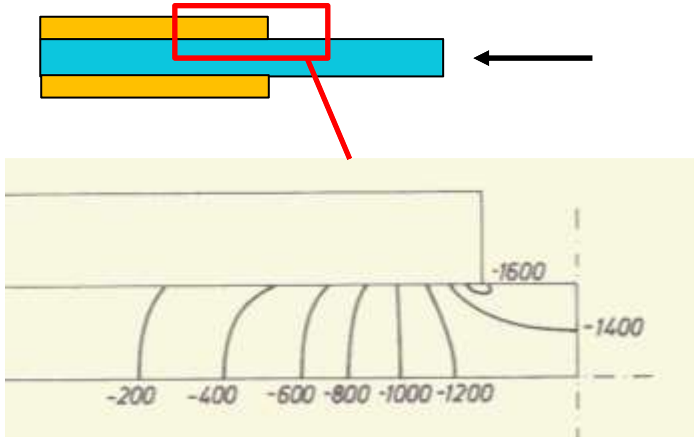
- Other definitions such as damage initiation stress are more subjective
- Can be applied to all the principal failure modes
- This workshop considers fibre direction compressive strength



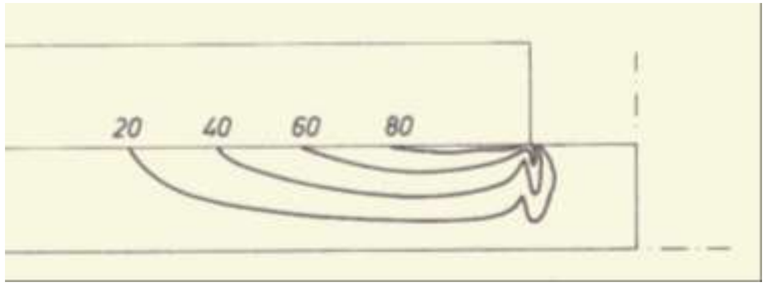
Wisnom and Paris, 2020

Compression testing is very hard!

- Must avoid buckling – affected by nonlinear response and shear
- But very short sections have non-uniform stresses
- Cannot avoid stress concentrations
- Other stress components are present
- Tests underestimate true strength



Stress concentration of compressive stress

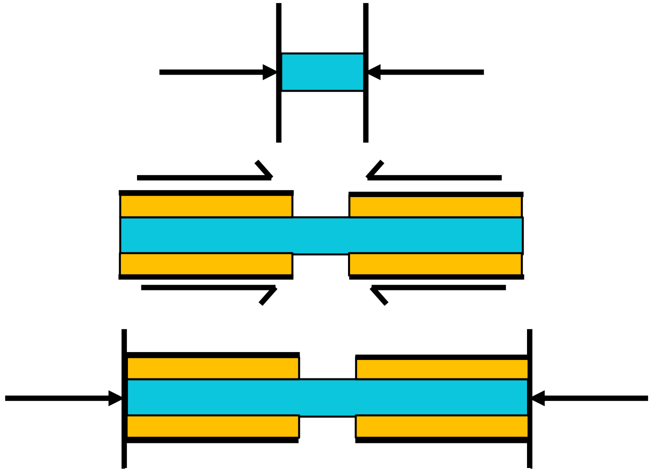


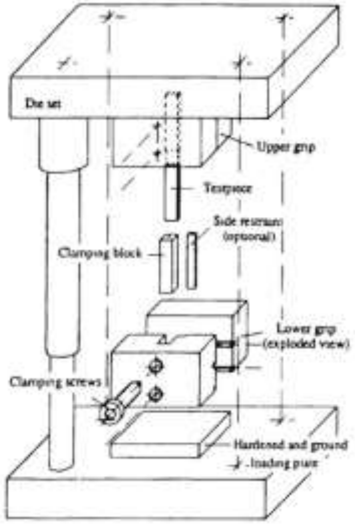
High interlaminar shear stress at same point

Wisnom, 1991

Direct versus indirect loading

- End-loaded specimens tend to split
- Shear loaded specimens have high stress concentrations
- Best compromise is combined loading
- Tabs take some load and avoid splitting
- Minimise thickness to reduce stress concentration
- Flatness and alignment crucial

