**Abstract**

Composite 3D woven components have been 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 for a textile with 10 weft layers, an exhaustive search of the design space is not possible. To resolve this, 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 had provided a framework to produce these models but were done by-hand using a manual process.

Initially, flat 3D woven structures were optimised to find the best through-thickness properties using algorithms from MATLAB’s optimisation toolbox. Several algorithms were evaluated 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. This resulted in a 94% reduction in run time for function evaluations using periodic boundary conditions when compared to literature values. The reduction in optimisation run time facilitated a novel optimisation of the peak through-thickness load using cohesive zone modelling.

A key outcome was the development of a tool to automatically model T-joint reinforcements using TexGen, the University of Nottingham’s 3D woven textile geometry modelling software. 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. This resulted with a 3D woven composite T-joint with an 8.8% increase in the load at initial failure when compared to a T-joint made using an orthogonal weave with no weft yarn crossover or entanglement. An analysis of the results of this optimisation was able to provide information about how weaving features improve the failure behaviour of the joints under tensile loading.

Acknowledgements

After several years there are some people I would like to thank. First I need to thank my supervisors, Tom Turner, Arthur Jones and Louise Brown. Your patience and guidance over many years are the reasons I have managed to get to this point. I would also like to thank Paul Johns and Liam Woods for their assistance and expertise in the lab keeping me safe and on track. I would also like to take this opportunity to thank the wider Composite Research Group community, in particular Mikhail Matveev, Preetum Mistry, Matt Thompson, Usman Shafique, Ming Xu and Fei Yu along with Albert, Guy, Joe, Grace and Angela for their friendship, wisdom and constructive conversations along the way.

To Harry, you are not just my twin brother but my best friend. Thank you for your patience while I have been working on this, your support has been invaluable, I could not have done this without you. To Phyllida and Evelyn, thanks for believing in me and having my back. To my parents for their love and encouraging me to work hard and supporting me in my education.

More thank-yous go to my closest friends: Eleanor for all the kind encouragement, introducing me to touch rugby and being an all-round great supporter. My life is much better for having you in it. Ellie for all those evening chats, slowly persuading me to aspire to better culinary choices than tuna and ketchup and laughing at my terrible jokes. You are truly a friend for life. Zaki for always being there, you are one of my closest friends, I will always be a Fanan and a friend.

To all the TAFKAP alumni: Poppy, Tom, Zaki, Stefan, Tiago, Ellie and Eleanor, thank you for putting up with my weird food habits and awful puns. I hope I repaid the favour by treating you all to my shower singing. Furthermore, to all those at Nottingham Touch Club, it has helped enormously to have something outside my research work to occupy me and get out of the house. Maybe one day I will also learn how to pass a ball.

Thanks go to the EPSRC for funding me through this work, Sigmatex for providing the weaves and to the University of Nottingham HPC service for advice and providing the compute resources needed.