Fatigue Damage Evolution in Fibre Composites for Wind Turbine Blades

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One of the largest challenges in wind turbine design, is realistically predicting the lifetime of the blades. Wind turbine blades experience a high number of fatigue load cycles during their life-time, and the fatigue damage mechanisms of the non-crimp fabric based glass fibre composites used for the load carrying parts of wind turbine blades are not well understood. This PhD project establishes experimental methods making it possible to monitor the damage initiation and progression of fibre composites in 3D using X-ray CT. To overcome the resolution challenges of X-ray CT, a tension clamp solution that applies load to the specimen during X-ray CT examination is presented, and the advantage of combining X-ray CT with other techniques such as transilluminated white light imaging is demonstrated. The established methods are used to monitor the damage initiation and progression of fatigue damage on the micro-scale in the non-crimp fabric based composites used for wind turbine blades.

The results show that fibre fractures in the unidirectional (UD) load carrying fibre bundles initiate from off-axis cracks in the thin supporting backing fibre bundles. With an increasing number of fatigue load cycles, the UD fibre fractures progress gradually into the thickness direction of the UD fibre bundles, which eventually results in final fracture of the fibre composite. It is also found that the UD fibre fracture regions generally grow larger and initiate earlier at cross-over regions of the backing fibre bundles than at single backing fibre bundle regions. Furthermore, UD Fibre fractures are only observed to initiate at locations where the backing fibre bundles are ‘in contact’ with a UD fibre bundle. By observing the damage progression in 3D, it is also clear that the UD fibre fractures initiated and progressed as local 3D phenomena rather than being homogeneously distributed within the UD fibre bundles. Hence, the results show the importance of considering the problem in 3D.

The knowledge obtained on the fatigue damage mechanisms during the project can not only be used to improve the materials, but also sets the stage for X-ray CT based modelling. This is a step towards more realistic fatigue life-time modelling of fibre composites used for wind turbine blades, which will make it possible to push the design limits of wind turbine blades and thereby decrease the cost of energy for the wind energy production. In addition, the methods established during the PhD project can be applied to other problems, material systems, and load conditions in the future, which opens up for many new opportunities.

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