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Unidirectional Fibre Composite Characterisation from X-ray Tomography

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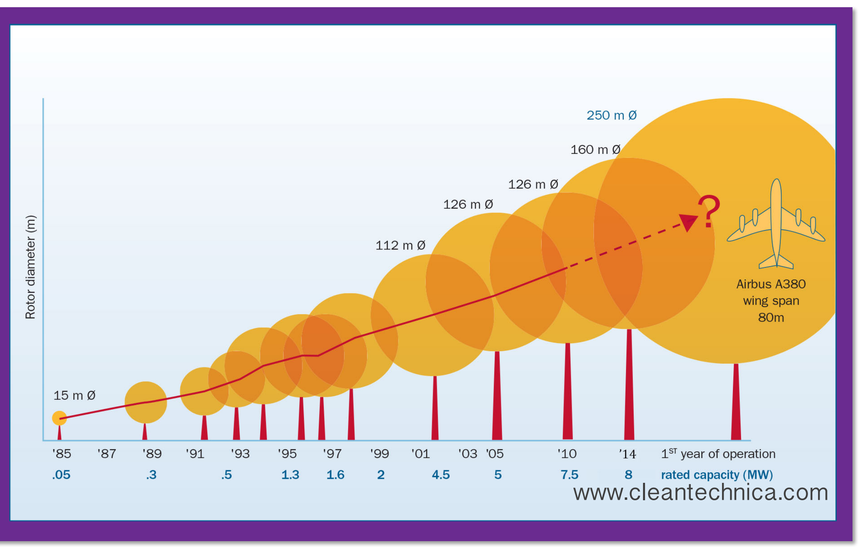
MOTIVATION

Wind turbine blades are becoming **longer** to decrease the **cost of energy**.

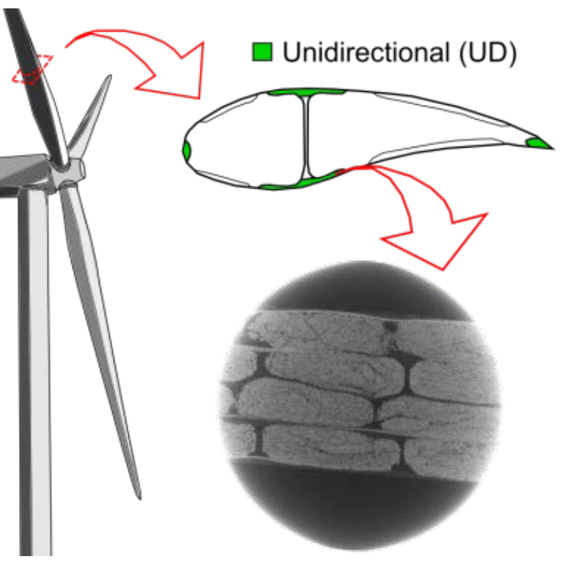
They need to stand higher stresses.



TASK

Extract individual glass/carbon fibres from tomograms of uni-directional composites to study the actual **fibre architecture**, which strongly affects the composite's **static and cyclic performance**. Uni-directional composites are used, for example, as the primary material in the **load bearing parts*** of wind turbine blades.

* green parts in the blade on the right



Multi-scale segmentation

1st step
Bundle segmentation

2nd step
Individual fibre segmentation

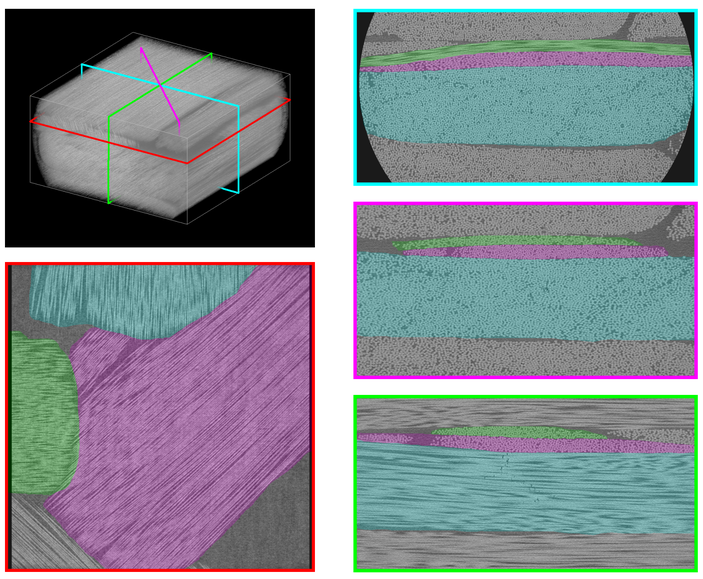
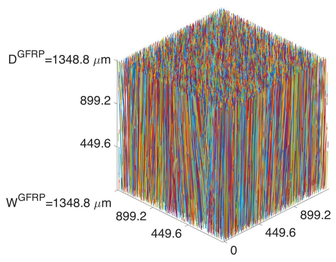
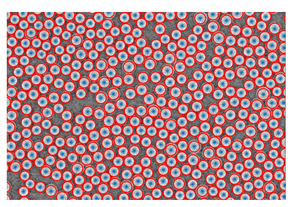