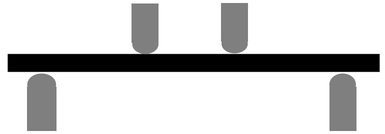


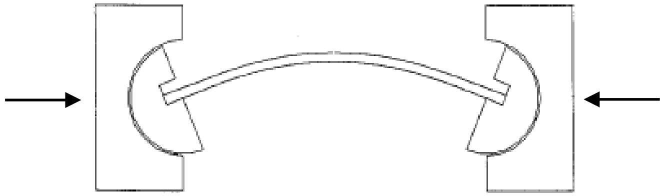


Imperial College rig
Haeberle & Matthews, 1994

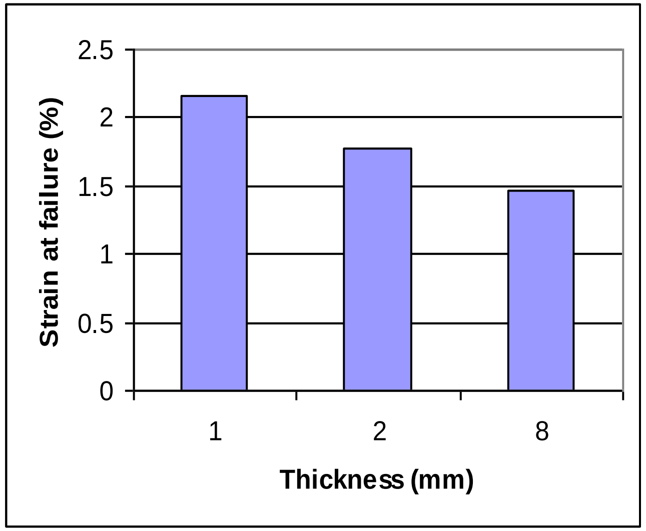
Other test methods

- Flexural tests avoid grip failure problem
- For many composites get compressive failure
- Gauge section failure if rollers are large enough
- Alternatively can used pin-ended buckling
- BUT fully scaled tests show failure strain is affected by strain gradient
- Also possible to produce compressive failure in tensile tests on specially designed laminates





