University of BRISTOL
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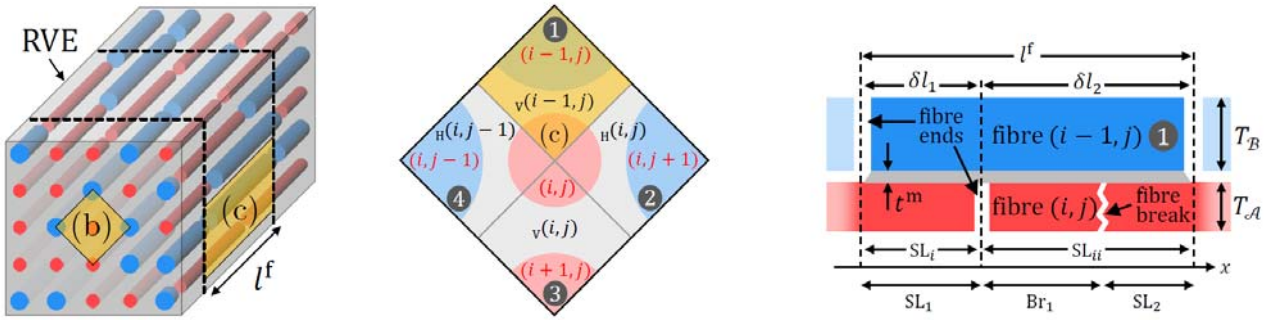
Final report: Modelling discontinuous composites across the scales

A semi-analytical virtual testing framework was developed to predict the response of aligned discontinuous composites with single [1] and hybrid [2-3] fibre-types, as produced by the HiPerDiF manufacturing process.

This framework uses a shear-lag model to predict matrix damage, and Weibull statistics to predict fibre fragmentation; moreover, it uses a non-linear fracture mechanics criterion to identify the location, size and shape of the critical weak region triggering failure of the entire specimen. These models are formulated analytically, and integrated in the numerical simulation of a composite specimen with individual fibres and matrix represented explicitly (see Figure 1).

Due to the combination of analytical and numerical methods, this framework can be used to model full specimens (with millions of fibres) within minutes. The predictions of this framework have been compared against experiments, both for non-hybrid, and hybrid composites (see Figure 2) [1-3]. The virtual testing framework was also used to explore the influence of fibre-type arrangements on the pseudo-ductility of hybrid composites; this work showed that failure can be delayed by promoting the intermingling of different fibre types (see Figure 3) [3]. Moreover, the virtual testing framework can provide further insight on the effect of different sources of variability and defects on the failure process of composites [4].

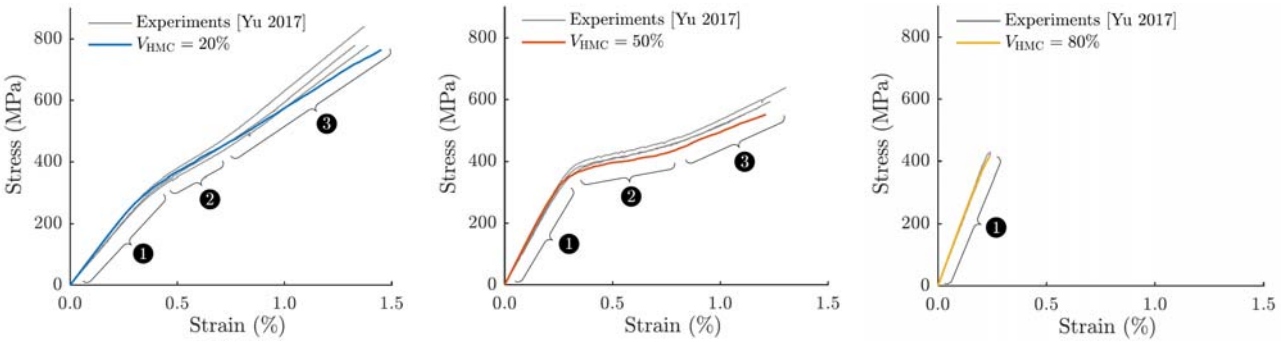


a) Representation of the specimen modelled.

b) Fibre interacting with its 4 nearest neighbours.

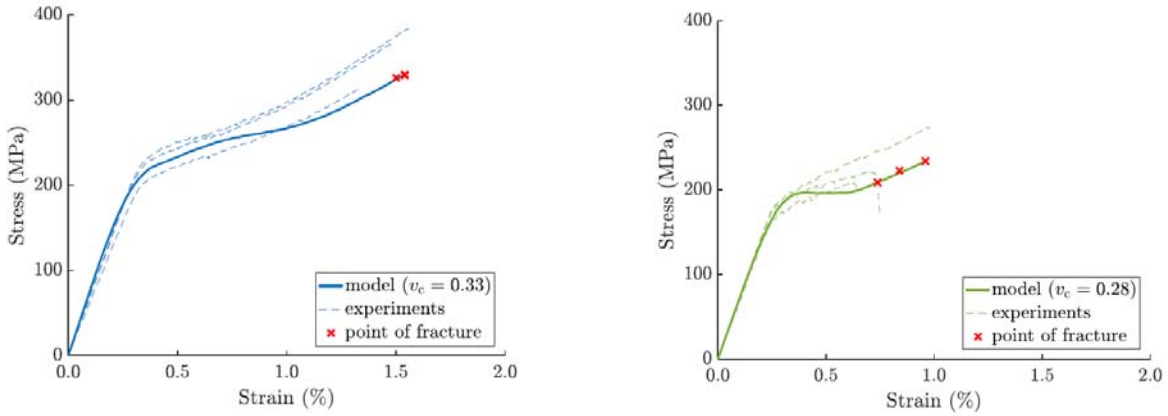
c) Shear-lag elements along the interaction between fibres.

Figure 1. Overview of virtual testing framework for aligned discontinuous composites [2].



d) 20% HMC / 80% glass. e) 50% HMC / 50% glass. f) 80% HMC / 20% glass.

Figure 2. Comparison between model predictions and experimental results, for High-Modulus Carbon (HMC) /Glass hybrids (at different volume rations between HMC and glass) [2].



a) Random intermingling of the two fibre-types within the cross-section.

b) Preferential clustering of HMC fibres at the centre of the cross-section.

Figure 3. Comparison between model predictions and experimental results, for High-Modulus Carbon (HMC) / Glass hybrids (at different volume rations between HMC and glass) [3].

References

[1] Henry J, Pimenta S, "**Semi-analytical simulation of aligned discontinuous composites**", *Compos Sci Technol 144* (2017), 230-244. DOI:10.1016/j.compscitech.2017.01.027.

[2] Henry J, Pimenta S, "**Virtual testing framework for hybrid aligned discontinuous composites**", *Compos Sci Technol* (2017), in press. DOI:10.1016/j.compscitech.2017.12.007.

[3] Finley J, Yu H, Longana ML, Pimenta S, Shaffer MSP, Potter KD, "**Exploring the pseudo-ductility of aligned hybrid discontinuous composites using controlled fibre-type arrangements**", *Composites Part A* (2017), in press. DOI: 10.1016/j.compositesa.2017.11.028.

[4] Pimenta S, Finley J, Henry J, "**The effect of randomness at the micro-scale on failure of composites**", *The 21st International Conference on Composite Materials* (20-25th August 2017), Xi'an, China.