COMPUTATION OF PERMEABILITY OF A NON-CRIMP CARBON TEXTILE REINFORCEMENT BASED ON X-RAY COMPUTED TOMOGRAPHY IMAGES

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Introduction

The paper presents the results on the determination of permeability of a non-crimp carbon textile reinforcement based on μCT images. The computation of permeability is done using simulations of the fluid dynamics with voxel models. The voxel models are constructed from the μCT images of the material samples using a statistical algorithm for image segmentation, based on the Gaussian mixture model. The method is architecture independent and allows studying variability of permeability for different unit cells of the textile.

Experimental

The material used in the study is a non-crimp carbon/epoxy composite from Saertex (540 g/m^2, +45/-45, franse stitch). The manufactured test plate had a thickness of 4.0 mm and a resulting fibre volume fraction of 45.5%. The data on the permeability of the studied NCF reinforcement is presented in [1]: at a fibre volume fraction of 50.8% the saturated permeability was measured as 0.5×10^{-4} mm^2 (in the 45° direction to the production direction). Based on linear fit of the fibre volume fraction – log (permeability) dependencies presented in [2] for non-crimp fabrics, similar to the one studied here, the permeability at fibre volume fraction of 45.5% can be estimated as $(1\ldots2)\times10^{-4}$ mm^2. Three samples of different size were cut from the plate and scanned with a Nanotom X-ray computed tomography system (General Electrics). The total number of unit cells in the scanned samples is 27.

Construction of voxel models and permeability computation

In order to construct voxel models, the micro-CT images of the material samples were segmented using a method proposed in [3]. The segmentation is based on two feature variables calculated from the image: average grey value and structural anisotropy. The structural anisotropy is calculated based on the structure tensor [4]. Based on the two variables, a statistical Gaussian mixture model is constructed, which consists of a set of two-dimensional Gaussian distributions for each component of the model (fluid/solid). The voxel model is constructed through classifying each voxel of the model to one of the components, based on the maximum probability, where the probabilities are calculated from the statistical model and the values of the feature variables at each voxel. Permeability calculations were performed with FlowTex software [5], developed at KU Leuven in collaboration with the Institute for Numerical Simulation at the University of Bonn.

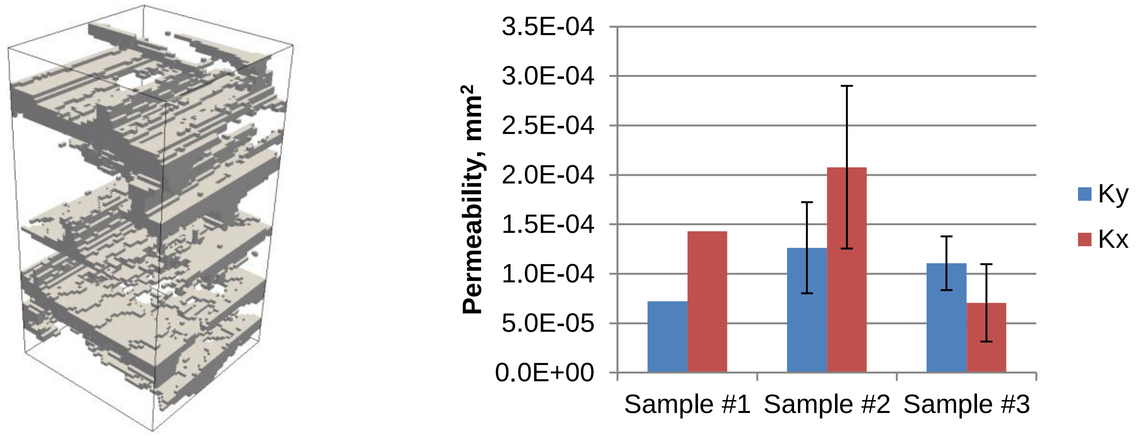

Figure 1: *A voxel model of a unit cell in the non-crimp carbon preform (left); and the predicted permeability values for the three studied samples (right).*

Results

The permeability varies quite significantly across the unit cells, in the range of $(0.5 \ldots 3.5)\times 10^{-4}$ mm^2, which is however in a good agreement with the experimental data ($1.0 \ldots 2.0\times 10^{-4}$ mm^2). Figure 1 shows average values of predicted permeability over the unit cells in the samples. Analysis of the correlation of permeability with the solid volume fraction in the unit cell models showed a significant negative correlation, i.e. permeability is lower with a higher solid volume fraction.

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