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NEW APPROACH FOR VALIDATING THE SEGMENTATION OF 3D DATA APPLIED TO INDIVIDUAL FIBRE EXTRACTION

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Summary: We present two approaches for validating the segmentation of 3D data. The first approach consists on comparing the amount of estimated material to a value provided by the manufacturer. The second approach consists on comparing the segmented results to those obtained from imaging modalities that provide a better resolution and therefore a more accurate segmentation. The imaging modalities used for comparison are scanning electron microscopy, optical microscopy and synchrotron CT. The validation methods are applied to the asses the segmentation of individual fibres from X-ray microtomograms.

1. INTRODUCTION

The recent development in resolution of 3D scanning techniques has enabled imaging of materials at the nano- and micro-scale. This facilitates the characterisation of their micro-structure, which is strongly related to their performance and lifetime.

The study of unidirectional fibre reinforced composites is imperative, as they are widely used materials, encountered for example in the aeroplane industry or the growing industry of wind power. For a complete characterisation of these composites, they should be studied at different scales. We study the micro-scale, where the individual fibres are distinguishable; and the bundle scale, where we have a reference measure, namely the tex-value.

Micro-computed tomography (μCT) allows for non-destructive 3D imaging of volumes containing many fibres and at different resolutions, permitting not only the segmentation of complete bundles, but also the segmentation of individual fibres; even when the scans are noisy and the fibre volume fraction is high [1, 2].

Segmentation of large data sets can be challenging to validate. Previously, it has been performed by comparing to computerised phantoms [3, 4]. Building these phantoms requires a model of the material's architecture so it is not suitable here, as we are assuming that fibre models are still under development. Other approaches involve estimating physical properties from a segmentation by quantification [2, 3] or by simulation, using a finite element micro-mechanical model built from the segmentation. These estimations can be then validated by comparing to physical properties obtained through other means, e.g. mechanical testing.

The aim of this work is to develop validation tools for methods that extract individual fibre centre lines from tomograms acquired through laboratory X-ray computed tomography (XCT). The validation consists on comparing results to i) those obtained through other imaging modalities (SEM, optical microscopy and synchrotron CT) and to ii) values provided by the fibre manufacturer.

2. VALIDATION METHODS

The data set selected for this study is a glass fibre reinforced polymer manufactured using a filament winding technique. The individual fibres extracted from the XCT scan are defined by a centre line and a constant diameter throughout each fibre.

The first validation method compares the amount of fibre material extracted from the XCT data to the amount of material that the manufacturer reports in the form of a tex-value [g/km]. This is only possible for

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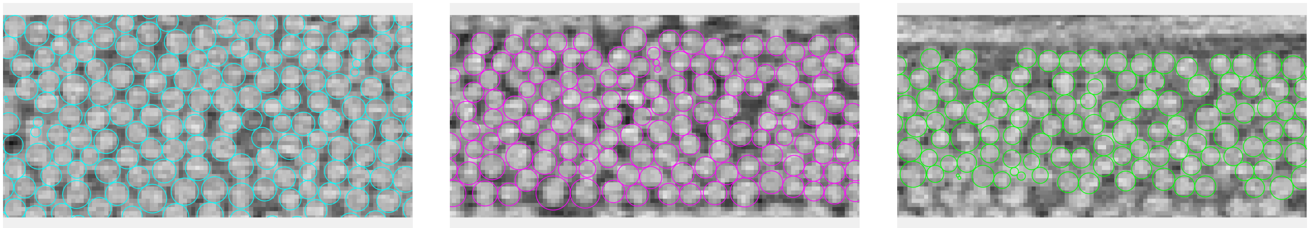
bundles that are complete inside the XCT data, as the tex-value refers to the grams of glass per kilometre inside a complete bundle.

The second proposed approach is a validation across modalities, that can be used regardless of whether bundles are complete in the XCT data. This method consists on comparing the estimations obtained from the XCT data for the diameter of each individual fibre and the total fibre volume fraction inside a region of interest, to the one obtained from the other imaging modalities.

3. RESULTS AND DISCUSSION

Initial results of diameter centre estimation are shown in Figure 1 for fibres contained in three different bundles. This initial study revealed that we were underestimating the amount of material [5], when validating the results by comparing the estimated average diameter for each bundle to the expected value provided by the manufacturer.



(a) **(b)** **(c)**

Figure 1: Diameter estimations for individual fibres contained in three different bundles.

After a visual investigation of the fibre tracks, it was concluded that this was due to i) a lack of precision in the centre estimation, ii) two fibres detected as one and iii) a big fibre detected as two. Although ii) and iii) do not occur very often, it does affect significantly the estimation of the diameters and consequently the predicted average diameter and total amount of fibre material.

Therefore, we are developing improved tracking and centre detection methods which will be demonstrated on XCT data acquired at different resolutions. The accuracy of the individual fibre segmentation will be validated following the approaches described in Section 2.

The strength of the presented validation methods is that the accuracy of the segmentation is assessed directly, ensuring that future estimations of physical properties and/or micro-mechanical models built from the segmentation are precise.

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