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MICROSTRUCTURAL ANALYSIS OF MATERIALS WITH COMPLEX ARCHITECTURES

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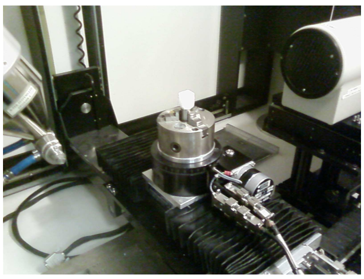
ABSTRACT

There is a current trend for the development of new materials for engineering and industrial applications. Many of these materials comprise a mixture of two or more simple ingredients, which when combined lead to a more complex material that has improved features, for example low density, high stiffness or better thermal conductivity. Due to the complexity of the architecture, material characterisation using standard computational mechanics techniques may not be straightforward for some of these materials. Simplified models may not adequately represent the behaviour that comes from the microstructure [1]. Nowadays, cheap parallel computing permits the analysis of very large models (hundreds of millions of equations). The authors suggest that this removes the traditional need to create a simplified model that will run in a reasonable time on a single PC or workstation. In this paper the authors present a technique for the characterisation of materials with complex architectures. Two examples are given, (1) an open celled aluminium foam subjected to a compression test in order to determine the Young's Modulus of the architecture and (2) a ceramic matrix composite studied to determine its bulk thermal properties.

Methodology

The FE mesh is generated according to the following 3-step process: Firstly a sample of material is scanned using an X-ray microtomography machine (figure 1 left).



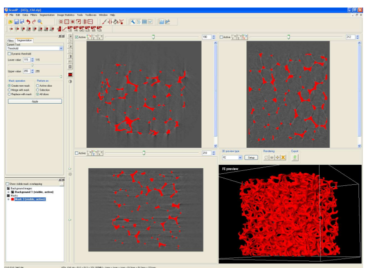


Figure 1: *X-ray microtomography* (*left*) *and FE mesh generation software* (*right*).

Secondly, a commercial software package (*Tomohawk*) is used to reconstruct a 3D voxel based image from the X-ray scans. Finally another software package (here from *Simpleware Ltd.*) is used to generate the FE mesh from the reconstructed image data (figure 1 right). The analysis is carried out using a parallel FE program that has been built using the building block routines from ParaFEM [2, 3] and the Smith and Griffiths text [4]. The libraries have been extended by the authors to include a large scale deformation capability and material anisotropy. The performance has been proved on HPCx, one of the UK's National Supercomputers. For example, the linear elastic solution of a model comprising 4 million equations is reached in 2 seconds when using 1,024 processors on that machine.

Results

A simulated standard compression test has been used to determine Young's modulus for an open celled aluminium foam. A mesh sensitivity analysis was carried out using a range of mesh sizes, from ones small enough to run on a PC to those that required supercomputing facilities. It was found that the smaller meshes running on a PC overestimated Young's modulus by around 20 %. A value of 179 MPa was obtained using a mesh with 77 million elements (figure 2 left). A second problem looked at heat transfer in a unit cell of a Silicon/Carbon composite using a mesh comprising over 2 million elements. Figure 2 (right) shows the heat flux, where the anisotropy can be clearly noticed. The objective of the analysis was to compute the global conductivity and a value of 14.4 W/mK was obtained.

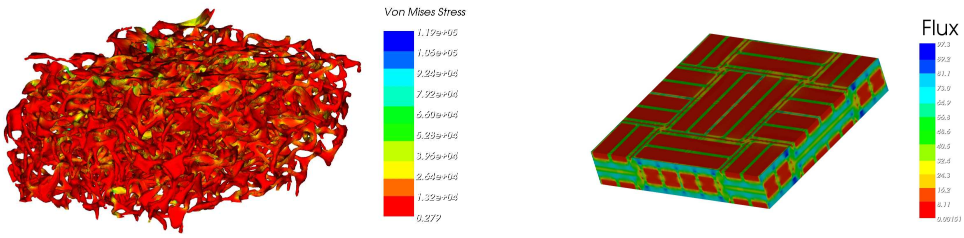


Figure 2: *Aluminium foam* (*left*) *and Silicon Carbon composite* (*right*).

Conclusions

The work demonstrates that image based modelling can be carried out routinely for materials with complex architectures. Large FE models can be generated directly from physical samples using micro-tomography techniques and solved using a computer with multiple processors.

Acknowledgements

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