T800/924

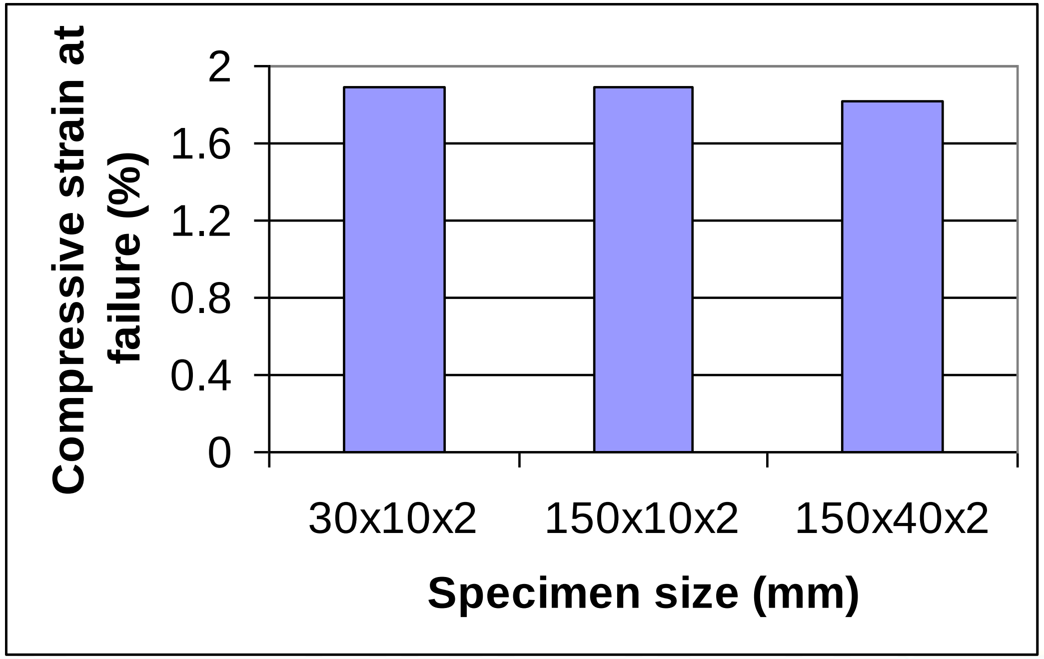


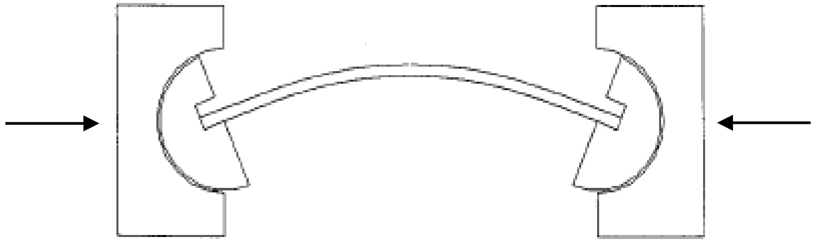
Wisnom, Atkinson and Jones, 1997

Effect of Stressed volume

- Could be a factor since failure depends on variable misalignment
- Not a large effect - pin-ended tests with different volume but same thickness give similar strengths

T800/924

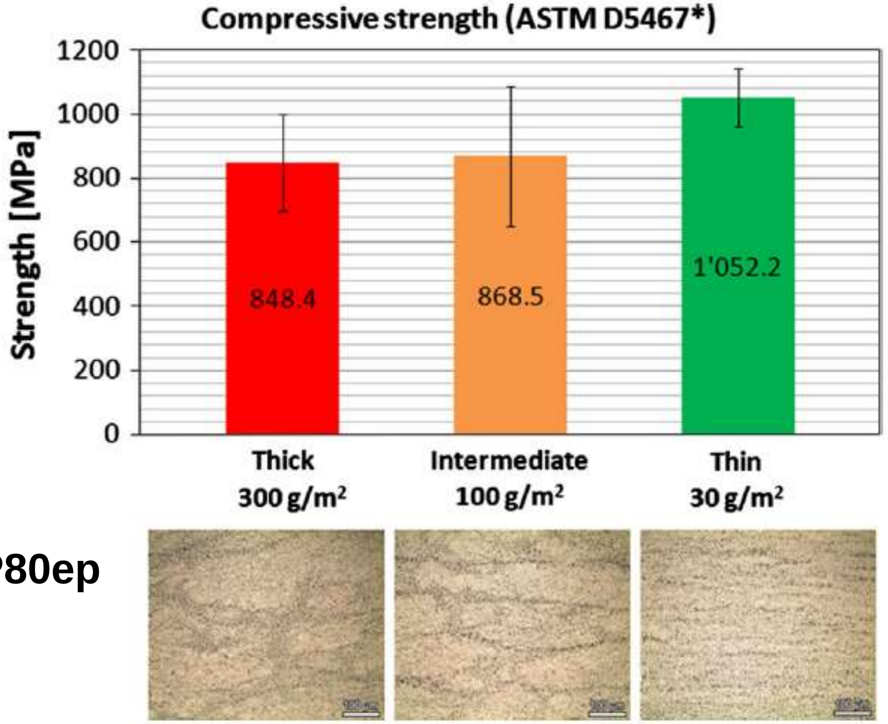




Wisnom, Atkinson and Jones, 1997

Effect of ply thickness, manufacturing

- Thin plies show higher strength
- Lower variability
- Greater homogeneity in plies
- Shows the potential effect of manufacturing
- Even larger effects if significant misalignment or wrinkles arise

