University of BRISTOL
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Final report: Hierarchical Bundle Composites

New classes of materials are required if we are to mimic natural structures which not only demonstrate high strength but also deform in a non-brittle manner. Nature's hierarchy with combinations of different fibres, matrices and interfaces at different length scales are utilized to create materials like bone, tendon, and plants etc. These natural materials have excellent damage tolerance but are challenging to reproduce synthetically. Exploiting hierarchy in the micro-structure of unidirectional fibre composites to enable progressive tensile failure was investigated through modelling (Figure 1) [1, 2] and through testing small fibre bundles [3].

Currently, continuous fibre reinforced composites fail when a relatively small critical cluster of broken fibres is formed, even if most fibres in the composite are still intact. This process is due to the stochastic variation of strengths of those individual fibres in composites, and to the fact that clusters of broken fibres lead to stress concentrations around their neighbours, causing premature failure of the composite structure. If these weak fibres/bundles can be isolated such that there is a reduction in the likelihood of the nearest neighbour failing when the weak fibre(s) fail, a more progressive global failure may be achieved.

The formation of these hierarchical micro- as well as macro-scale fibre bundles, or bundles-of-bundles from standard tows, is non-trivial and requires a steady hand! The range of fibres in a bundle was varied from 3 to 12 000 through a bottom-up, and top-down approach. An example of 20 carbon fibres is shown in Figure 2. These bundles were tested to validate the model and further work on creating bundles of bundles is on-going. Ideally the process of fabricating these bundles may be carried out at the point of fibre manufacture. This as well as the potential for varying the interface between the bundle-of-bundles, or within the bundles, has an exciting future.

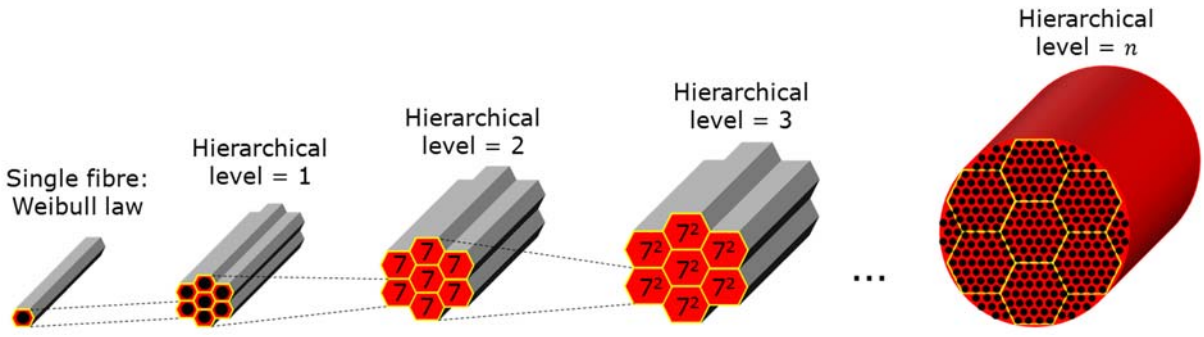

Figure 1. Schematic of hierarchically modelled system shown with a coordination factor of 7.

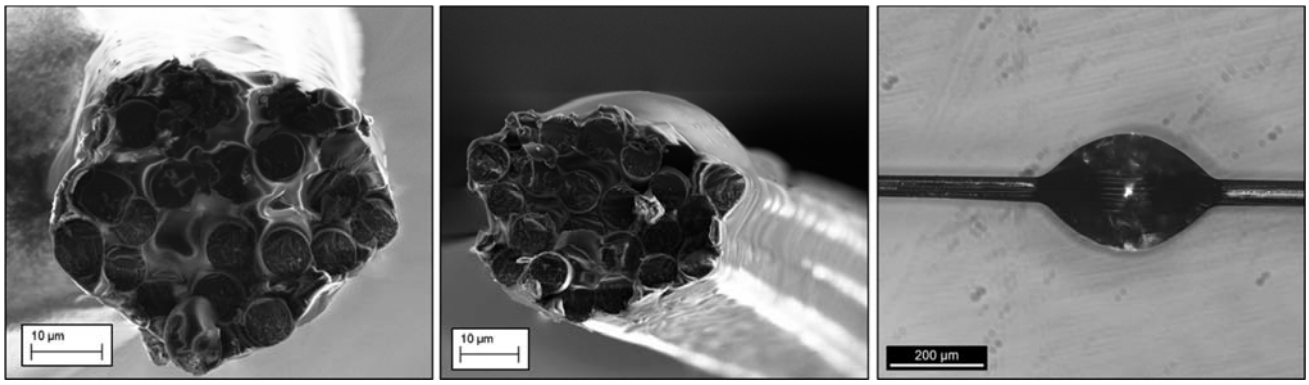

Figure 2. Small composite bundles produced from a bottom-up fabrication route.

References

[1] Grail G, Coq M, Pimenta S, Pinho S T, Robinson P, 2015, Exploring the potetnial of hierachial composite fibre bundles to improve the tensile performace of unideriectional composites, *20th International Conference on Composite Materials (ICCM20)*, Copenhagen, Denmark. Paper ID: 3117-2

[2] Grail G, Coq M, Guesdon C, Pimenta S, Pinho S T, Robinson P, 2016, Combined FE/statistical approach for the strength of composite fibre bundles considering hierarchical failure, *17th European Conference on Composite Materials (ECCM17)*, Munich, Germany. Paper ID: 3.01-03

[3] Anthony D B, Grail G, Bismarck A, Shaffer M SP, Robinson P, Pimenta S, 2016, Exploring the tensile response in small carbon fibre composite bundles *17th European Conference on Composite Materials (ECCM17)*, Munich, Germany. Paper ID: 3.14-04