The University of Manchester

Prof C Soutis PhD(Cantab), CEng, FREng,
Northwest Composites Centre
Department of Materials
constantinos.soutis@manchester.ac.uk

Factors affecting UD compressive strength

- ❑ Constituent material properties & interface
- ❑ Fabrication induced defects
- ❑ Test Standards
- ❑ Specimen design, test Fixture & instrumentation
- ❑ Skills of operator
- ❑ Environment….

Selecting the right constituents at the very beginning of the design process requires careful material properties profiling.

Factors affecting UD compressive strength

❑ Fabrication induced defects:

Defects in the form of voids, resin rich regions, ply undulation, fibre misalignment and fibre waviness contribute to the triggering of fibre microbuckling.

❑ Test method, fixture & skills of operator

The test method, test fixture, specimen alignment in the testing jig and skills of operator also affect the measured strength value.

Test standards provide detailed specimen preparation and specimen design, test fixture (e.g. Celanese, ITTRI, variation), properties to measure, and acceptable failure modes……

Factors affecting UD compressive strength

- **Test Standards, EN ISO 14126, ASTM D-3410, CRAG, ICSTM…**

The test method describes the way the load is applied, i.e.,
a) direct end-loading, e.g., ASTM D695
b) shear loading, e.g., ASTM D3410
c) mixed shear/direct end-loading, e.g., ASTM D6641
d) sandwich beam, 4 point-bending, e.g., ASTM 5467

Analysis helps specimen design and to estimate the likely performance of a composite before making and testing it.

Test Standards guide us!

Factors affecting UD compressive strength

❑ Specimen design:

(i) end-tabs to effectively transfer load from the test machine grips to the specimen and to provide an adequate restraint against specimen buckling and brooming;

(ii) the overall specimen stability needs to be sufficient to ensure that compressive failure occurs significantly before potential buckling, implying correct combination of specimen length and flexural stiffness.

$$L_{max} \leq \pi t \sqrt{\frac{0.67kE}{12\sigma_{ult}}}$$

Factors affecting UD compressive strength

It has been shown that interfacial splitting due to excessive shear stresses could be avoided when the specimen is waisted following the taper contour equation, which gives the minimum gauge length:

$$L_{min} = ln(t/t_0)\frac{\sigma_c}{\tau_c}t_0$$

To satisfy the conditions of both equations the gauge length L_g of the specimen must lie between the limits:

$$L_{min} \leq L_g \leq L_{max}$$

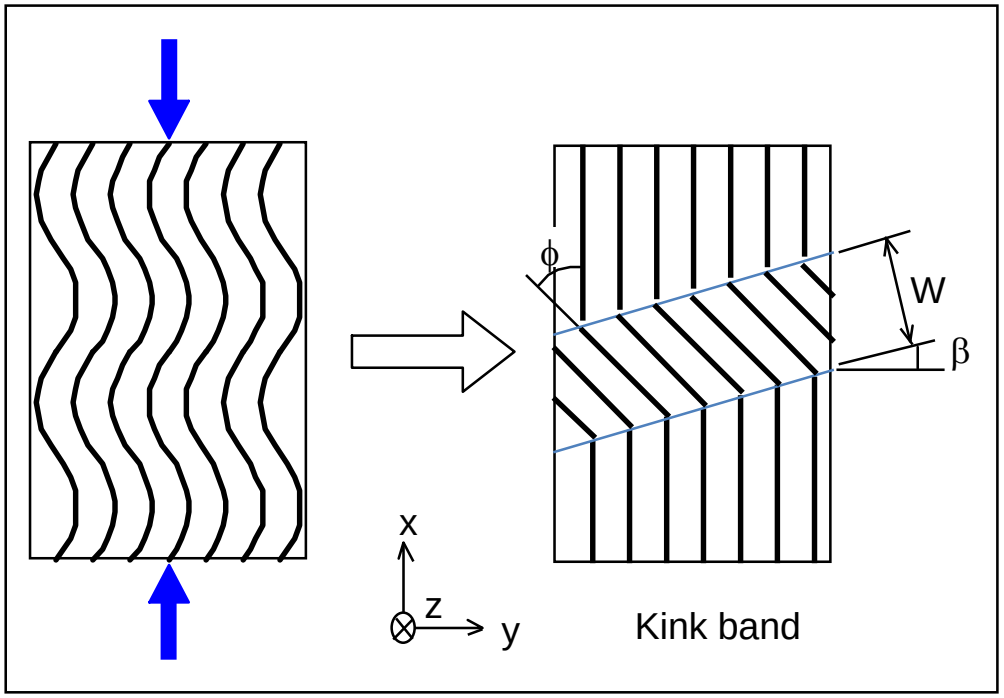
e.g., an 8 mm IM7/8552 UD specimen with waisted gauge section $\left(\frac{t}{t_0} = 1.5\right)$ not to fail by Euler bending the gauge length has to be < 56 mm, but >33 mm to avoid splitting