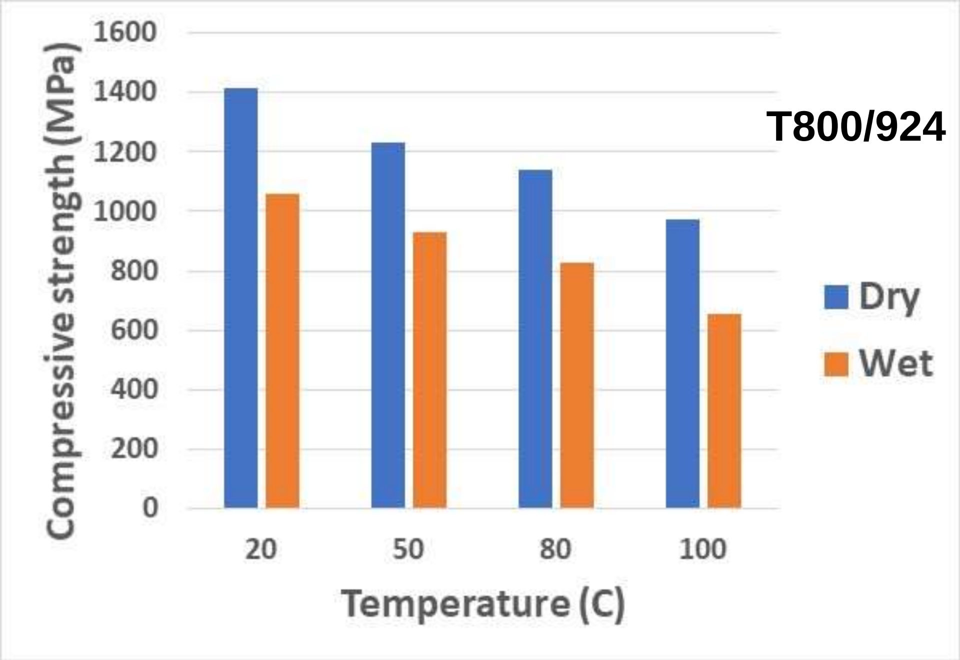


M40JB / North TP80ep

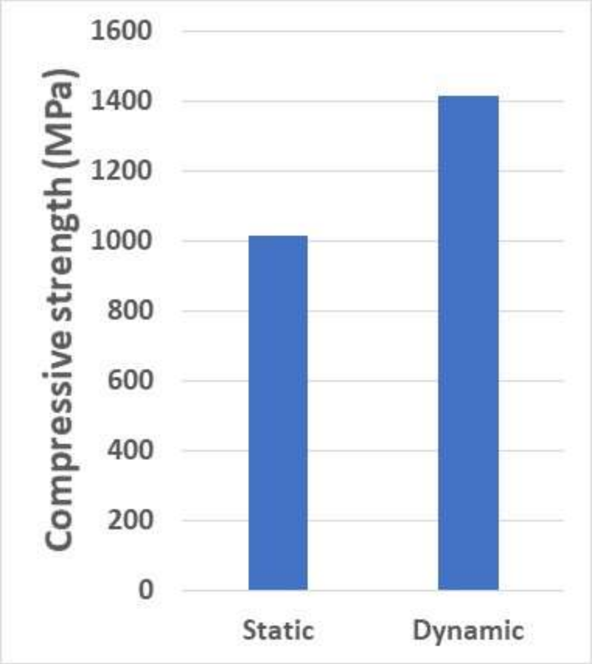
Amacher et al, 2014

Factors affecting compressive strength

- Temperature and moisture decrease strength significantly
- High strain rate increases strength



