## Article Title

X-ray computed tomography and scanning electron microscopy datasets of unidirectional and air textured glass fibre composites.


## Authors

Filip Bo Salling[1*], Jesper H. Hattel[1] and Lars P. Mikkelsen[2*].

## Affiliations

[1]Manufacturing Engineering, DTU Mechanical Engineering, Technical University of Denmark, DK-2800 Lyngby, Denmark.
[2]Composite Mechanics and Structures, DTU Wind Energy, Technical University of Denmark, DK-4000 Roskilde, Denmark.

## Corresponding authors

[*]Filip Bo Salling – fsras@mek.dtu.dk; [*]Lars P. Mikkelsen – lapm@dtu.dk


**Reference to this work**

This small manuscript should be considered as supplementary material to the related research paper [1] to where the reference should be made.


## Abstract

The data presented in this paper consists of four X-ray computed tomography (XCT) datasets of two different material samples: a unidirectional glass fibre reinforced thermoset resin composite (UD-fib) and an air textured glass fiber reinforced thermoset resin composite (air-tex). In addition, two corresponding scanning electron microscopy (SEM) datasets of the material systems are presented.
The XCT datasets is obtained using a Zeiss Xradia 520 Versa laboratory X-ray tomography scanner while the SEM datasets is obtained using a VEGA3 SBU tabletop microscope.
This data formed the basis for individual fibre inclination segmentation and fibre efficiency considerations for longitudinal stiffness as reported in the co-submitted publication.
The data is well-suited for evaluating segmentation methods or for comparative analyses with other composite systems, e.g. for the purpose of evaluating fibre volume fraction, fibre architecture, fibre agglomeration, mechanical properties, etc.



## Keywords

Fibre reinforced polymers; continuous glass fibres; fibre diameter; fibre volume fraction; fibre architecture; fibre inclination; comparative composite systems; comparative characterization techniques.

## Specifications Table

| | |
|---|---|
| **Subject** | Material Science |
| **Specific subject area** | Continuous fibre reinforced polymer (FRP) composites.<br>Fibre orientation characterization. |
| **Type of data** | Image<br>Graph<br>Matlab script |
| **How data were acquired** | Zeiss Xradia 520 Versa laboratory X-ray tomography scanner (XCT).<br>VEGA3 SBU tabletop microscope (SEM).<br><br>Reconstructor Scout-and-Scan version 14.0.14829 |
| **Data format** | Raw data: SEM individual micrographs in ".bmp" format.<br>Processed data: X-ray reconstruction: 3D tomogram in ".txm" format and 2D slices in ".tif" format; SEM stitched micrograph in ".tif" format.<br>Analysed data: ".fig" files of the fibre tracking sorted after overall orientation angels. |
| **Parameters for data collection** | The 3D tomograms were obtained using X-ray CT with an accelerating voltage of 35-45kV with a voxel size of 1.99µm<br>The 2D micrographs were obtained using SEM with an accelerating voltage of 20kV with a pixel-size of 98-169nm |
| **Description of data collection** | Rods with a diameter of Ø5mm were machined from the centre part of pultruded composite material beams.<br>The rod for SEM were embedded and prepared by standard grinding and polishing followed. Subsequently a layer of carbon was applied on the surface using a Bal-Tec SCD 005 Sputter Coater. |
| **Data source location** | DTU Wind Energy, Roskilde, Denmark.<br>Latitude: 55.695343, Longitude: 12.08921 |
| **Data accessibility** | Repository name: Zenodo.org<br>Data identification number: 4484289<br>Direct URL to data: http://doi.org/10.5281/zenodo.4484289 |
| **Related research article** | F.B. Salling, N. Jeppesen, M.R. Sonne, J.H. Hattel and L.P. Mikkelsen, Individual fibre inclination segmentation from X-ray computed tomography using PCA. Submitted. |

## Value of the Data

- The datasets are useful for detailed information about the fiber volume fraction, fiber diameter and fiber architecture.
- The datasets can be used by researchers for comparative analysis of different composite systems as well as different characterization and segmentation techniques.
- The XCT data contain information on fiber undulation, inclination and agglomeration, which can be used to gain further insight in the relation between fiber architecture and mechanical properties.
- The data-sets can be used to develop advanced novel segmentation techniques as reported in [1].
- The data-sets can also be used to evaluate fiber efficiency and mechanical properties.

