Non-traditional laminates

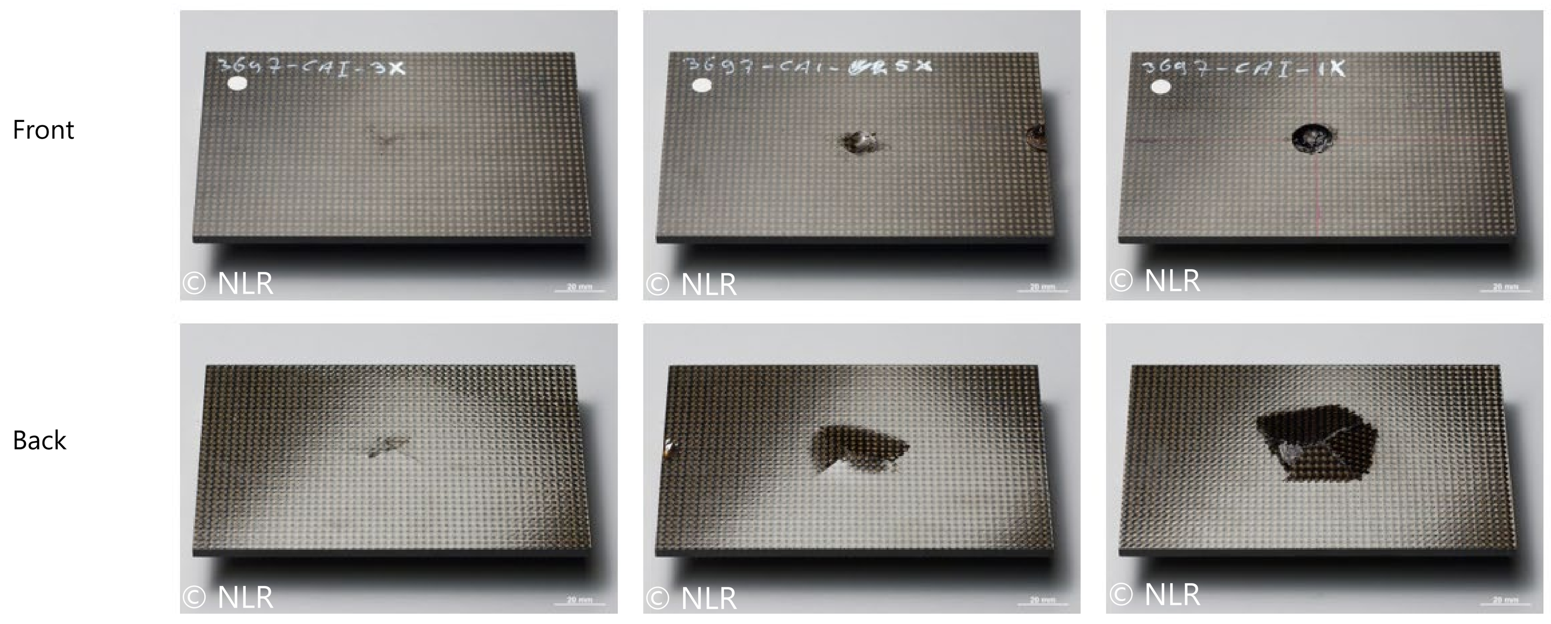
Contact: Royal Netherlands Aerospace Centre | composites@nlr.nl |

BACKGROUND

- For composite structures, damage tolerance is one of the most important design drivers in large parts of the aircraft. The structure is designed to sustain certain defects and/or damage without catastrophic failure until the damage can be detected.
- This drastically reduces the design strain levels in composite structures, especially under compression. The Compression After Impact (CAI) design strains are generally limited to maximum 3000-3500 με.

HOW?

- The Damage Tolerance philosophy is basically a Safety-by-Inspection concept. Damage detectability is a key part of that philosophy.
- Application of non-traditional laminates will change the way (impact) damage develops, and thus the detectability of damage.
- Instead of comparing the CAI strength at a certain energy level (as is often done in the research performed so far), one should compare the residual strength at equal levels of detectability.
- Step 1: determine BVID energy level for standard laminates and non-traditional laminates (thin-ply laminate, hybrid laminate, non-standard fibre angles).
- Step 2: determine the CAI strength (at the BVID energy level) of 'hard' laminates instead of QI laminates and investigate the influence of non-traditional laminates.
- Step 3: investigate the effect on OHT/OHC and FHT/FHC.
- Step 4: investigate the behaviour of non-traditional laminates when applied in sandwich structures.
- Step 5: develop analysis methods to explain and in the end predict the observed behaviour.

