8th. World Congress on Computational Mechanics (WCCM8)
5th. European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 – July 5, 2008
Venice, Italy

3D IMAGE-BASED MODELLING OF A CARBON/CARBON COMPOSITE

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Key Words: *image-based modelling, finite element method, carbon-carbon composite.*

ABSTRACT

Image-based modelling allows bulk property prediction for materials with a complex and irregular microstructure. The image-based modelling approach considered here, uses 3D image data obtained by X-ray microtomography (XMT), which is converted into a finite element mesh for analysis.

The main challenges are 1) to image a representative volume at a high enough resolution, so that all features of the material are captured and 2) differentiating material phases that have similar densities and give indistinguishable image intensities. In this study it is examined if, and how, low-resolution image data of a specific carbon/carbon composite, NB-31, can be used for image-based modelling. The composite has a complex 3D structure with layers of unifilament fibres and 2D woven fibres, reinforced by needled fibres [1, 2].

A cylindrical specimen (5mm height, 10mm radius) of NB-31 is scanned with a resolution of 15µm, which is the highest possible resolution for the specimen size that the used XMT machine allows. Individual fibre diameters are smaller than this, and fibres have a density similar to that of the matrix, so fibres can neither be located nor differentiated.

A custom image segmentation algorithm is developed to differentiate layers of unifilament fibres and layers of 2D woven fibres, by exploiting the distribution of porosity in this composite material. Needled fibres are ignored. The algorithm compromises four steps:

1) Calculate porosity mask using thresholding of grey level values
2) For each non-porosity voxel calculate distance along z-axis to next porosity voxel
3) Segment regions by using the results from the previous step
4) Apply median filter to smooth mask

With these segmentation masks, finite element meshes are then created using a commercial software package [4]. A number of meshes with between 10 million and 175 million elements are generated, representing physical volumes between $7mm^3$ and $108mm^3$. Both smoothed and unsmoothed meshes are evaluated.

A series of steady state heat transfer analyses are carried out to calculate the bulk thermal conductivity of NB-31 with Fourier's law. Material properties for the two layers are calculated by analytical methods, e.g. the rule of mixtures, from properties of the constituent materials found in literature [3]. To cope with the large number of elements the simulations are performed with a parallel finite element library, ParaFEM [5-7].

Results compare well to bulk properties of NB-31 published in literature [8]. Nonetheless, to fully make use of the possibilities offered by image-based modelling, a full representation of material structure is required. For composite materials this would include the individual fibres, or at least fibre tows, and would then pose the challenge to 1) accurately distinguish fibres / fibre tows from each other, especially in woven structures and 2) automatically determine and assign material orientations, e.g. for orthotropic fibres or fibre tows.

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