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X-ray computed tomography (CT) is a powerful tool for characterising materials for its ability to reveal their internal structure in a non-destructive manner. The recent advances in X-ray imaging have brought high-resolution X-rays to laboratory sources, making this tool available to a broader public. Additionally, thanks to the developments in ultra-fast X-ray imaging at synchrotron beamlines, it is now possible to capture the very fast structural changes inside materials under realistic working conditions, e.g. in operation or under loading.

There is a need for advanced image analysis methods that can exploit the information contained in these 3D and 4D data-sets of high spatial and temporal resolution, which often contain image artefacts and noise. We have developed a method to characterise the geometry of materials reinforced with long fibres [1], such as glass and carbon fibre reinforced polymers. The method is based on segmenting individual fibres and the task is specially challenging when the image is noisy and its resolution is limited, because the fibres are densely packed. A limited spatial resolution might arise from the need of performing fast scans, to capture the sudden micro-structural changes that happen when reaching the composite's collapse load, and will facilitate scanning large fields of view containing many fibres, necessary to ensure representative characterisations of a material's micro-structure.

Due to the robustness of our method to image quality [2], we have been able to characterise fibre orientations and diameter distributions in complete bundles, relevant for investigating the effect of the design and manufacturing processes on the mechanical properties of the materials. Moreover, we have applied our methodology to study the behaviour of a fibre composite under compressive loading. Following the changes in each individual fibre under progressive loading conditions, and correlating these with the initial structure of the material, can reveal the precursors to the very complex damage mechanisms that affect fibre composites.
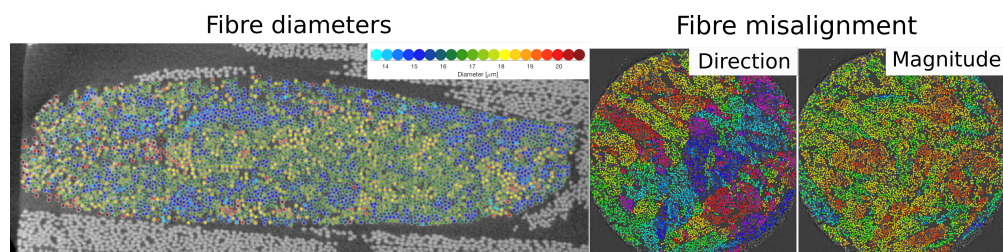

Figure 1: Characterisation of the micro-structure inside UD fibre reinforced composites.

[1] M. J. Emerson, K. M. Jespersen, A. B. Dahl, K. Conradsen, L. P. Mikkelsen, Individual fibre segmentation from 3D X-ray computed tomography for characterising the fibre orientation in unidirectional composite materials. Composites Part A 97 (2017), 83-92.
[2] M. J. Emerson, V.A. Dahl, K. Conradsen, L. P. Mikkelsen, A. B. Dahl, Statistical validation of individual fibre segmentation from tomograms and microscopy, Compos. Sci. and Technol. 160 (2018) 208-215.