Abstract

Composite 3D woven components have been researched to be used in aerospace components because of their improved through-thickness properties and ability to be woven integrally in near-net shape. The complex stress conditions and long time required to manufacture and test physical specimens means that the relationship between the reinforcement's weaving pattern and the mechanical behaviour of 3D woven composite T-joints is not well understood. With approximately 3.6 million possible combinations of weft yarn configurations alone, an exhaustive search of the design space is not possible.

The aim of this project was to apply optimisation algorithms to 3D woven profiled structures such as T-Joints. Previous geometry modelling work in the literature provided a framework to produce these models but were done by-hand using a manual process. As such this approach is not suitable for use in optimisation which requires models be produced without any input from the user.

A tool was developed to automatically model T-joint reinforcements, using TexGen the University of Nottingham's in-house 3D weave geometry modelling software. Particular focus was placed on replicating the order in which wefts wrap around each other. This was achieved by determining the ordering of the weft yarn interlacement at the bifurcation region of the 3D weaves. This was then used to facilitate an optimisation of the weft yarn configuration to find the reinforcement weaving pattern that was best able to resist failure under tensile pull-off loading.

Initially, flat 3D woven structures were optimised using algorithms from MATLAB's optimisation toolbox, for their resistance to delamination. This was used to investigate both the possibility of using cohesive zone modelling in the T-joint optimisation and the computation time and resources required to carry out optimisation using a more complex function evaluation than had been used previously. This work evaluated several algorithms before determining that the genetic algorithm was the most appropriate based on the time to find an optimum solution and the accuracy. Methods were developed to rule out the large number of

spurious weave designs generated by the optimisation algorithm and to speed up the application of surfaces for the cohesive zone modelling.

Automatically generating the full T-joint model geometry required reading the pattern draft using TexGen's built-in function. From the pattern draft, the information about the interlacement was able to be determined by using the height positions of the weft yarns after the bifurcation and the order in which they were inserted. Subsequently, the wefts were placed so that they nested and replicated the structure of the wefts that was seen in the μCT data which is detailed in the experimental section. A geometry transform was then used to open the weave into the net shape profile of the T.

Using the ability to automatically generate weave patterns, an optimisation run using a genetic algorithm was conducted. To limit the algorithm to produce permutations of the design variables, a method encoding the variables in binary and ranking the resultant strings was implemented. This was used to find the best weft yarn interlacement configuration to optimise the load required to cause initial failure of the composite part. An analysis of the results of this optimisation was able to yield information about which weaving features improve the failure behaviour of the joints under tensile loading.

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