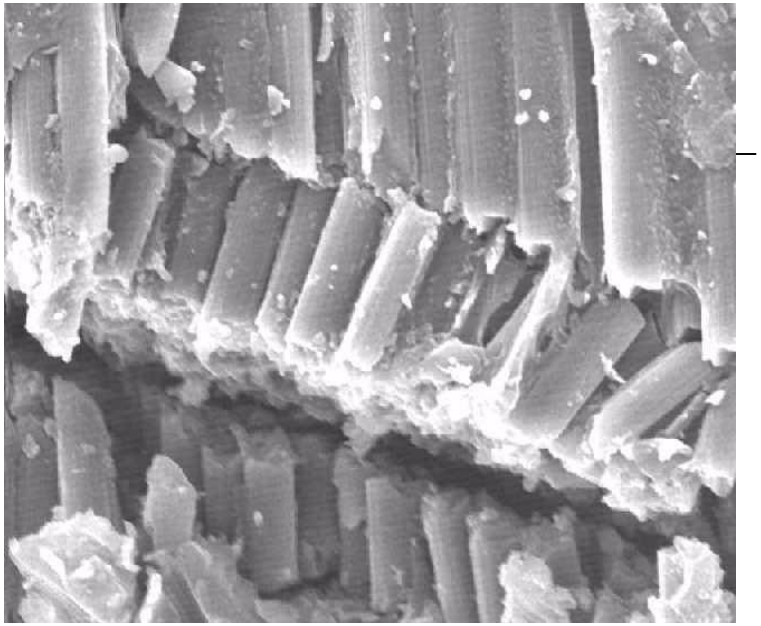
Composites are weaker under Compression

Soutis *et al*

Modern polymer composites fail by microbuckling, a fibre instability failure mode.