## Data Description

The data presented in the current paper consist of 4 datasets, i.e. 4 datasets obtained by X-ray Computed Tomography (XCT) and 2 datasets obtained by Scanning Electron Microscopy (SEM). Hence, 3 pairs of dataset which each consist of 1 dataset for a UD glass fibre composite (UD-fib) and 1 dataset for an air textured glass fibre composite (air-tex).

The XCT datasets are obtained with a field of view of 2mm and 4mm where the 2mm case is central location in the 4 mm field of view scan. The reconstructed tomographic volume and tomographic slices are available as ".txm" and ".tif" files, respectively. The XCT datasets of the 2mm case are depicted in Fig. 1 by three orthogonal cross-sectional centre planes and in Fig. 2 where the cross-sectional view orthogonal to the longitudinal fibre direction is depicted together with a cropped version of the centre part to illustrate the resolution. It is the two 2mm field of view scan cases which has been used for the analysis presented in reference [1].

The SEM datasets consist of a stitched image with a field of view of 5mm and the individual micrograph images used for stitching. The stitched overview images are in ".tif" format and the corresponding two sets of individual micrographs used for stitching are in the ".BMP" format. The stitched overview images are depicted together with one of the corresponding individual micrograph images in Fig. 3.

The data-files for each of the material systems (UD-fib and air-tex) are:

- .txm-files: 3D reconstructed x-ray scan files
    - FoV 2mm binning 2 (analyzed in [1])
    - FoV 4mm binning 1 (additional data-set)
- 2Dtif.zip-files: 2D tif-stack version of the 3D reconstructed data-set
- .tif-files: stitched SEM scanning file used for fiber volume fraction determination
- .hdr-files: meta-data ASCII file behind the SEM scan
- tif.zip-files: The individual images behind the stitched SEM scanning file
- fig-files: digital form of the fibre trajectories colored according to their individual mean inclination used in figure xx in reference yy
- m-files: Matlab-script for calculating the fibre volume fraction (Vf) from the SEM image
- mat-files: Mat-file with the segmented part in the SEM image used for the Vf calculation

