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Investigating 3D fatigue damage progression in fibre composites by combing X-ray tomography with trans-illuminated white light imaging

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Abstract

To make it possible to design lighter and longer wind turbine blades, understanding the underlying mechanisms of fatigue damage progression in the fibre composites used for the blades is vital. The fibre composites used for the parts of the blades carrying the main fatigue loads are usually made from non-crimp fabric based composites, which have a fibre bundle structure. As a result, the damage mechanisms are complex and have been found to appear as local three dimensional (3D) phenomena in the composite [1]. Fig. 1 shows examples of the materials at the bundle and fibre scale along with an example of some damage observed by X-ray computed tomography (CT).

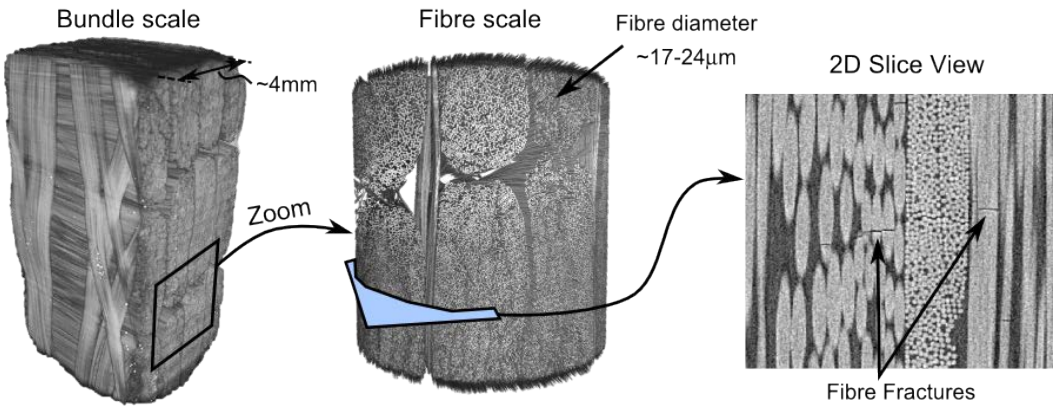

Fig. 1: Hierarchical view of non-crimp fabric based glass fibre composite

Hence, it is necessary to establish methods making it possible to not only observe the damage in 3D but also to monitoring the damage progress. Previously, using an ex-situ X-ray CT approach [2], the progression of individual fibre fractures in the load carrying fibre bundles could be observed. However, due to the limitations of X-ray CT, cracks with small or no openings are not visible in the images. The visibility of such cracks can be improved by applying tension to the specimen while performing X-ray CT to open up cracks. However, it is challenging to apply high loads for several hours of scanning without relaxation affecting the scan quality. Furthermore, some cracks might not become visible even under tension.
As an alternative approach to dealing with the limitations of X-ray CT, the current study combines the ex-situ X-ray CT approach [2] with in-situ trans-illuminated white light imaging to study the fatigue damage progression of fibre composites. By continuously capturing camera images while illuminating the specimen from behind during fatigue testing, off-axis cracks in the thin backing fibre bundles are observed in the considered composite material. By interrupting the fatigue test several times for X-ray CT examination, load carrying fibre fractures are also visualised. The results are analysed both quantitatively and qualitatively. It is confirmed that although not visible in the X-ray CT scans, many off-axis cracks exist early in the fatigue life. The observations provide new knowledge on the damage progression mechanisms, and based on these a 3D damage progression scheme is established.

References

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[2] K. M. Jespersen and L. P. Mikkelsen, “Fatigue damage observed non-destructively in fibre composite coupon test specimens by X-ray CT,” *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 139, p. 12024, 2016.