Multiscale simulation framework for interlaced laminates

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MULTISCALE SIMULATION FRAMEWORK FOR INTERLACED LAMINATES

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ABSTRACT

The pursuit of weight savings in the aerospace and automotive industries has driven the adoption of composites for structural applications. Despite exceptional in-plane strength and stiffness, further adoption of composite materials is limited by their poor response to low velocity out-of-plane impact loading [1]. Low-velocity impacts cause delamination - leading to significant reductions in laminate properties, most notably, compressive strength. Furthermore, because damage occurs at the interfaces between plies, rather than externally, delamination damage can be difficult to detect (not visible to the human eye) and challenging to repair.

Improving the impact tolerance of composite laminates is achieved primarily by reducing the incidence and propagation of delamination. To this end, existing research has focussed on either the development of high toughness constituents e.g. thermoplastic matrices, or on the modification of laminate's internal architecture. The issue with existing architectural methods such as z-pinning, stitching etc. – is that despite their proven efficacy in improving impact tolerance, they also negatively affect a laminate's undamaged strength and stiffness [2].

A novel laminate design concept; interlacing (also known as AP-PLY or pseudo-weaving) has the potential to provide improved impact tolerance while retaining the excellent stiffness and strength of conventional angle-ply laminates. Interlaced laminates are produced using automated tape laying (ATL) machines. Conventionally, ATL machines form laminates in a process emulating manual layups; tapes are placed in unbroken layers resulting in angle ply laminates. In the production of interlaced laminates gaps are left between tapes placed in a single layer, see Figure 1. Later passes of the tape placement machine "fill in" these gaps, causing tapes to undulate between layers in the laminate. In doing so, interlaced laminates form a woven-like architecture which effectively arrests delamination.

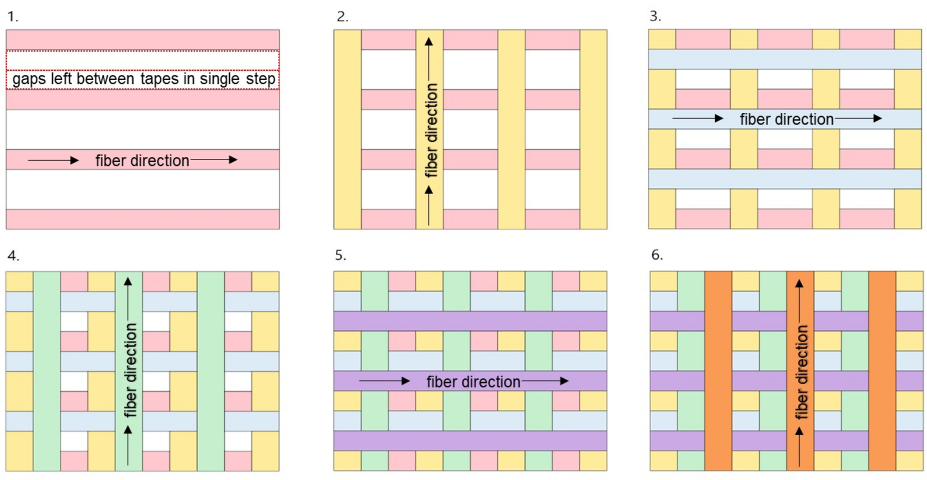

Figure 1: Interlaced laminate manufacturing process.

A multiscale numerical framework was developed using Python and Abaqus to simulate the behavior of interlaced laminates and to determine how the specific internal architecture of a panel affects its behavior. Numerical and experimental tensile tests were conducted to compare the in-plane stiffness, and strength of interlaced and angle ply laminates. Figure 2 illustrates the tensile stiffness of three interlaced panels relative to a baseline conventional cross-ply laminate. Figure 3 illustrates the interlaced configurations of the aforementioned panels. Clearly, the interlaced architecture had a negligible effect on the in-plane stiffness of the laminates. Other researchers have reported similar losses of between 1.5% to 4.7% (depending on the interlacing pattern) [3][4]. There is good agreement between the numerically calculated stiffnesses and their experimentally determined values.