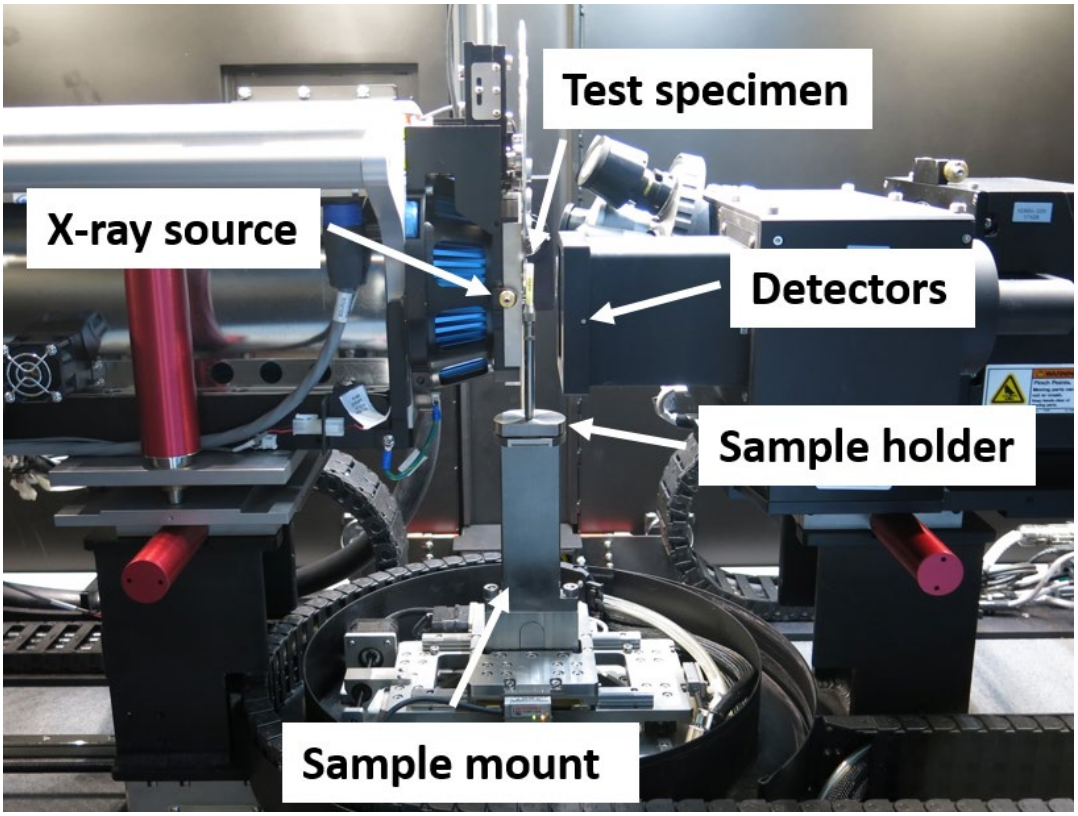


Figure 1: Zeiss Xradia Versa 520 scanner at DTU Risø (Roskilde) with the sample air-tex.