Figure 1: 3D visualization of the volume, with the three cutting planes shown in cyan (0 degrees), magenta (45 degrees) and green (90 degrees). For illustration, a single horizontal slice (red) is also shown.

Fibre trajectories



Diameter estimates



Challenges in fibre trajectory segmentation [1]

1. Composite materials with high fibre volume fraction.
2. Large data sets to obtain representative results.
3. Relatively low quality scans to:
   - Avoid long acquisition times.
   - Perform in-situ compression or tension tests.
   - Obtain a large field of view.
   - Zoom inside large samples for multi-scale imaging.

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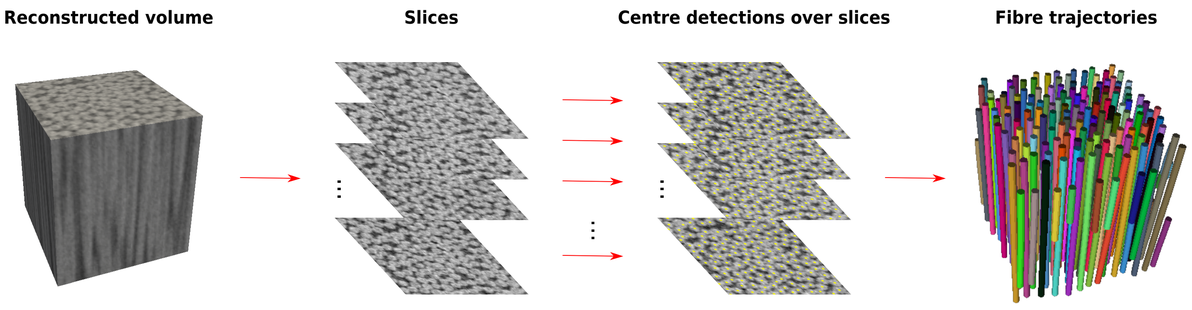
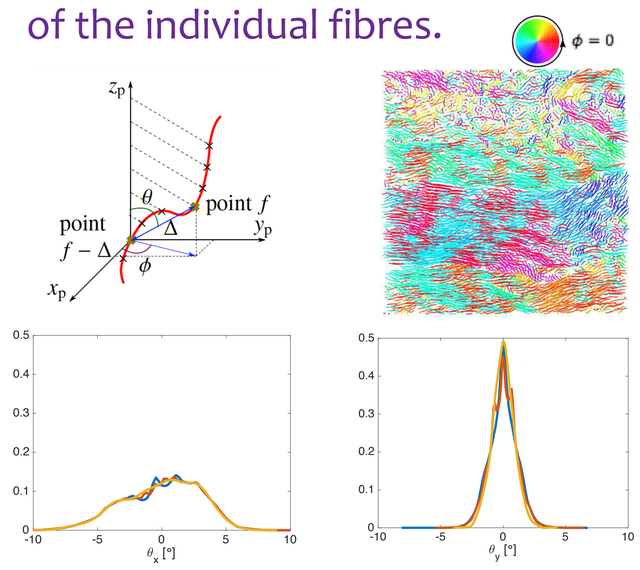
Individual fibre segmentation [1]