30-40% weaker than in tension

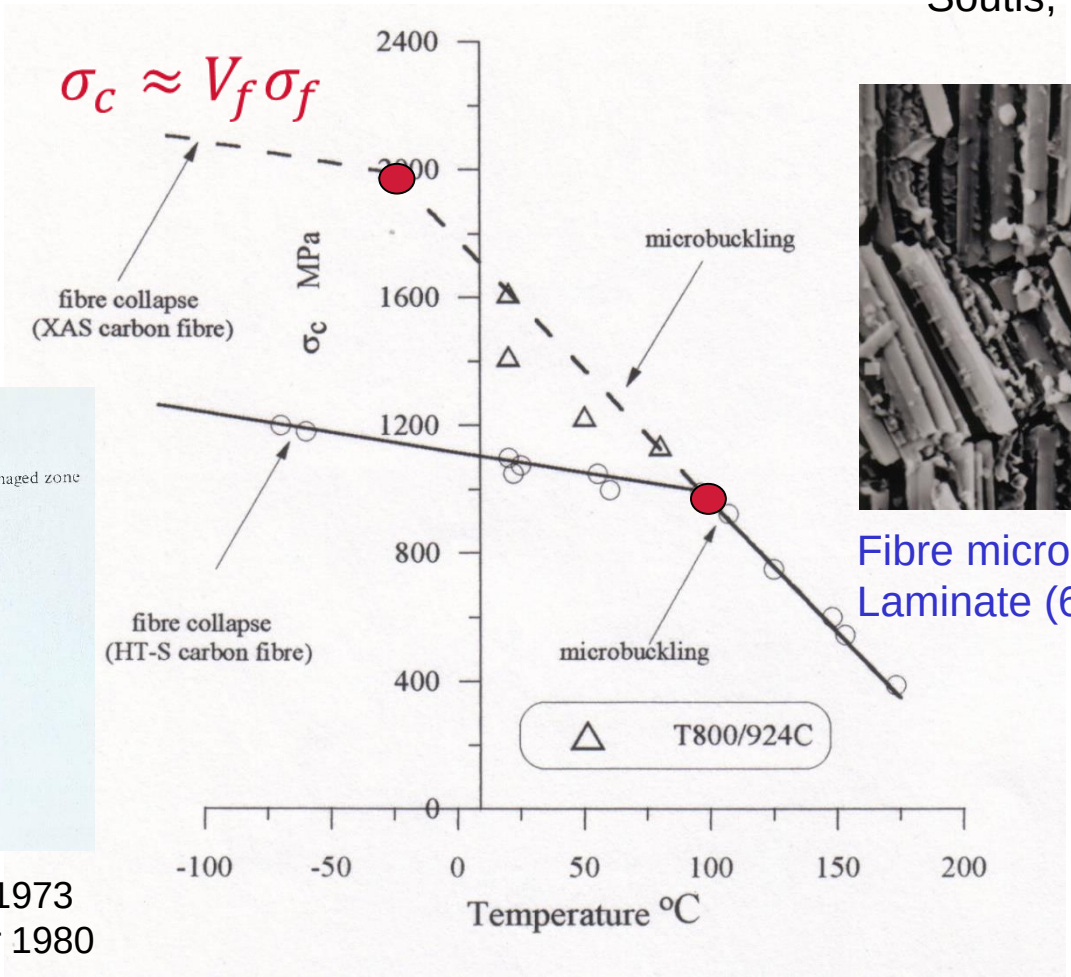


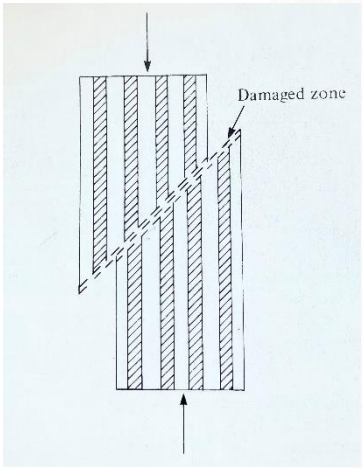


Kink band in multidirectional IM7/5552 laminate

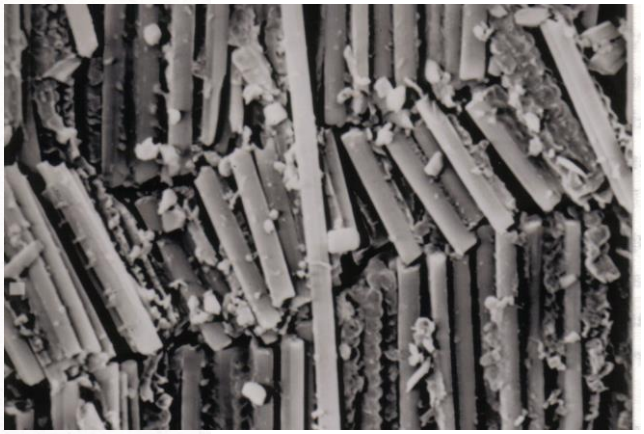
Compressive failure modes

Soutis, Fleck (1989)





