

# INVESTIGATION OF THE EFFECT OF SPECIMEN WIDTH ON OPEN HOLE TENSILE STRENGTH

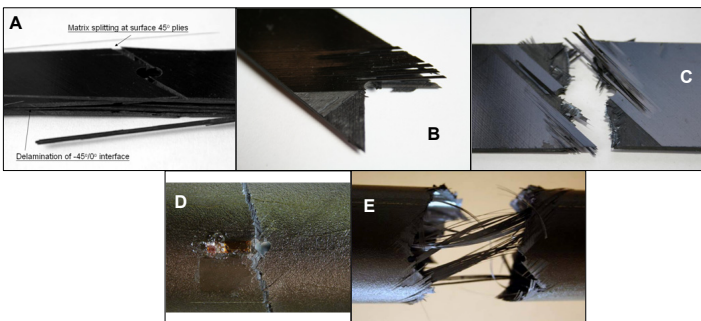
*Marco Cheung and Stephen Hallett*

Recent work at the University of Bristol has shown the importance of sub-critical damage in open hole tension tests. This is significant for both the ultimate failure stress and failure mode. A critical event is the point at which sub-critical damage joins up across the width of the specimen and propagates through the thickness of the laminate. The specimen width can therefore influence results, even though the linear elastic stress distribution has reduced to the far field stress at the edge for the standard hole diameter to width ratio of 5. A number of tests have been conducted to investigate this effect.

## Testing programme

A [45/90/-45/0]<sub>s</sub> quasi-isotropic layup of IM7/8552 prepreg with hole diameter 1/8" (3.125mm) was used.

- Baseline specimens with one ply in each orientation, symmetric were 1mm thick.
- This was scaled to 2mm thick by both increasing the number of sub-laminates and increasing the ply block thickness.
- Flat specimens with a width to diameter ratio (w/d) of 5 and 10 were tested
- To remove the effect of the free edge completely, tubular specimens with a 61.5mm internal diameter and two holes opposite across the diameter were manufactured. This gave an equivalent width of 96.6mm (half circumference).

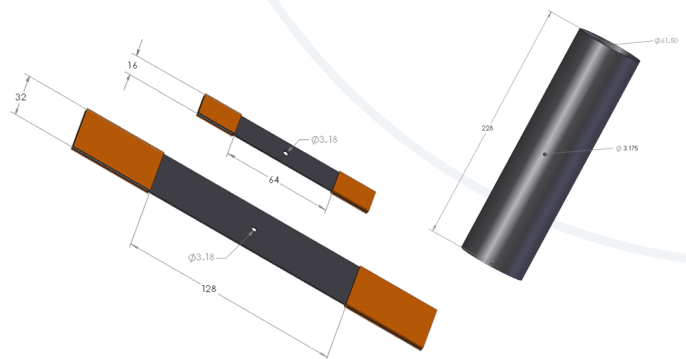


Failure modes exhibited a) Delamination - 16mm wide ply level scaled, b) Pull out - 32mm wide, ply level scaled, c) Pull out/brittle - 32mm wide, sublaminate level scaled, d) Brittle - 1mm thick tubular, e) Pull out - 2mm thick ply level scaled tubular

## Effect on strength

The change in damage mechanisms towards a more brittle failure has previously indicated a reduction in strength due to reduced notch blunting by the sub-critical damage.

- Keeping hole diameter constant and increasing w/d resulted in a significant increase in strength (when normalised by a finite width correction factor).
- This can be explained by the increasing difficulty for the sub-critical damage at the hole and free edge to join up which in the pull out and delamination failure modes is the critical event.
- The only exception to this trend was the 1mm tubular specimens in which manufacturing difficulties could not be ruled out.



## Failure mode

The failure modes for open hole tensile specimens can be classified as brittle, pull-out and delamination. It was notable that as the specimen width was increased there was a transition towards more brittle failures.

- **Baseline 1mm thick:-** 16mm and 32mm wide flat specimens showed a pullout type failure. The tubular specimen failure is more difficult to classify but generally was a brittle failure at one hole and a pullout failure at the other.
- **Sub-laminate 2mm thick:-** 16mm wide specimens showed a pullout failure whilst the 32mm wide showed a combined brittle and pullout mode within each specimen. The tubular specimens showed a predominately brittle type failure.
- **Ply level 2mm thick:-** 16mm wide specimens showed a delamination type failure. At 32mm wide the majority showed a pullout failure mode. Tubular samples also showed what appeared to be a pullout type failure but this was more difficult to classify.

