Determination of porosity from tomographic data of hydroxyapatite scaffold-like structures

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Abstract

In many fields, researchers take advantage of knowledge of material's porosity. For obtaining quantitative information of sponge, encased cavities, a lot of methods have been developed. The situation gets complicated when pores are interconnected within the structure. This is the case of foams and scaffolds, which are used in modern medicine research for tissue engineering.

X-ray computed microtomography (µCT) is a nondestructive method for 3D imaging of materials. For getting quantitative information about porosity in foams or scaffolds scanned with µCT, many software offer various approaches. In this work, different software for pore analysis are compared. As a testing sample, a tomographic data of hydroxyapatite foam for bone replacement were used. It was scanned on GE phoenix L240 with linear voxel size 5 µm. The material was segmented from background using Otsu method implemented in ImageJ.

Results

Pore3D

Type of software: open source for commercial IDL.

Version: Pore 3.0.0 [1], IDL 7.0.

Result: Sizes and list of pores and joints between them ("Throats"). Skeleton visualizing connectivity of the pore space. Pore and throats space are available as a binary mask, which can be opened and visualized in VGStudio MAX.

Usage: Requires knowledge of basic programming.

Figures: Pores are marked with random colours for pores visualization. Faces are marked with blue colour.

VGStudio MAX

Type of software: commercial programme.

Version: 3.0. [2]

Result: Volume, list and advanced statistics of pores and contact surfaces between them ("Faces"). Thickness map of the material matrix (Struct thickness). 3D renders of analysis are available.

Usage: Easy usage, although choice of right parameters in analysis settings might be difficult.

Figures: Pores are marked with random colours for pores visualization. Faces are marked with blue colour.

MAVI

Type of software: commercial programme.

Version: 1.4.1. [3]

Result: Sizes and basic statistics of pores and contact surfaces between them ("Faces"). 3D renders of analysis are not available.

Usage: More complicated procedures for analysis, less user-friendly software.

Figures: Pores are marked with random colours for pores visualization.

X-ray computed tomography

X-ray computed tomography (CT) is a nondestructive method for imaging of inner structure of materials. The sample is placed between the X-ray tube and the detector. A lot of projections from different angles of rotation of the sample are recorded. From these projections, slices through the sample are reconstructed to get 3D data. Grey values in slices correspond to linear attenuation coefficient of material.

Table 1: Comparison of pore analysis of CT data of hydroxyapatite foam from different software (total volume of the examined sample was 8.00 mm³).

<table>
<thead>
<tr>
<th>Program</th>
<th>Number</th>
<th>Total volume of pores (mm³)</th>
<th>Average pore volume (mm²)</th>
</tr>
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<tbody>
<tr>
<td>VGStudio MAX</td>
<td>1946</td>
<td>5.6</td>
<td>70</td>
</tr>
<tr>
<td>MAVI</td>
<td>2362</td>
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<td>71</td>
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<tr>
<td>Pore3D</td>
<td>917</td>
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References