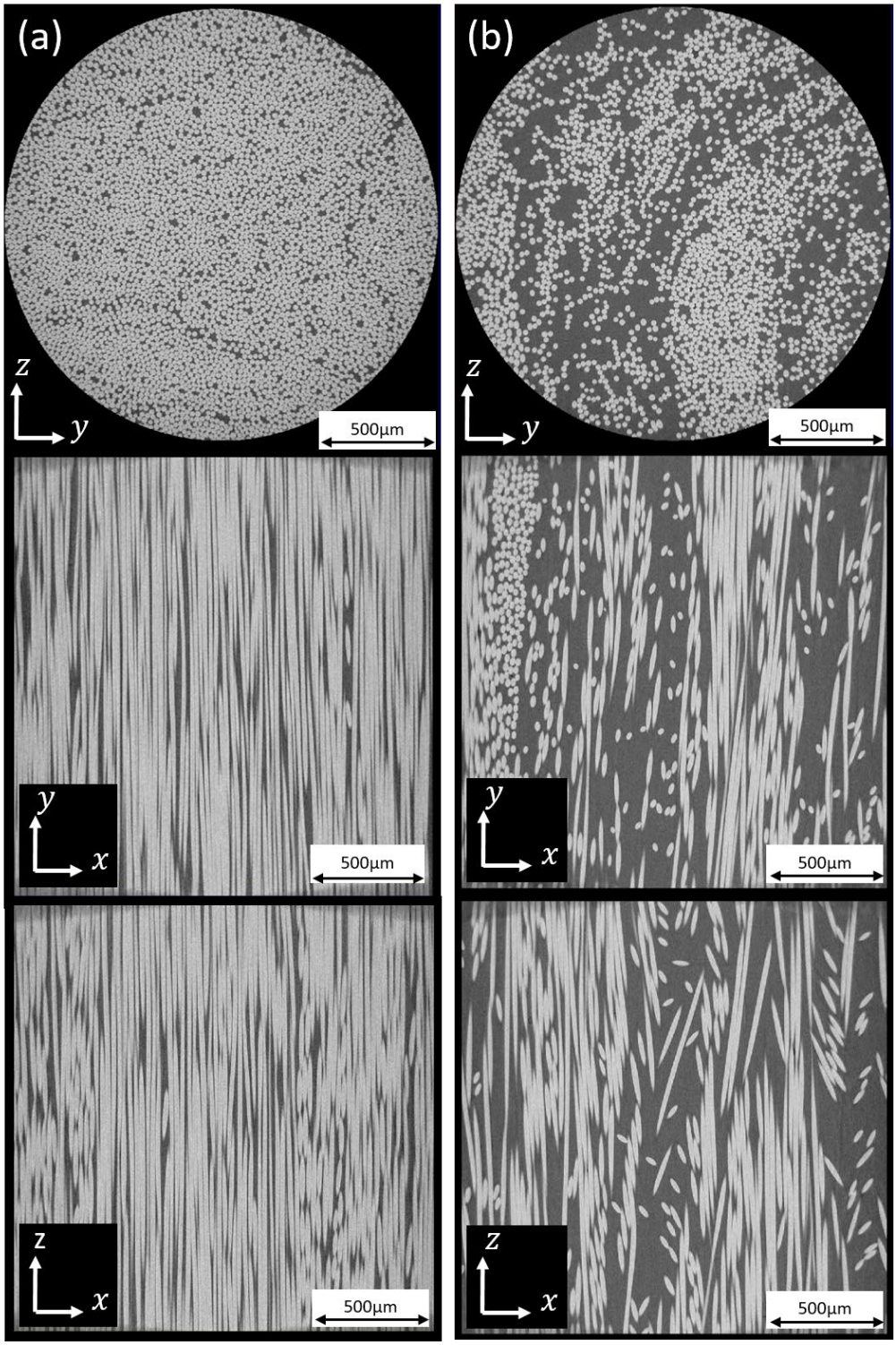


Figure 1: Cross-sectional views of reconstruction from XCT with a voxel size of 1.989µm: a) UD-fib, b) air-tex.

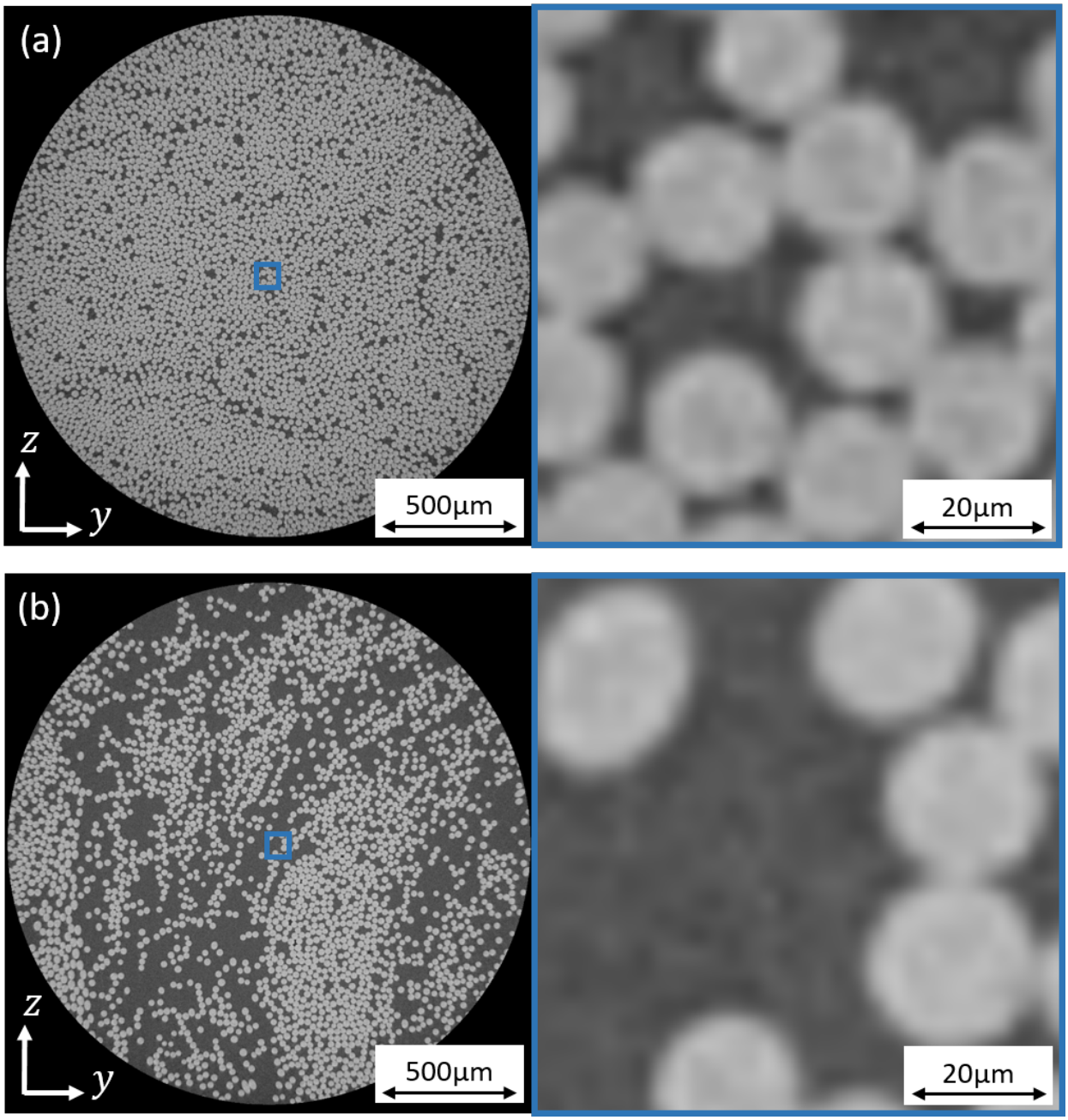

Figure 2: Cross-sectional view of the yz-plane from XCT with a voxel size of 1.989µm (including zoom-in of the blue box): a) UD-fib, b) air-tex.