Soutis & Turkmen, 1997

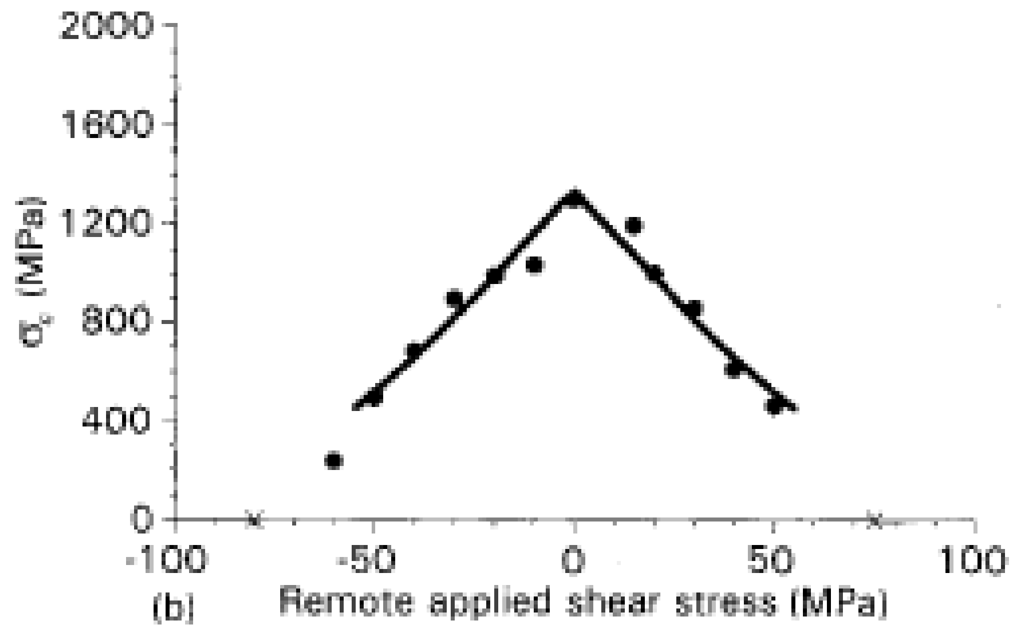


IM7/8552

Koerber & Camanho, 2011

Effect of other stress components

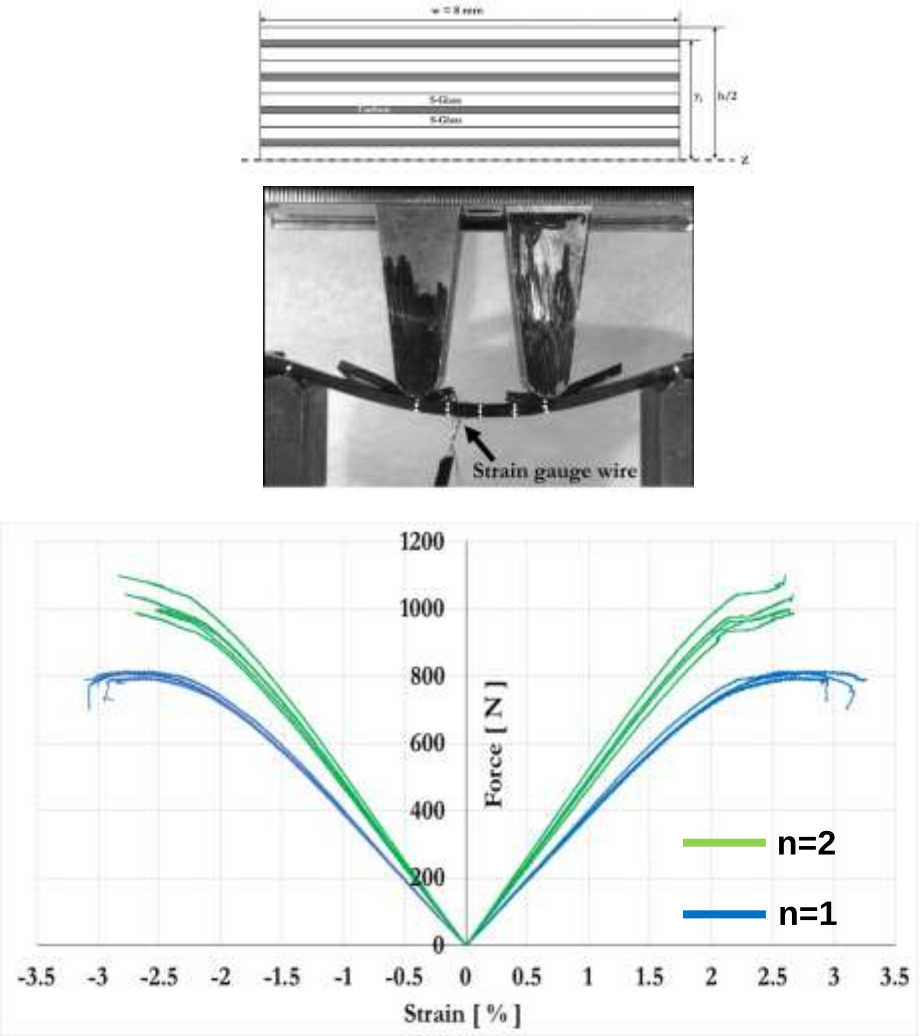
- Shear stress reduces compressive strength
- Demonstrated with tubes under combined compression and torsion
- Interaction of other stress components less clear
- Need better tests!



Jelf & Fleck, 1994

Other factors affecting strength

- Hybridisation – up to 3% compressive strain in thin-ply TC35 between S-glass plies
- Layup – some indications of higher 0° strain in laminates with many 45° plies
  e.g. Berbinau et al, 1999
- Modelling suggests stacking sequence may affect strength
  e.g. Davidson and Waas, 2021
- Need better experimental data



Suwarta, 2020

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