GENERATING REPRESENTATIVE VOLUME ELEMENTS OF YARNS WITH NON-CIRCULAR FILAMENTS' CROSS-SECTIONS

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Keywords: *RVE, filament cross-section, filament distribution*

Introduction

Microscopic flow and structural simulations are used for virtual material characterisation. Several well described methods to generate representative volume elements (RVE) of yarns are already published [1] [2]. Most of them are based on the assumption of parallel filaments with circular cross-sections. Structural simulations and steady-state flow simulations with such idealised RVEs show reasonable results [1] [3]. However, yarns with higher yarn counts show a strong deviation from circular cross-sections and mean diameter (cf. fig. 1). To generate realistic RVEs, different new aspects, such as non-circular cross-sections and bundles, are taken into account. The aim of the described approach is to model a RVE that enables the virtual characterisation for filling and forming simulations as accurate as possible.

Geometry characterisation

The filaments' cross-sections are derived from micrographs of non-crimp fabric made out of 50k carbon fibre yarns (cf. fig. 1). The variance of these cross-sections' contours can be observed. The filaments' cross-sections vary from circular to bean similar shapes.

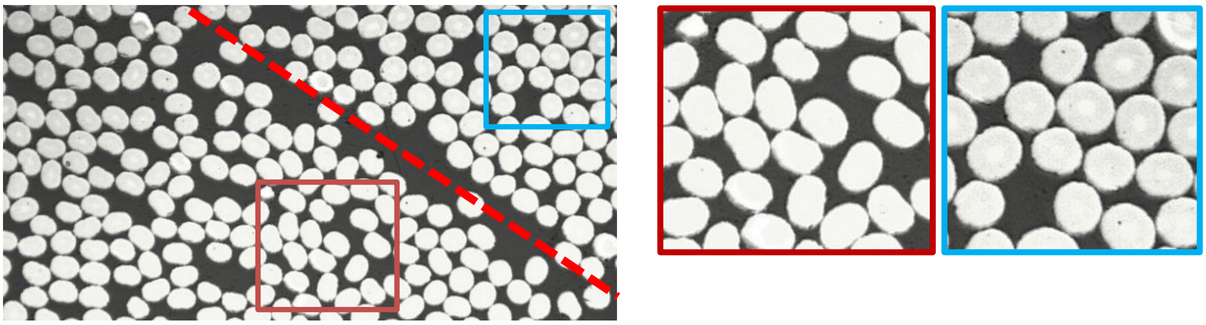

Figure 1: *Micrograph of a 50k carbon fibre yarn (left) with line of demarcation (dashed line) and enlargement of specific areas (right);* red: *bean similar shaped fibres;* blue: *variation in filaments' diameters.*

The filaments' cross-sections are automatically evaluated by an image processing software to determine the mean diameter and the form factor of each filament. The form factor describes the grade of similarity to a circle. A circle has a form factor of 1.

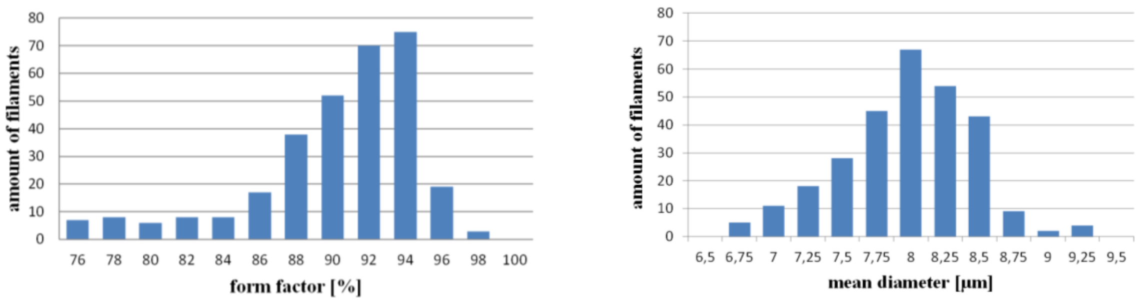

Figure 2: *Distribution of the filaments' characteristic parameters, form factor and mean diameter.*

In figure 2 the distributions of these parameters are shown. It can be seen, that there are no ideal circular filaments in the considered micrographs.

Representative filaments' cross-sections

To generate representative filament cross-sections (RFC), a method was developed to create filaments' cross-sections based on the form factor and the mean radius. The artificial cross-section is based on an ellipse, where one part of the outline is replaced by a spline. The grade of spline's deviation of the ellipse as well as the shape of the ellipse is calculated based on the form factor. The size of the cross-section is defined by the mean radius. Although the form factor is not normally distributed (cf. fig. 2), both parameters are randomly set to normally distributed values.

Based on the determined parameters shown in figure 2, a number of RFCs is shown in fig. 3. Additional to the RFC, the geometries are rotated by randomly set angles. To have a better impression of the non-circular cross-sections, the mean radius is set constant.

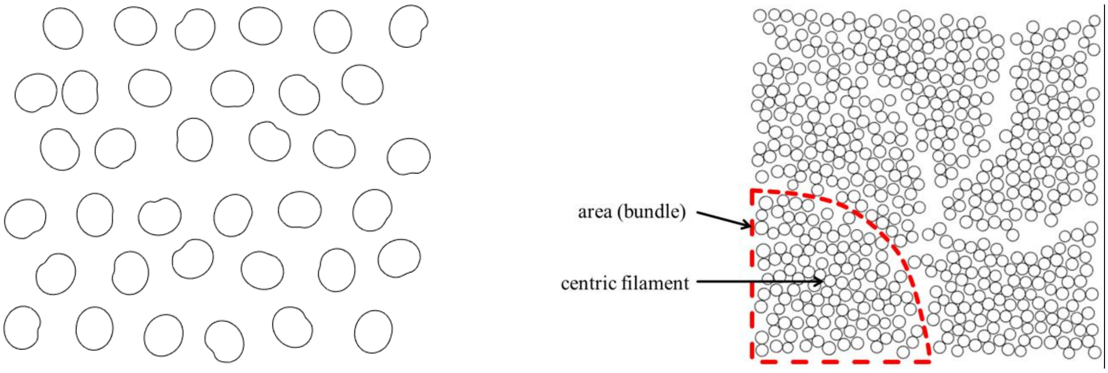

Figure 3: *Stochastically generated filaments' cross-sections (left) and two-dimensional RVE with bundles (right).*

Representative filament distribution

The evaluation of micrographs shows lines of demarcation between the filaments (cf. fig. 1). The absence of strongly elliptic cross-section in that area leads to the assumption that the filaments on both sides of the line of the demarcation have different mean fibre orientations. This circumstance has to be taken into account for the generation of the RVE. Therefore, a two staged approach for the two-dimensional RVE is chosen. In the first stage the approach of Wongsto et al. [1] with additional normally distributed maximum filaments' diameters is chosen. In a second step the filaments are locally compacted to bundles. For this purpose the RVE is separated to randomly picked areas and the filament closest to the centre of gravity of each area is determined. Then all fibres of each area are moved approximately in the direction towards the centric filament with a randomly picked distance.

Outlook

In the ongoing work the two-dimensional RVE tool will be extended to a three-dimensional RVE tool. In difference to existing three-dimensional approaches the RVE will have a global fibre angle distribution and a local angle distribution in the bundles which will be less than the global one. Additionally the filaments will be slightly bent to meet the conditions in a real yarn. The necessary parameters will be derived from µCT images.

Subsequently, the RVEs will be used for virtual characterisation of filling and forming simulations.

Acknowledgements

We would like to acknowledge the federal state of Baden-Württemberg for funding this work.

References

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