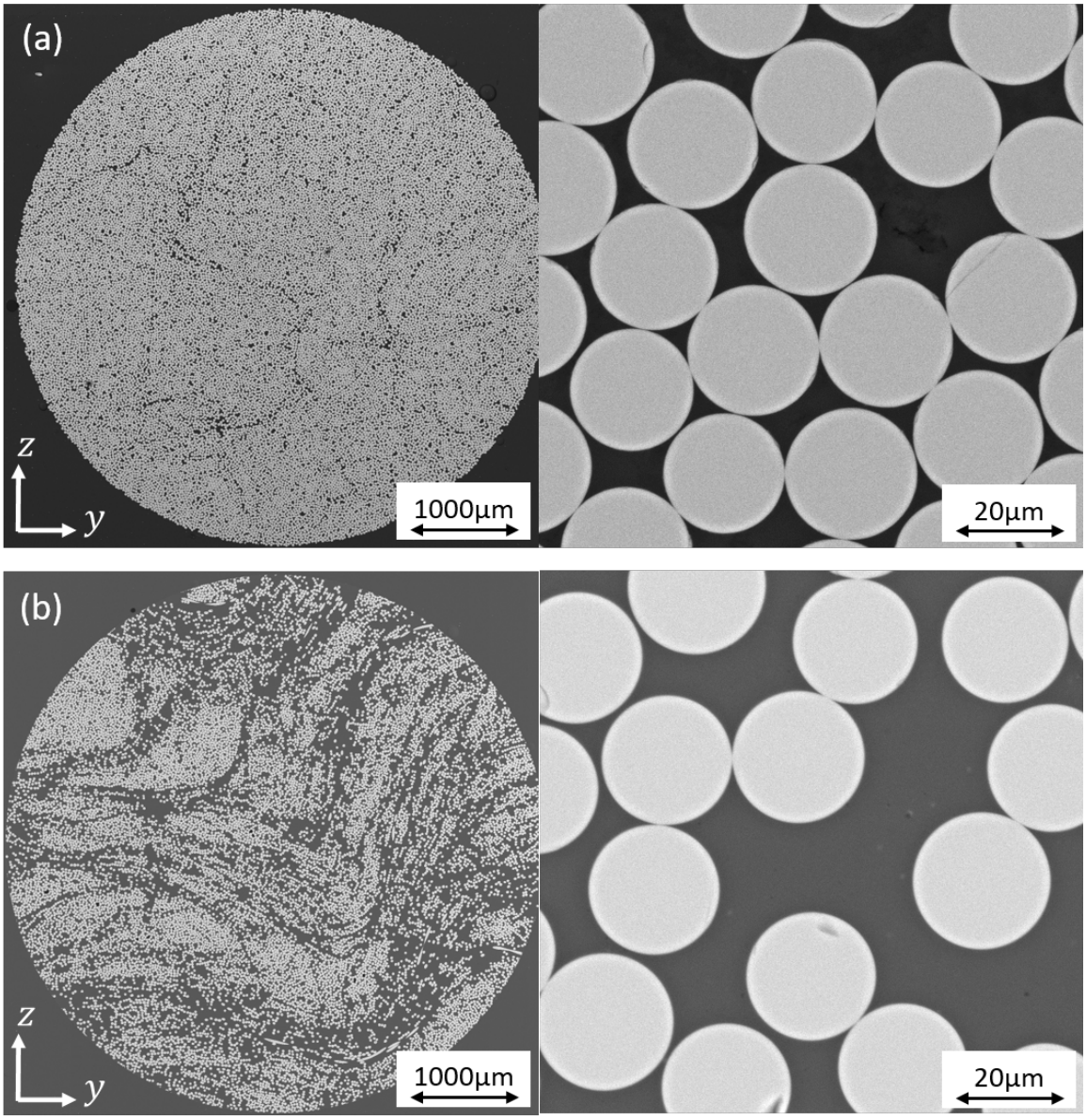

Figure 3: Cross-sectional view from SEM: a) UD-fib, b) air-tex. (cf. Table 2 for pixel size).

