Fatigue damage evolution in fibre composites for wind turbine blades

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Fatigue damage evolution in fibre composites for wind turbine blades

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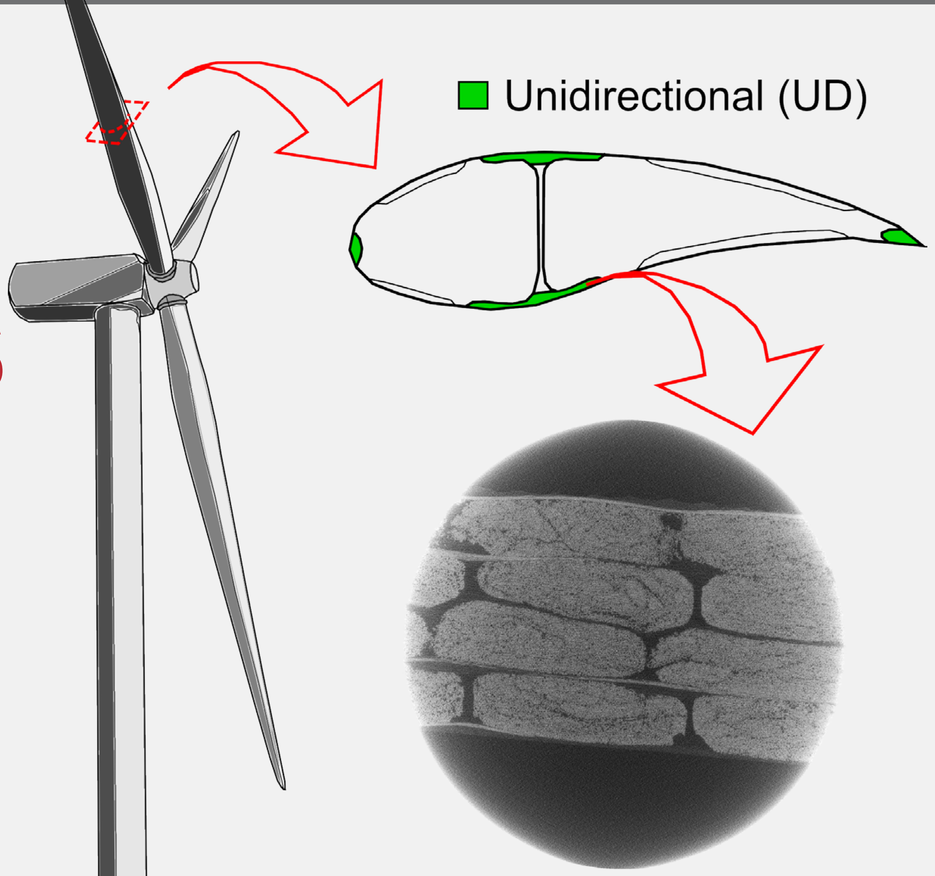
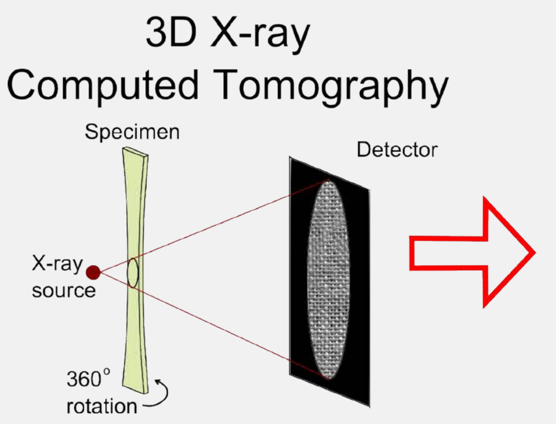
Unidirectional (UD) glass fibre composites are used for wind turbine blades due to their high stiffness to weight ratio. One of the main limiting factors of increasing the blade length is the lack of knowledge on fatigue damage evolution, making it necessary to include high safety factors. This study focuses on fatigue behaviour through 3D X-ray Computed Tomography (CT) experiments and Finite Element Method (FEM) simulations.

