MECHANICAL CHARACTERISATION OF SCAFFOLDS

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INTRODUCTION

Recent development of high resolution imaging modalities such as Micro-CT allow realistic porous structures to be straightforwardly and accurately scanned with sub-micron image resolutions possible on some commercially available systems. Combined with novel meshing techniques, these imaging techniques allow for robust and rapid conversion of the 3D scan data into finite element and finite volume meshes which can straightforwardly be used to characterize the response. In addition, various image processing tools allow for interesting sensitivity analyses to be carried out helping to elucidate relationships between key architectural parameters, such as rib thickness and bulk properties. A number of studies demonstrating the ease with which fidelic models of the complex micro-architectures of bio-scaffolds can be generated will be presented.

DATA ACQUISITION

A porous hydroxyapatite/tricalcium phosphate (HA/TCP) bone scaffold manufactured at the University of Bath [1], shown in Figure 1, was studied. The manufacturing process consists broadly of coating a polyethylene open celled foam in hydroxyapatite and sintering the foam using the dipping method [2]. 3D image scanning was performed using the Sky-Scan1174 compact micro-CT. For the specific case a magnification of 18 µm and an exposure time of 4350 ms have been selected.

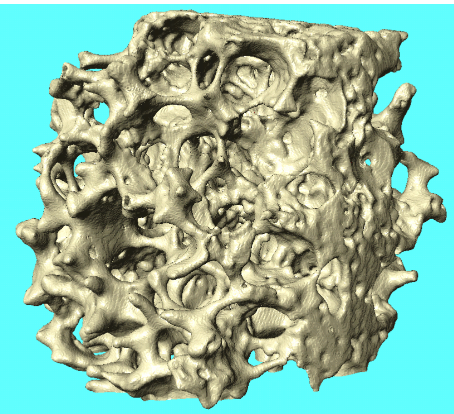

Figure 1: (HA/TCP) bone scaffold 3D reconstruction from micro-CT data in ScanIP (Simpleware) of 3D scan.

SEGMENTATION AND MESHING

Resultant image files were imported into ScanIP (Simpleware Ltd., Exeter, UK) and thresholded, re-sampled and rescaled to preserve the original size. An image of the model generated in ScanIP is presented in Figure 1. The relative density computed is $\Phi = 24.7$ %. The model was imported into +ScanFE (Simpleware Ltd., Exeter, UK) and a mesh of both HA and the void domains inside the struts was generated, consisting of 4,464,293 linear tetrahedral elements and 992,000 nodes was generated. The meshing scheme was automated and robust with no need for correcting for pathological or poor quality elements. The voids were used to measure the internal porosity related to the manufacturing process, and the HA mesh was used to establish bulk stiffness and to explore the influence of the microstructure on the strength of the structure [3].

MECHANICAL CHARACTERISATION

The finite element analysis was run using Abaqus/Standard (Dassault Systèmes Simulia Corp., Providence, RI, USA) within the framework of the small displacement theory. The response to the static displacement was of interest in order to understand how the microscructure influences the mechanical property of the scaffold. The effective Young's Modulus of the structure computed $E^* = 0.49$ GPa is over eighty times lower than the Young's modulus of the parent Hydroxyapatite (40 GPa). Although the effective density of the scaffold is only slightly less than a quarter that of uniform HA, this is not an unexpected result as the relationship between effective density and the Young's modulus is highly non-linear [4]. The stress distribution calculated in Abaqus (Figure 2) shows that the bigger amount of the stress is localized where the coating of HA around the ribs of the original polyurethane foam is thinner.

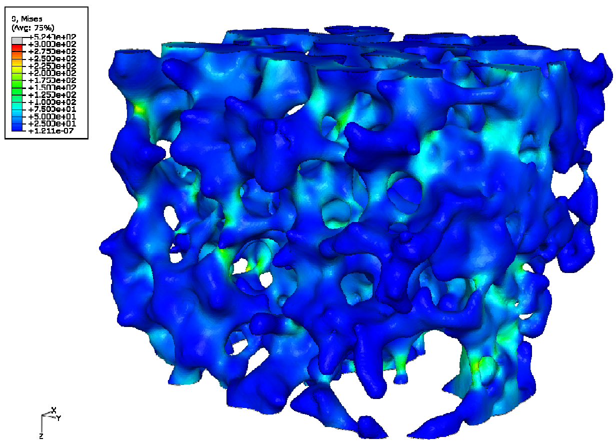

Figure 2: Stress-strain distribution in ABAQUS.

CONCLUSIONS

The work carried out highlights the potential use of image based meshing techniques for the ad hoc characterization of scaffolds as well as for assisting in the design of scaffolds with tailored strength, stiffness and transport properties.

REFERENCES

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