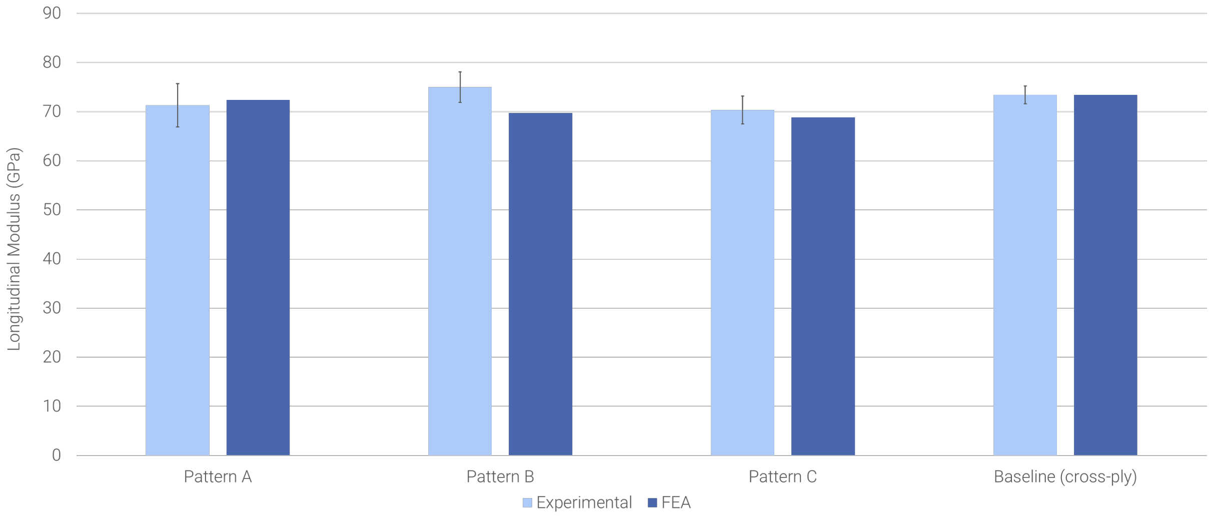

Figure 2: Longitudinal stiffness of various interlaced architectures compared with a baseline cross-ply laminate. Experimental results and numerical simulations.

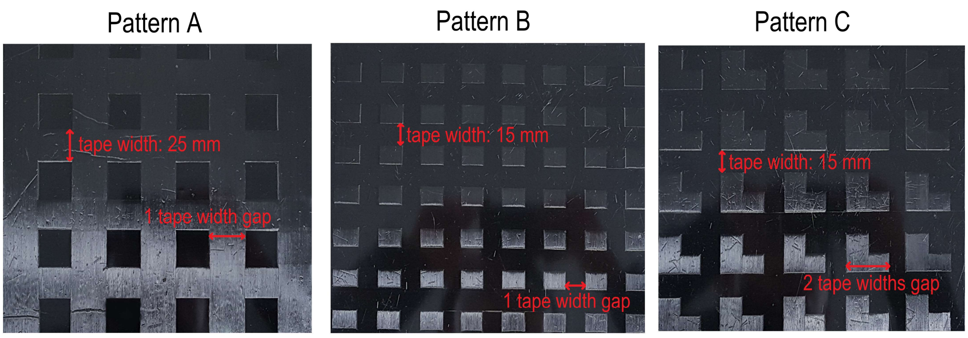

Figure 3: Images of the three different interlaced laminate configurations presented in Figure 2.

Future work will focus on impact testing of various interlaced laminate architectures and their numerical simulation. Subsequent work will aim to implement optimization routines to determine the best placement of tapes for improved impact tolerance and in-plane strength and stiffness.

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