HiPerDuCT Programme Grant

Final report: Shifted in-plane waviness in UD laminates

‘Brick and mortar’ composite architectures (see Figure 1a) have been investigated to produce a ductile failure process [1-2]. The pseudo-ductility of the architectures results from either complete yielding of the matrix in the overlap region, or from cracks initiated at the ends and growing inwards towards the centre of the overlap region. However, in a composite containing many overlaps, the failure tends to localise at one set of overlaps running across the thickness of the specimen.

A modified continuous unidirectional ‘brick and mortar’ composite architecture (Figure 1b) with in-plane wavy connecting segments was investigated. The in-plane wavy segments (in the low initial stiffness state) extend and stiffen after failure of one overlap, so that the applied load is transmitted to the adjacent overlaps. In this way the localisation problem can be avoided and a pseudo-ductile stress-strain relationship permitted.

It is important to ensure that the in-plane wavy segments extend and carry the load after failure of the adjacent overlaps. To achieve this, the composite must fail by shear cracking between the fibres. This allows the composite to extend and stiffen as the fibres become straighter. An interleaved wavy unidirectional carbon fibre/epoxy composite has been manufactured containing polystyrene (PS) interleaves.

Preliminary investigation was conducted on flat unidirectional carbon fibre/epoxy composites of HexPly T300/914 with polystyrene interleaves ([0°/PS/0°/PS/0°/PS/0°/PS/0°/PS/0°/PS/0°/PS/0°], nominal thickness = 1.7 mm). The PS interleaf can lose its stiffness when heated above the glass transition temperature and regain the stiffness when cooled down [3]. To take advantage of this, specimens were heated to 120°C and re-shaped by axially compressing to form the required wavy profile. They were cooled down to room temperature and tested under tension. The stress-strain relationship from a tensile test (see Figure 2) shows that delamination of the polystyrene interleaves occurred at around 0.8% strain and the composite continued to straighten and stiffen, and finally failed at around 2.7% strain. As expected, this significantly surpasses the failure strain (~1.3%) of the pristine unidirectional carbon fibre/epoxy.

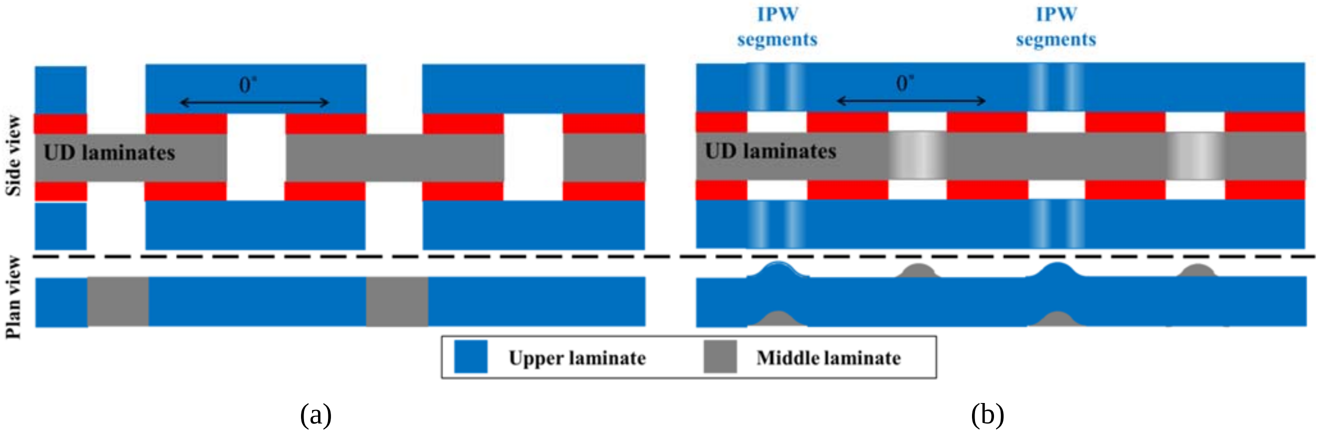

Figure 1. Sketches of (a) ‘bricks and mortar’ composite architecture [1-2] and (b) modified ‘brick and mortar’ composite with in-plane wavy segments.

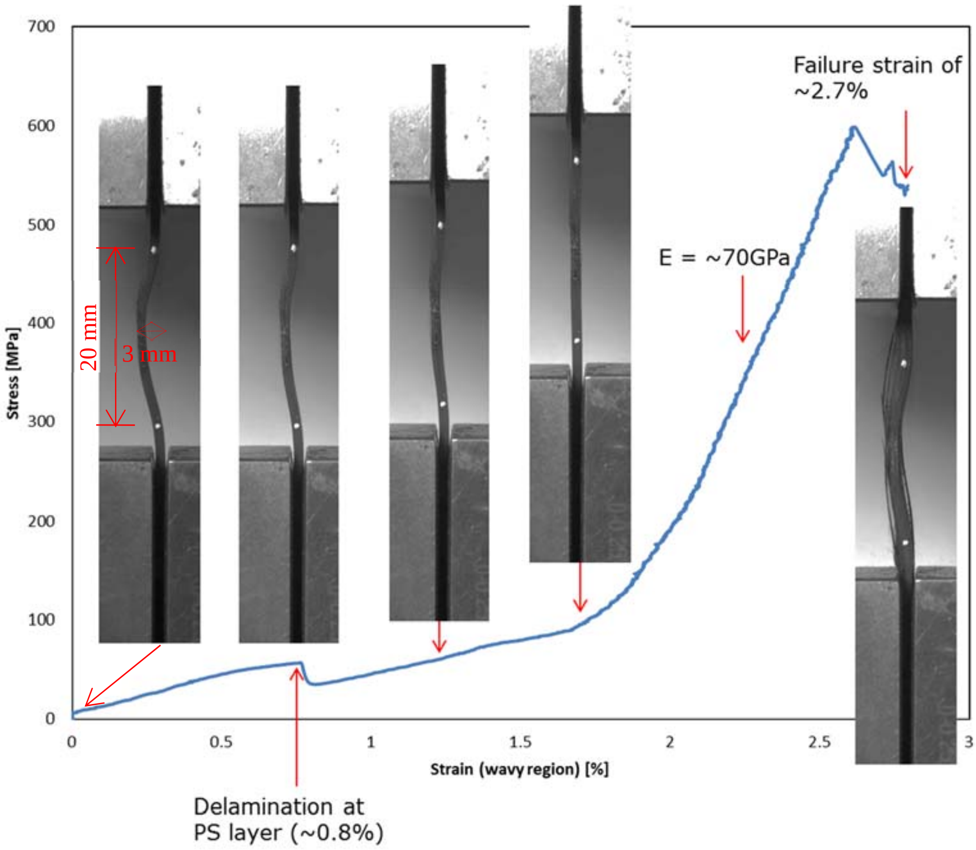

Figure 2. Resulting stress-strain relationship of an interleaved wavy specimen under tension at room temperature.

References

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[2] G. Czél, S. Pimenta, M. Wisnom and P. Robinson, Demonstration of pseudo ductility in unidirectional discontinuous carbon fibre/epoxy prepreg composites, *Composite Science and Technology,* **106**, 2015, pp. 110-119.

[3] H.A. Maples, S. Wakefield, P. Robinson, and A. Bismarck, High performance carbon fibre reinforced epoxy composites with controllable stiffness, *Composite Science and Technology,* **105**, 2014, pp. 134-143.