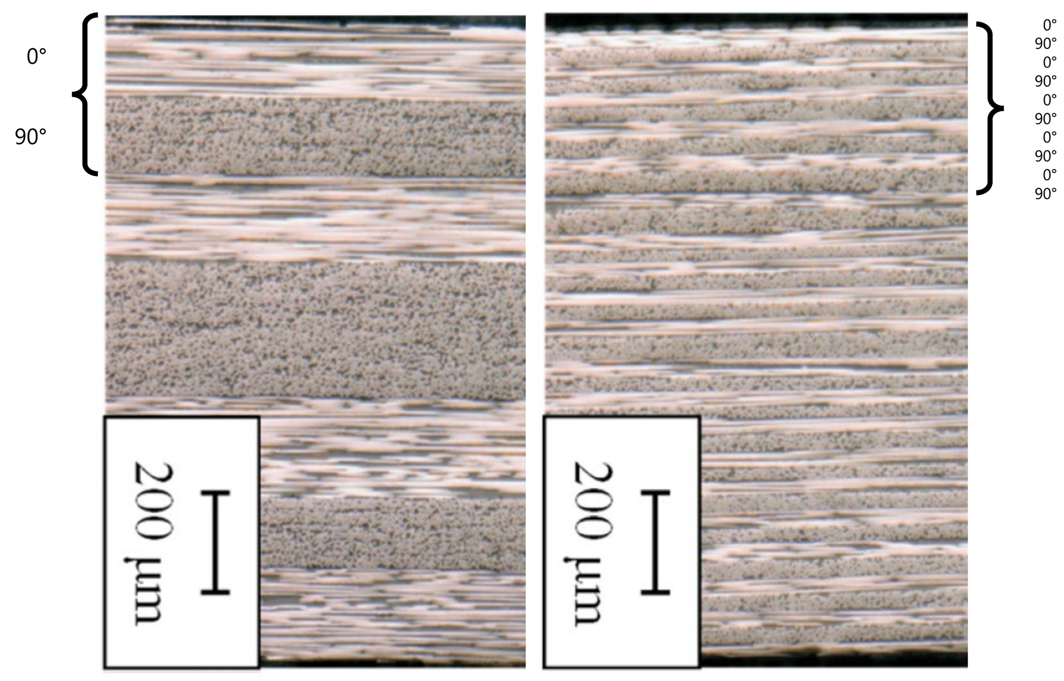


OBJECTIVE(S)

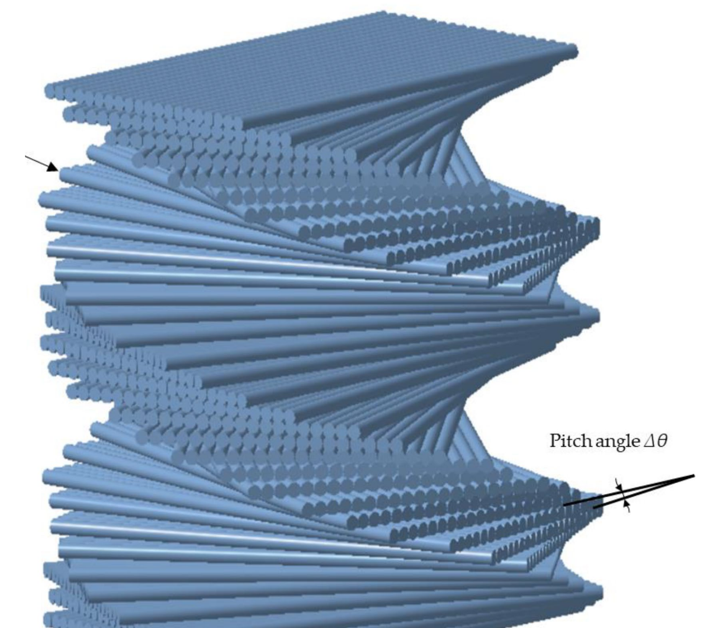
- Increase the damage tolerance design strain levels for future composite aircraft structures by the application of non-traditional laminate configurations.

WHY?

- Alternative laminate architectures, e.g. non-standard ply orientations, thin-ply laminates or hybrid laminates, result in a different behaviour when subjected to impact and have the potential for improved damage tolerance behaviour.
- Higher DT design strain levels lead to lighter and more efficient structures.



Cross-sections of thick- and thin-ply laminates [1]



Helicoidal laminate [2]

RESULTS

- Literature review conducted
  - Unnotched strength of thin-ply laminates is higher due to suppression of matrix cracks and free edge delaminations
  - OHT strength of thin-ply laminates is lower. The suppression of matrix cracks results in quasi-brittle behaviour for open hole and notched laminates without any blunting effect of the peak stress at the hole
  - A hybrid laminate containing a combination of thick an thin ply can solve this issue

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Acknowledgement
This research is conducted within the research and innovation programme Luchtvaart in Transitie, which is co-funded by the Netherlands National Growth Fund

[1] Naito, K.; Seki, Y.; Inoue, R. *Static and Fatigue Tensile Properties of Cross-Ply Carbon-Fiber-Reinforced Epoxy-Matrix-Composite Laminates with Thin Plies. J. Compos. Sci.* 2023, 7, 146
[2] Yu, Z. et al., *Increasing the Compressive Strength of Helicoidal Laminates after Low-Velocity Impact upon Mixing with 0° Orientation Plies and Its Analysis.* Materials 2023, 16, 4599. ©*CC-BY*