## Experimental Design, Materials and Methods

A sample of each of the material systems, i.e. UD-fib and air-tex, have been tomographically scanned using the Zeiss Xradia Varsa 520 scanner with an accelerating voltage of 35-45kV, a power of 2.5-3.5W and 4× optical magnification. The scan was performed using 4501 projections of binning 2 resulting in a $1000^3$ voxels volume with a voxel size of 1.989µm. The X-ray tomography settings are summarized in Table 1.

A sample of each of the material systems, i.e. UD-fib and air-tex, have been investigated by SEM in order to determine the fibre volume fraction. The SEM scan was binarized using an Otsu threshold value. Based on the binarization, fibre volume fractions of $V_f = 0.726$ and $V_f = 0.412$ were found. Figure 4 shows the determinization of the Otsu threshold value and Figure 5 shows the fibre volume fraction determination. The contours show the average fibre volume fraction over a moving square with the size of 5x5 fibre

diameters and the overall fibre volume fraction is found as an average over the total circular scanned area.

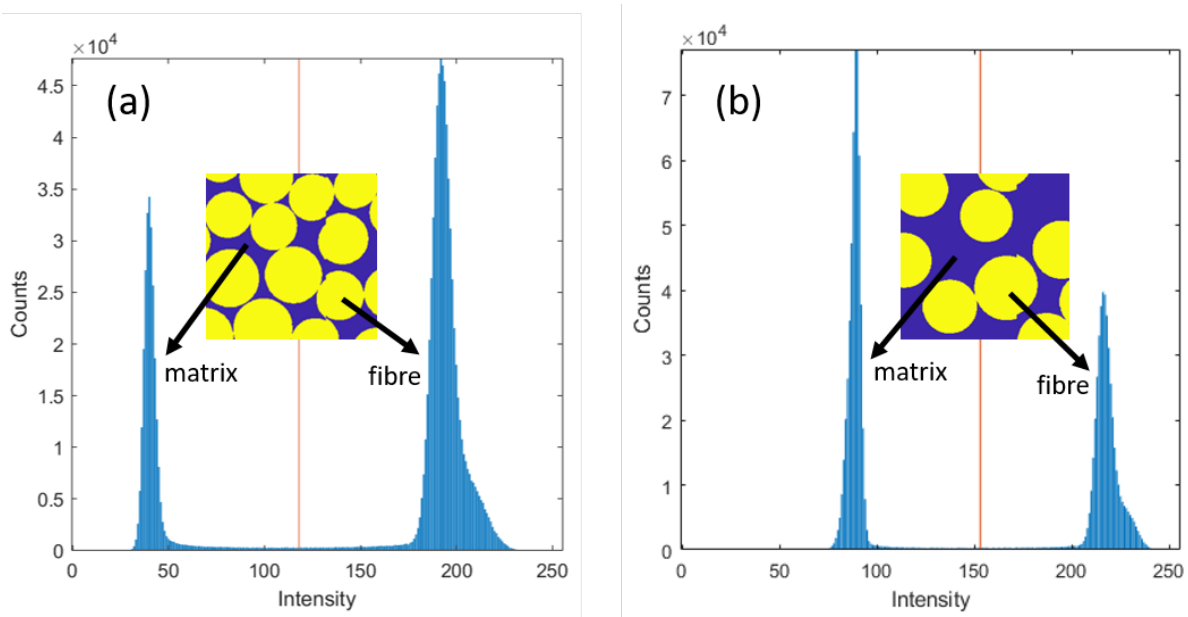


Figure 4: Example of Otsu threshold for: a) UD-fib and b) air-tex.

