Non-destructive Imaging of Microstructures Using X-ray Microtomography

Introduction

X-ray Microtomography (XMT) operates on the same basic principles as X-ray CT scanners found in hospitals, but has a spatial resolution that is typically hundreds or more times higher. X-ray tomograms (i.e., reconstructed slices through a scanned object) map the relative density distribution. Therefore, if the materials in the scanned object are known, the tomograms can be used to assess where different materials are in the structure. Tomograms can also be stacked to provide the 3D structure. XMT is an ideal non-destructive means to image microstructural features of materials.

Applications

Structural characterisations using XMT performed by the Centre include:

- Functional materials (e.g., carbon composite)
- Calcified tissues and bone biomaterials (e.g., mice lungs and human femur)
- Metal powders (e.g., used for selective laser sintering in rapid prototyping)
- Phase distinctions (e.g., in liberation of minerals from ore)
- Structural uniformity (e.g., of catalyst pellets, detergent and drug tablets)
- Agglomerates (e.g., for micro-mechanical studies)
- Fibrous materials (e.g., in textiles)
- Polymer films (e.g., for controlled fragrance release)

Case Study 1 – Fibre Reinforced Composite

Confocal Laser Scanning Microscopy (CLSM) used to be the only technique that has been used successfully to reconstruct fibres in 3D. However, being an optical technique, CLSM relies on the penetration of visible light into the bulk of the sample, which introduces a depth restriction. The XMT enables imaging with far greater depth of penetration enabling the reconstruction of significant sample volumes. The data from XMT can be transferred directly into the microstructural finite element models to predict the bulk properties such as the elastic moduli of real components. Figure 1 shows a reconstruction of a glass fibre reinforced composite which has been imaged using XMT.

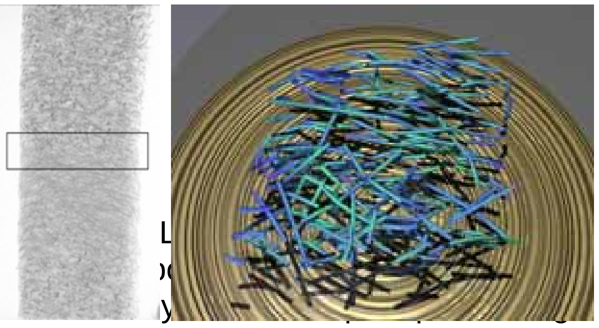

Figure 1: Reconstruction of glass fibre reinforced composite

Case Study 2 – Granulation

Granulation is a widely used method of production for granular products in the pharmaceutical industry. Granules produced in this manner are often agglomerates of finer particles. Their internal structures and distributions of different components affect the observed properties (e.g., dissolution, and mechanical strength) of the agglomerates. XMT is an ideal means to obtain the structural information, figure 2. On the left are the shadow X-ray image and some basic structural statistics along the line indicated in the image on the right, which is a cross-sectional slice through one of the scanned granules. The pseudo colours are used to indicate the relative density of the different regions in the agglomerate.

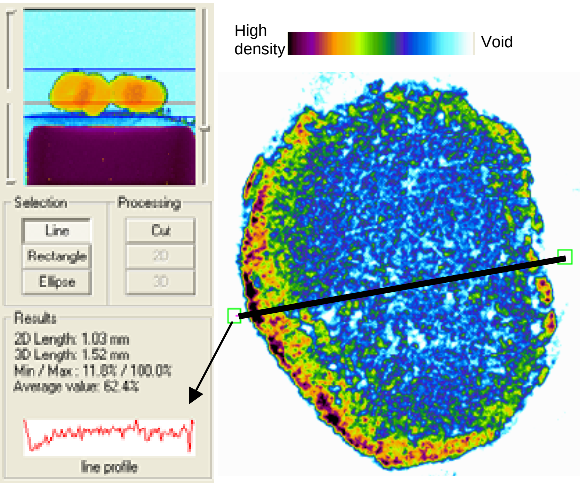

Figure 2: Shadow image and an example of cross-sectional slices of agglomerates.

Case Study 3 – Foam Structure

Figure 3 is a 3D reconstruction of XMT imaged foam structure. The pseudo colours are used to indicate temperature distribution calculated by a thermal conduction simulation. Since heat transfer by conduction is dependent on the connectivity inside the structure, the colour map also shows how well connected the different parts are in this particular piece of foam. For example, the blue stripe remains at a lower temperature, indicating that it has much less contact area than other parts.

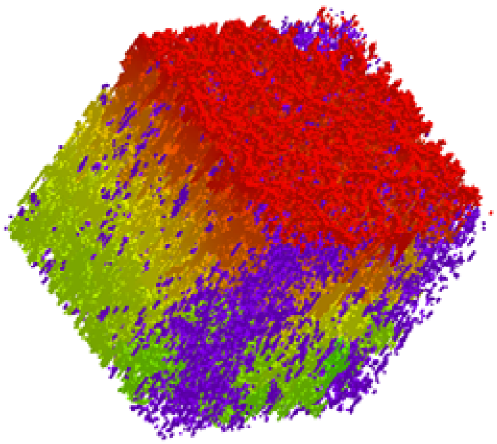

Figure 3: 3D reconstruction of a XMT measured foam structure and simulated temperature distribution. Red indicates high temperature, blue low temperature.

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