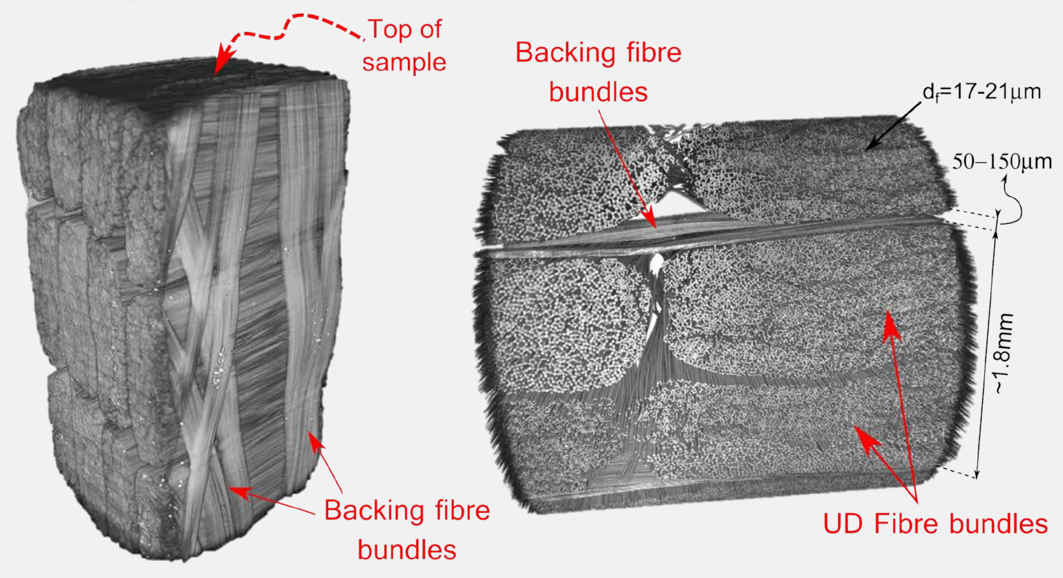


UD glass fibre composite material is used for the load carrying parts of the wind turbine blade considered (marked with green). The glass fibres are gathered in bundles which are held in place by stitching them to a backing layer. The glass fibres are in the range of 17-21 microns in diameter and are surrounded by a polyester resin.

Overall Approach

In this PhD project, 3D X-ray Computed Tomography (CT) is used to observe fatigue damage over time and to characterize the microstructure. The experimental results from the non-destructive X-ray CT experiments are used as a basis for FEM modelling using the commercial software ABAQUS.





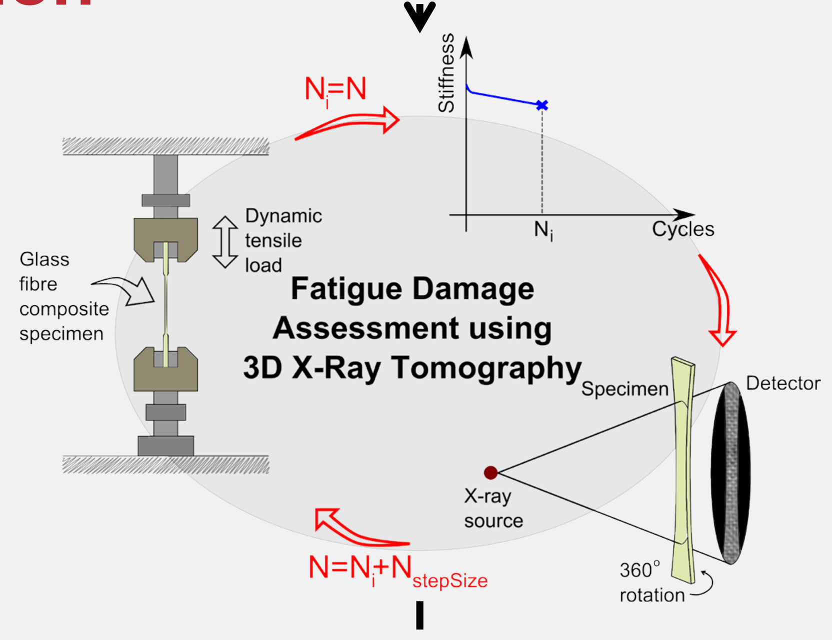
3D X-ray CT

3D X-ray CT is a non-destructive imaging technique where the sample is placed between an x-ray source and a detector and x-rays are emitted through the sample which creates a projection image on the detector. The sample is rotated in steps for each of which a projection image is stored. An algorithm is then used to reconstruct a 3D image from the 2D projection images.

Fatigue Damage Observation

The fatigue damage in the material will be found over time by performing ex-situ start-stop fatigue tests where the sample is scanned using 3D X-ray CT at different time steps during the tension-tension fatigue test.

The damage in the material can be visualized and segmented for each time step.



Quantification of Microstructure

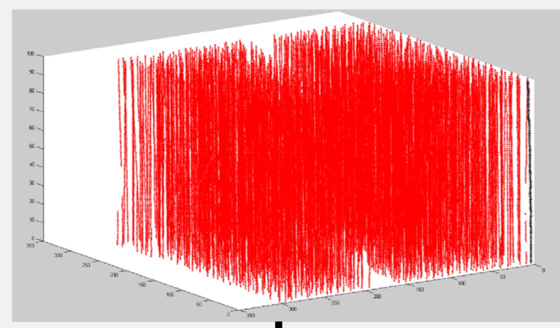
From the 3D image obtained of the microstructure, image processing algorithms are applied to extract microstructural parameters:

- Fibre centre lines by slice by slice coordinates
- Fibre diameters related to each individual fibre