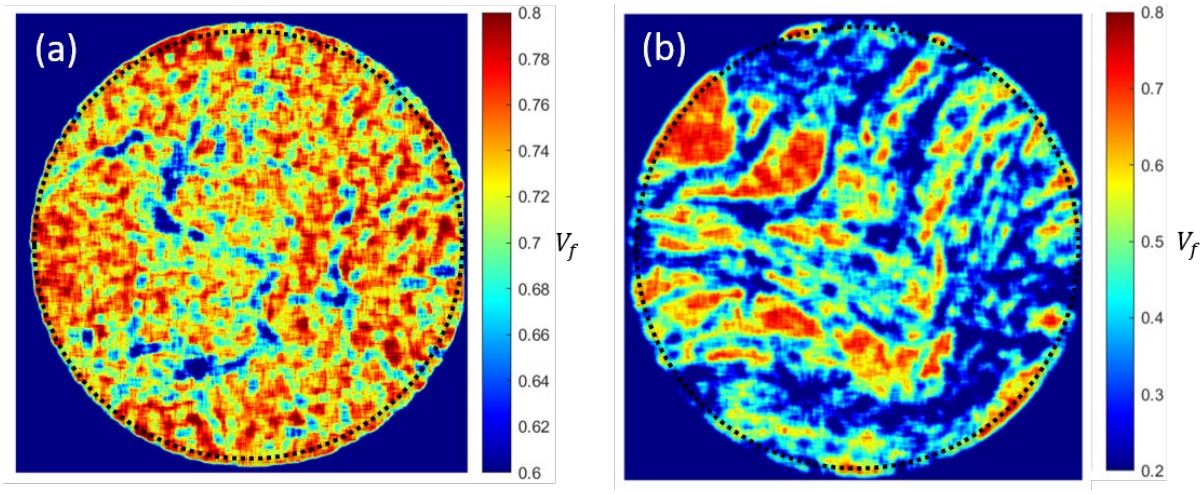


Figure 5: Fiber volume fraction full SEM scanned cross-section of: a) UD-fib with $V_f = 0.726$ and b) air-tex case with $V_f = 0.412$

**Table 1.** X-ray tomography settings.

| Parameter | UD | Mock | UD B1 | Mock B1 |
|---|---|---|---|---|
| FoV (mm) | 2 | 2 | 4 | 4 |
| Optical magnification | 4× | 4× | 4× | 4× |
| Source to sample distance (mm) | 9 | 9 | 9 | 9 |
| Detector to sample distance (mm) | 21.5 | 21.5 | 6.3 | 6.3 |
| Exposure time (s) | 12 | 12 | 11 | 25 |
| Scan time (h) | 17 | 20 | 22 | 35 |
| No. of projections | 4501 | 4501 | 5501 | 4501 |
| Rotations | 360 | 360 | 360 | 360 |
| Accelerating voltage (kV) | 40 | 40 | 45 | 35 |
| Power (w) | 3 | 3 | 3.5 | 2.5 |
| Binning | 2 | 2 | 1 | 1 |
| Source filter | LE4 | LE3 | LE4 | LE3 |
| Reconstruction settings | Default | Default | Default | Default |
| Number of slices | 988x1013x999 | 988x1013x999 | 1984x2030x2016 | 1984x2030x2016 |
| Voxel size ($\mu m$) | 1.989 | 1.989 | 1.980 | 1.980 |

**Table 2.** Scanning electron microscopy settings

| Parameter | UD Sample 2 | Mock Sample 1 |
|---|---|---|
| Pixel size scan [nm] | 97.66 | 97.66 |
| Pixel size stitched [nm] | 165.56 | 168.63 |
| Magnification | 1384 | 1384 |
| Detector | BSE | BSE |
| Acc. voltage [kV] | 20 | 20 |
| Scan speed | 5 | 5 |
| Exposer time [µs/pxl] | 10 | 10 |
| Number of images | 2970 | 3080 |
| Overlap [%] | 10 | 10 |
| Total scan time [h] | 16:55 | 17:26 |
| File size [GB] | 1.724 | 1.722 |

## CRediT author statement

**Filip Bo Salling:** Conceptualization, Methodology, Visualization, Writing – Original Draft, Writing – Review & Editing. **Jesper H. Hattel:** Funding acquisition, Writing - Review & Editing. **Lars P. Mikkelsen:** Conceptualization, Methodology, Visualization, Supervision, Writing - Review & Editing.

## Ethics Statement

This work has not involved any use of human subjects and animal experiments.


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## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships which have or could be perceived to have influenced the work reported in this article.

## References


[1] Salling FB, Jeppesen N, Sonne MR, Hattel JH and Mikkelsen LP 2021. Individual fibre inclination segmentation from X-ray computed tomography using principal component analysis. *Submitted.*