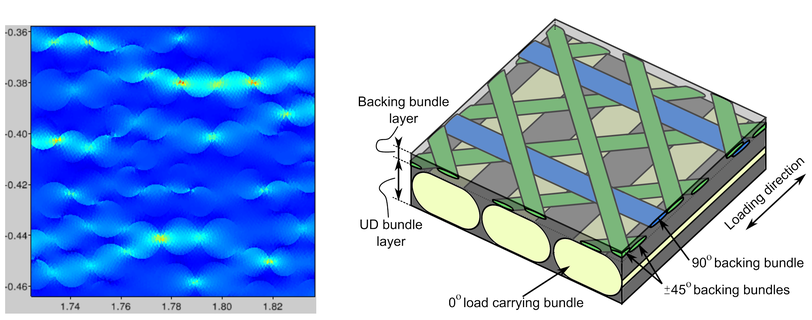


APPLICATIONS

➢ Study the **orientation [1]** and **waviness** of the individual fibres.



➢ Build a micromechanical **finite element model [2].**



(a) (b)

Figure 2: (a) The normal horizontal stress contour plot of a transverse loaded 45º backing bundle and (b) the 3D structure where the resulting constitutive law will be implemented.

➢ Perform a **quantitative analysis** for each fibre bundle

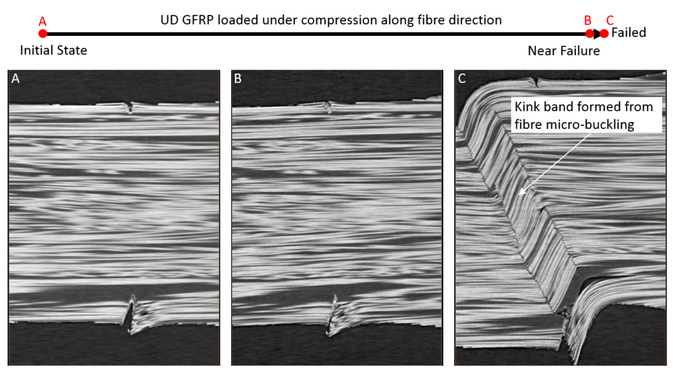
- Number of fibres
- Contact points
- Average diameter per bundle
- Fibre volume fraction
- Tex value [g/km], amount of fibre material per km.

Relating microstructure to behaviour so as to **design high quality composites for better performance.**

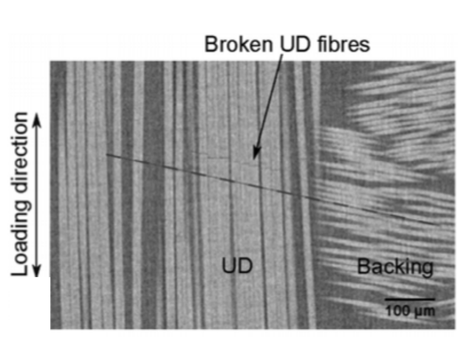
- Fatigue performance
- Tensile strength
- Compression strength
- Stiffness

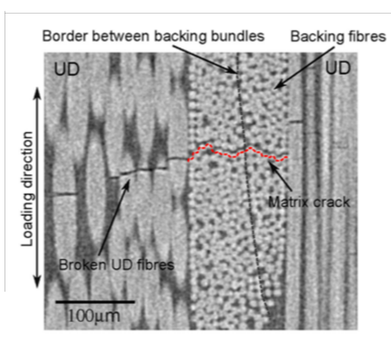
Some **behaviours** to be understood

❖ Kink band formation under compression



❖ Damage/fractures [3]





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[1] Emerson MJ, Jespersen KM, Dahl AB, Conradsen K and Mikkelsen LP. Individual fibre segmentation from 3d X-ray computed tomography for characterising the fibre orientation in unidirectional composite materials. *Composites Part A: Applied Science and Manufacturing* 2017.

[2] Mikkelsen LP, Emerson MJ, Jespersen KM, Dahl VA, Conradsen K and Dahl AB. X-ray based micromechanical finite element modeling of composite materials. *In Proceedings of 29th Nordic Seminar on Computational Mechanics* 2016.

[3] Jespersen KM, Zangenberg J, Lowe T, Withers PJ and Mikkelsen LP. Fatigue damage assessment of uni-directional non-crimp fabric reinforced polyester composite using X-ray computed tomography. *Composites Science and Technology* (2016).