

IMPROVEMENTS OF AN ANALYSIS TOOL FOR THE PORE SIZE DISTRIBUTION ASSESSMENT

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1. Introduction

Knowledge of the inner structure is an important prerequisite for estimation of the mechanical properties of heterogeneous materials. This article is focused on the assessment of pore size distribution of a porous material.

2. Investigated materials

As representatives of biological materials specimens of human and porcine trabecular bone were tested (both harvested from region of proximal femur), as representatives of the artificial material synthetic pumice and frit glass were used.

3. Image acquisition

Three different devices (confocal microscope, CCD camera and flatbed scanner) were used for image acquisition.

Confocal Laser Scanning Microscope LEXT OLS3000 (Olympus Inc., Japan) performs the reconstruction of the scanned surface using a laser beam [1] with magnification up to 15000× and resolution higher 0.1μm. Results of the scanning are represented by a 2D matrix of heights and high resolution images (1024×768px). Physical size of the scanned area is 1280×960μm with minimal magnification (120×). This device is suitable for micro-porosity estimation. Obtained data are easily processable. The only limitation of this device is the small scanning area in case of macro-porosity.

Using of a CCD camera CCD-1300F (VDS Vosskühler GmbH, Germany) with resolution 1280×1024px attached to an optical microscope (Navitar Imaging Inc., USA) allows to capture 8-bit colour depth images with up to 24×

magnification. The advantage of this method consists in continual magnification setup (3-24×), but the image quality is very sensitive to illumination conditions.

In the third case, the images of the samples were acquired by a high resolution flatbed scanner EPSON Perfection V350 (Seiko Epson Corporation, Japan). Maximal resolution 4800dpi was used (1px corresponds to 5μm) with 16-bit colour depth. Physical size of the scanned area is up to 210×297mm. This method is suitable for materials with larger pores, because samples with dimensions corresponding to representative area were required to register enough wide range of voids.

4. Image analysis

The image analysis procedure consists of two main steps: image segmentation and connected component analysis. Both parts of the procedure were implemented in Matlab [2]. For the image segmentation thresholding was performed to convert captured grayscale images into binary ones and morphologic operations (opening and closing) were used to separate connected cross-section of voids. To estimate the area of voids two-pass algorithm for connected component analysis [3] was used. This algorithm allows to estimate size of the recognized objects and other characteristics e.g. perimeter or orientation.

5. Stereological calculation

For the pore size distribution assessment based on the sizes of cross-sections estimated from two-dimensional data a stereological calculation technique was used. A method introduced by Xu & Pitot [4] based on geometric properties of a sphere was chosen and implemented as a Matlab

function. Pore sizes obtained by 2-D image analysis were arranged into 25 size classes and the pore size distribution was estimated.

6. Results and conclusions

Using described analysis tool pore size distribution curves were obtained for three specimens of each material listed in section 2. These curves are depicted in Fig. 1 (biologic materials) and Fig. 2 (artificial materials).

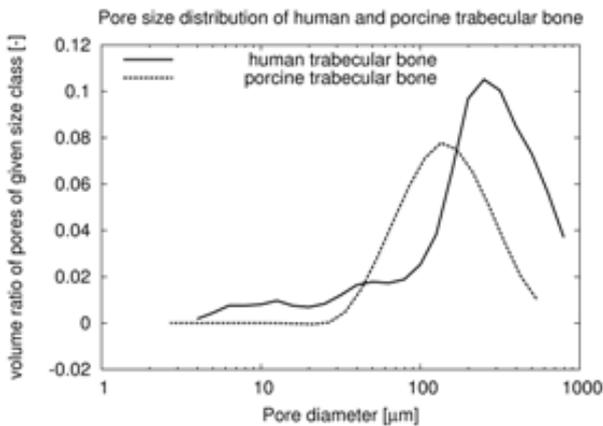


Fig. 1: Pore size of biologic materials distribution obtained by image analysis

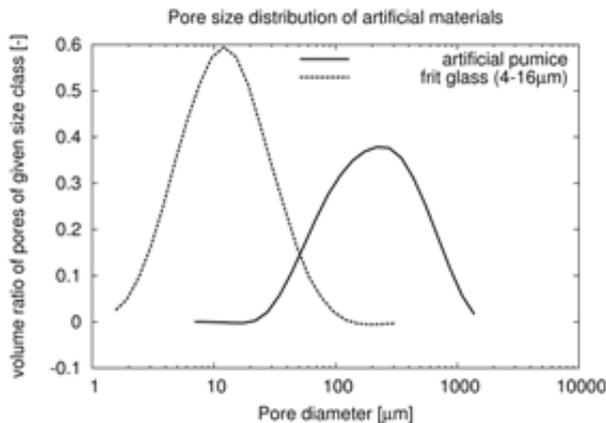


Fig. 2: Pore size distribution of artificial obtained by image analysis

Three distinct approaches to acquire image data were tested. Comparison of properties of the used image acquisition techniques is listed in Tab. I.

Tab I.: Properties of image acquisition methods

Image acquisition method	Lower size limit of registered pore [μm]	Maximal samples dimensions [mm]
Confocal microscope	1	0.64×0.48
CCD camera	5	18×12
Flatbed scanner	20	210×297

Obtained results show possibilities and limitations of the presented analysis tool. In case of well chosen image acquisition method voids in required size range can be registered. The range is also limited by the used stereological calculation, ratio between the lower and upper size limit of registered pores is 250 (determined by number of size classes and scale factor between the size classes).

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