Quantifying fibre reorientation during axial compression of a composite through time-lapse X-ray imaging and individual fibre tracking

The sudden compressive failure of unidirectional (UD) fibre reinforced composites at loads well below their tensile strengths is a cause of practical concern. In this respect and more generally, analytical and numerical models that describe composite behaviour have been hard to verify due to a lack of experimental observation, particularly in 3D. The aim of this paper is to combine fast in-situ X-ray computed tomography (CT) with advanced image analysis to capture the changes in fibre orientation in 3D during uninterrupted progressive loading in compression of a UD glass fibre reinforced polymer (GFRP). By analysing and establishing correspondence between a sequence of time-lapse X-ray CT images of the composite, we are able for the first time to follow each fibre and quantify the progressive deflection that takes place during axial compression in the steps leading up to fibre micro-buckling and kinking. Even at just 25% of the failure load, fibres have started to tilt in approximately the direction of the ultimate kink band. The rate of tilting increases as the composite approaches the collapse load. More generally, our approach can be applied to investigate the behaviour of a wide range of fibrous materials under changing loading conditions.

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