Highly flexible, Ultra-thin CFRP Layups for the use in Deployable Structures

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Why ultra-thin composites?

High specific strength and stiffness + Ply-thicknesses down to 20µm [1] + Positive size effects [2]

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Smaller **bending radii** and fulfilment of specific folding scheme requirements

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Enhanced **packaging** efficiency, highly desirable for reducing the stowage volume of **large space deployable structures**

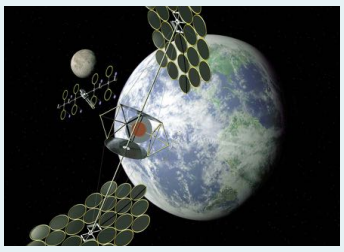


Fig. 1: Integrated Symmetrical Concentrator [3].

Objectives

- **Develop** a suitable bending test technique for ultra-thin laminates.
- **Characterize** the minimum bending radius of different angle-ply laminates.
- **Optimize** the layup design for a ultra-thin foldable hinge with minimum radii constraints and utilizing maximum stiffness.

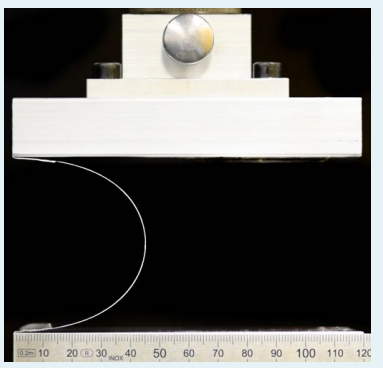


Fig. 2: Flat platen compression fixtures for ultra-thin laminates testing.

1 Design of the thin specimen

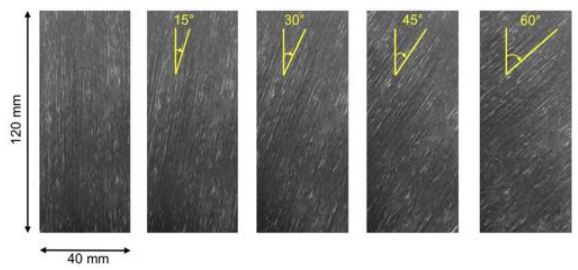


Fig. 3: Five sets of 4-ply symmetric and balanced ultra-thin specimens: $[0_2]_s$, $[\pm15]_s$, $[\pm30]_s$, $[\pm45]_s$, $[\pm60]_s$, respectively.

- Prepreg T700s fibers - ThinPreg™ 402 (epoxy matrix).
- Carbon fiber reinforced flat mold.
- Symmetric and balanced 4-ply laminates with an average ply-thickness of **21.08 µm ± 0.52 µm**.

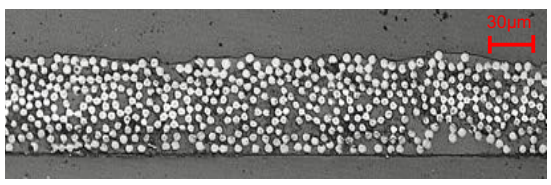
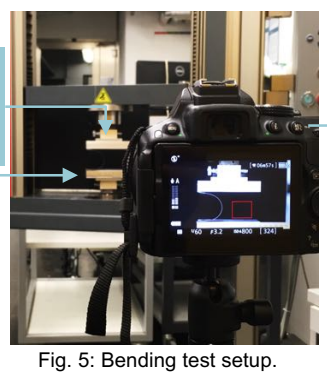


Fig. 4: 20X micrograph of a 0° UD specimen.

