X-RAY COMPUTED TOMOGRAPHY FOR PORE NETWORK CHARACTERIZATION OF POLYSTYRENE FOAM

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Summary: We investigated pore scale characterization of polystyrene foam. X-ray micro-tomography was used for the characterization of the pore network. Relevant parameters, such as porosity and tortuosity, were quantified with Octopus Analysis. The porosity of our sample is 17%. Additionally a study on representative elementary volume (REV) was performed. The calculated estimated porosity REV was 4 cm^3 for our samples, which is smaller than the typical scanned volume of 21 cm^3 for the uncompressed polystyrene foam.

1. INTRODUCTION

Through recent advances in micro-tomography, a new field of research has emerged: pore network characterization of building materials [1][2].
The micro-tomography with X-rays allows us to reach at the heart of the material and to observe the differences of composition. Also it allows to localize, very finely, any heterogeneous, peculiarity, empties or inclusion present in an object, as well as to verify the assembly and the positioning of the complex structures.
We are interesting in the characterization of the pore network for polystyrene foam in order to establish a link between the macroscopic properties and the 3D microscopic characteristics. The multiscale 3D pore network will be used as an input in order to study acoustic emission in relation to the microstructure of the materials.
Two scans were done per sample: first we acquired a low resolution CT data set of the entire sample and then a high resolution data set for the region of interest (ROI) [3]. The region of interest has several important advantages. For example, it will greatly reduce the size of the image data set by requiring micro-scale sampling only in the ROI. Additionally, ROI scanning allows us to do scan at higher resolution. We could observe inclusions or irregularities that we could not observe in the entire sample [4].
The representative elementary volume (REV) is the smallest volume which a sample is representative. The choice of the REV has to satisfy certain criteria: it has to contain enough pores to have a significant global average. Although we can define the REV for several parameters: porosity, permeability, fluid saturation, in this study we will focus on the REV for porosity.

2. EXPERIMENTAL METHOD

Two cylindrical samples of polystyrene foam (diameter=26 mm, length=46mm) was used for this analysis. One of the samples is uncompressed and the other is uncompressed. For now, we will present the results for the uncompressed polystyrene foam. The results of the compressed sample will be derived soon.
The sample was placed at HECTOR [5], the high energy scanner of UGCT Ghent University. For single scans, the X-ray tube was operated at 35kV and a power of 10 W. 1401 projections were taken over 360° with an exposure time of 1 second. One scan took approximately one hour giving 10 gigabytes of tomographic images. The size of the full scan was 1000x1000x1000. A voxel resolution of 55 µm is obtained for the whole core and 10 µm for a ROI scan.
The tomographic images were reconstructed with the Octopus reconstruction software [6] and the 3D analysis was performed with Octopus Analysis [7].

3. RESULTS

The global porosity was computed on segmented data by counting the voxels. The entire 3D pore space consisted out of 17% porosity.

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We could determine the vertical and radial porosity profile to understand how the porosity is distributed within the volume. Vertical porosity profile was obtained by calculating the average porosity in each slice, thus determining the average porosity as a function of the orthogonal direction to the slices (Z direction). Radial porosity profile is given by calculating the average porosity as a function of distance from the central axis. It defines a rotation axis and calculates the average porosity (average intensity in fact) at a distance from this rotation axis. The porosity values ranged from 11% to 24%.
The REV for the porosity was determined for the entire scan by taking 500 cubic subsamples in the centre, with increasing size. The cube dimensions were expanded symmetrically in all directions from a 1x1x1 voxels[3] .The maximum volume for the cube is determined by the radius of the sample ($L_{max}=2R/\sqrt{2}$ where $L_{max}=(V_{max})^{1/3}$). For each cube we calculated the porosity and the REV was obtained when the porosity value became stable.
In Figure 1.a the porosity is shown as a function of the subsample volume. We can observe three regions. Region I represents at small scales random fluctuations due to microscopic structure; associated with pore scale heterogeneity. The left-hand boundary of region II shows a minimum REV; inside this region the measurements are scale-independent and precisely represent a larger sample. Region III represents variations due to microscopic heterogeneity of the structure. The porosity data indicates a REV around 4 cm^3, which represents approximately 4-6 grain diameters.

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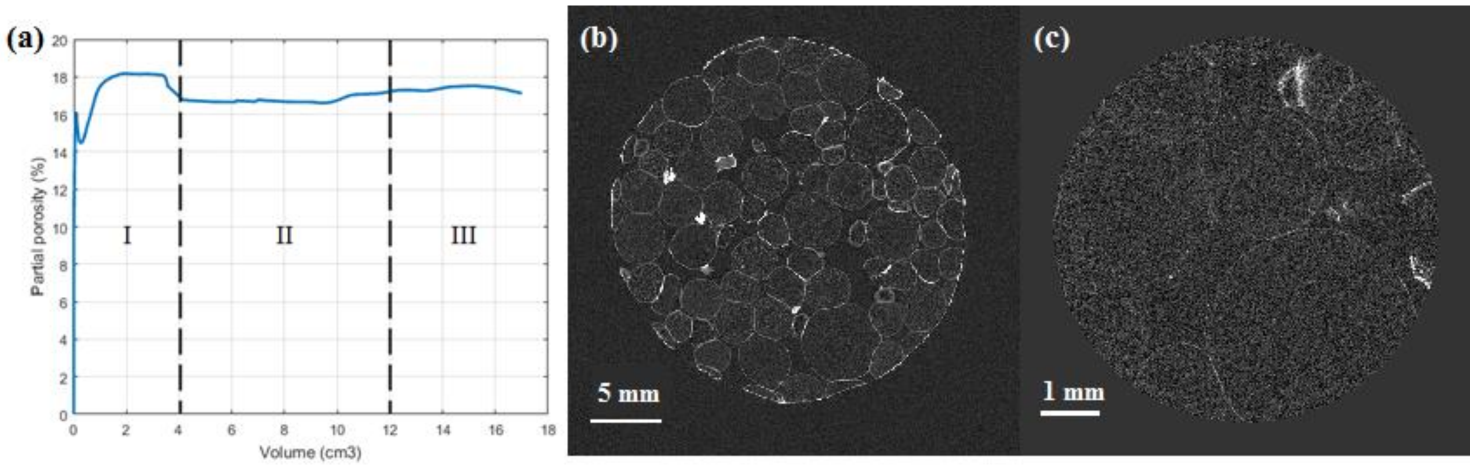

Figure 1: (a) Porosity as a function of the volume (b) Tomographic image of uncompressed Polystyrene: whole core (c) ROI