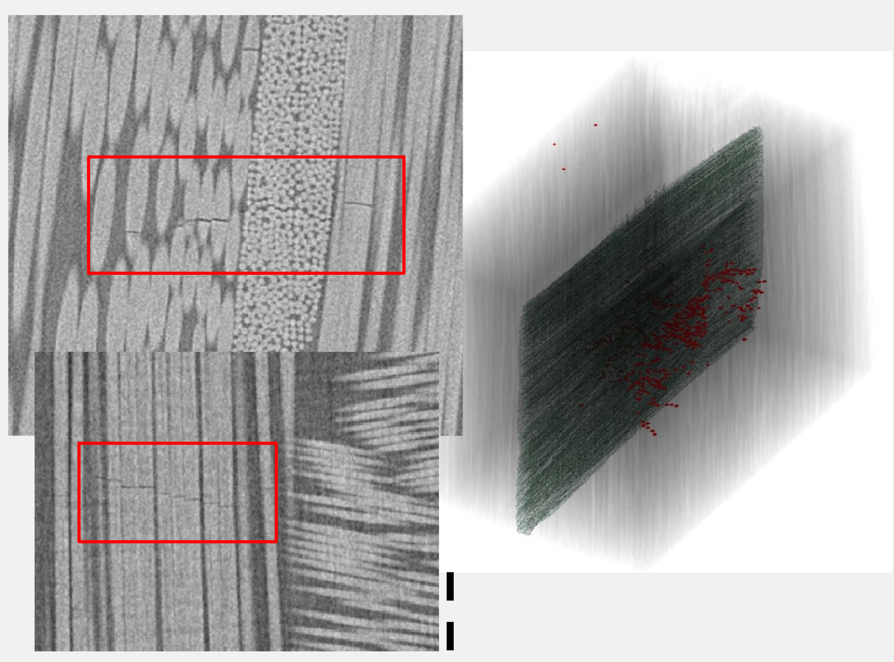
From these parameters, additional parameters will be calculated:

- Fibre misalignment
- Fibre contact point
- Local fibre volume fraction

Fibre centre lines and diameters algorithm



Visualization and Segementaiton of broken fibres

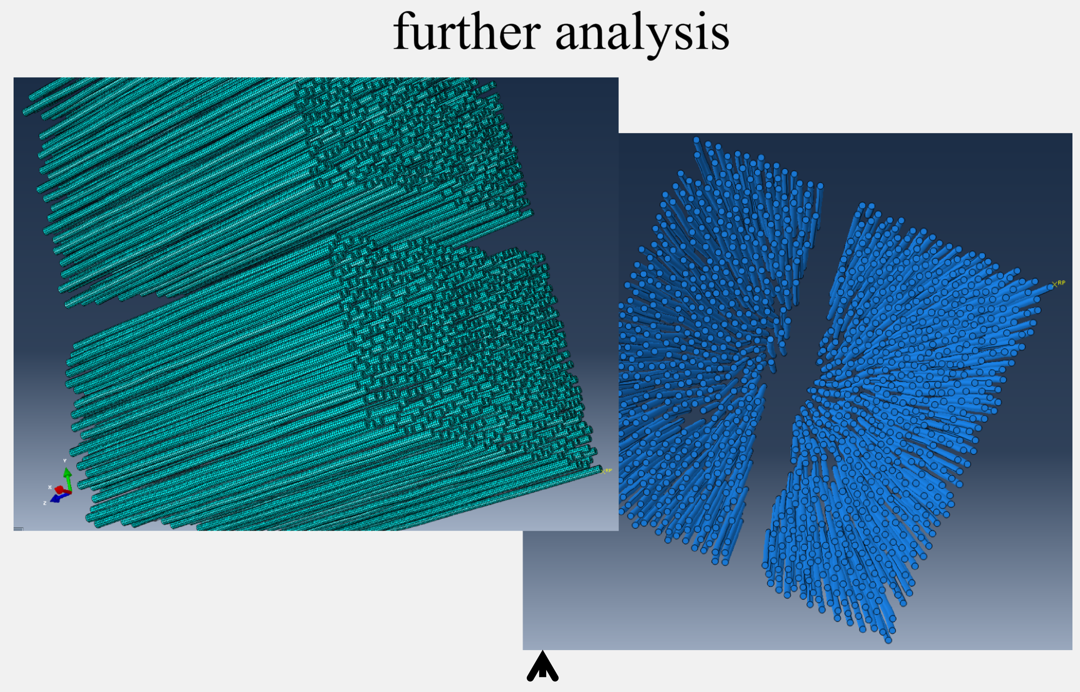


ABAQUS Modelling

The modelling part of this project is still in its initial part, and at this point the fibres can be imported into ABAQUS and meshed. The following is planned to be carried out in the future:

- Introduce fibre fracture into the imported volume and view effect on stiffness etc.
- Include supporting off-axis backing bundles and their local effect on fibre fracture of the load carrying UD fibres
- Use quantified microstructural parameters to generate an equivalent volume on which fatigue properties can be evaluated.

Python script for import into ABAQUS for further analysis



Utilize knowledge to create a realistic FEM model and for validation

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