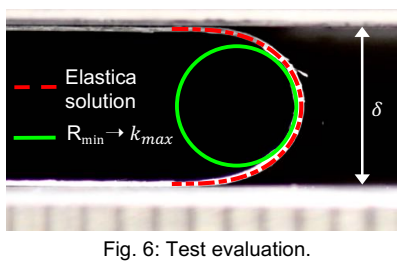
2 Bending test setup

Flat platen compression fixtures



Optical method for maximum curvature measurements

Fig. 5: Bending test setup.



$$\epsilon_{max} = \frac{t}{2} k_{max}$$

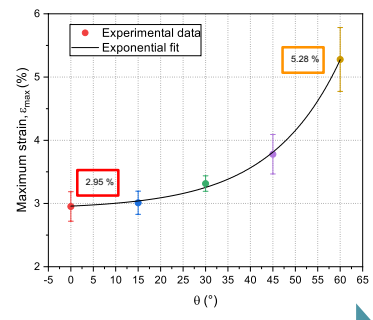
Euler's Elastica Theory:

$$E(\delta)I = \frac{M_{mid}}{k_{max}}$$

Fig. 6: Test evaluation.

3 Test results, layup optimization and SEM analysis

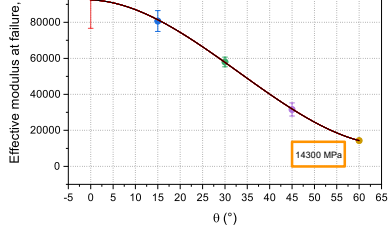
Angle-ply laminates results



Maximum strain

0° | ±15° | ±30° | ±45° | ±60°

Stiffness



Layup optimization

GOAL
R_{min} = 1.3 mm

- 6-ply configuration
- $\varepsilon_{max,\ predicted}$ = 4.78%

$[\pm59, 0]_s$

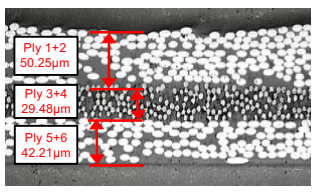


Fig. 7: 20X micrograph of the layup cross section.

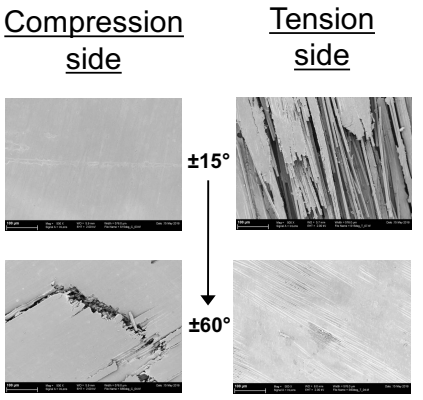
Layup test results

R_{min} = 0.98 mm

ε_{max} = 6.12%

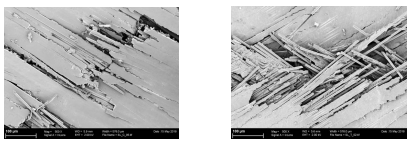
E = 17800 MPa

SEM – fracture behaviour



- Change in failure mechanism with increasing fiber angle.

$[\pm59, 0]_s$



- Simultaneous failure on both sides for the layup.

4 Conclusions and outlook

The large strain behaviour of ultra-thin CFRP angle-ply laminates under bending loads was investigated and successfully optimized to build up ultra-thin layups. It was demonstrated that:

- Thin specimens can withstand significantly higher strains than thick ones;
- Increasing fiber angles leads to drastically **lower bending radii**;
- The **better stress distribution** inside the optimized layup is responsible for the resulting 33% smaller bending radius.

Future work shall focus on symmetric but non balanced laminates, in order to fully exploit the maximum strain achievable by each layer of the laminate. A micromechanical numerical investigation should complete the work.

5 References

[1]: R. Amacher et al., *Thin ply composites: Experimental characterization and modeling of size-effects*, *Composites Science and Technology*, 2014.
[2]: M. R. Wisnom, *Size effects in the testing of fibre-composite materials*, 1999, UK
[3]: C. Carrington, J. Fikes et al., *The Abacus/Reflector and integrated symmetrical concentrator - Concepts for space solar power collection and transmission*, 35th Intersociety Energy Conversion Engineering Conference, 2000.