Ewins & Ham 1973
Ewins & Potter 1980

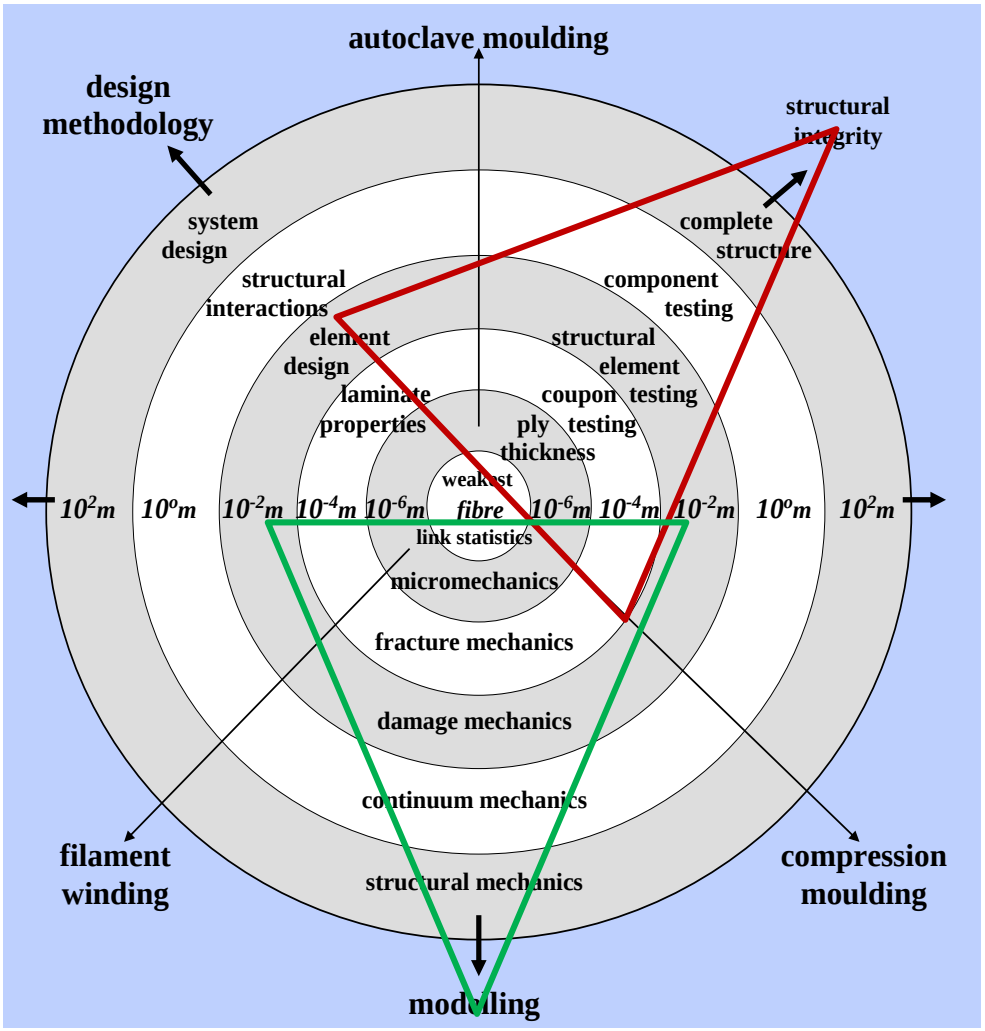


Fibre microbuckling in a T800/924C Laminate (6μm fibre diameter)

- Transition from fibre shear mode to buckling mode failure, resulting in reduced ultimate stress.

northwest composites centre

Composites Design



Soutis & PWR Beaumont
Multi-scale modelling

- Although confidence in failure criteria is low, modelling can reduce testing
- Need to include manufacturing defects