APPLICATION OF MICRO COMPUTER TOMOGRAPHY TO IDENTIFICATION OF PORE STRUCTURE PARAMETERS OF POROUS MATERIAL

Mieczysław Cieszko, Zbigniew Szczepański
Institute of Environmental Mechanics and Applied Computer Sciences
Kazimierz Wielki University, 85-064 Bydgoszcz, Chodkiewicza 30, Poland

1. Introduction

Determination of the pore space structure parameters of porous materials is very important for applications. Porous materials are commonly present in: nature (e.g. the rocks, soils, wood), biology (e.g. bone tissue, lung, membranes) and technology (e.g. sintered metals, ceramics, aerogels and concretes). Their pore structure plays important role in many physical and chemical processes occurring in such materials: in transport of mass, momentum and energy, in wave propagation or chemical reactions. It also strongly influences mechanical properties of the skeleton.

There are many different methods used for identification of pore structure parameters: optical, dynamical (e.g. ultrasonic and vibration methods) and static (e.g. permeametry, gas picnometry, electric spectroscopy and mercury porosimetry). To the static methods belongs also the Micro Computer Tomography (μCT). It is very modern method of identification of microscopic structure of inhomogeneous materials. This allows to determinate their stochastic characteristics, macroscopic parameters of structure and also material constants.

The purpose of this paper is to apply the scans of microscopic geometry of human bones obtained by μCT method to identification of their macroscopic pore structure parameters: volume porosity, permeability and tortuosity of pores and skeleton. These parameters, except the volume porosity, have been determined by simulations of microscopic processes of viscous fluid flow and electrical current passage through samples of bones. The simulations were performed using the COMSOL's Multiphysics environment assigned for solution of boundary value problems described by partial differential equations, by use of the finite element method.

2. Identification of microscopic geometry of pore space

Virtual models of microscopic geometry of porous samples of human bones ware obtained in the paper applying the μCT method. This method like tomography uses X rays to non-invasive identification of the three-dimensional internal structure of physical objects. It concerns e.g. small animals, tissues, microfossils and micro inhomogeneous materials like bones.

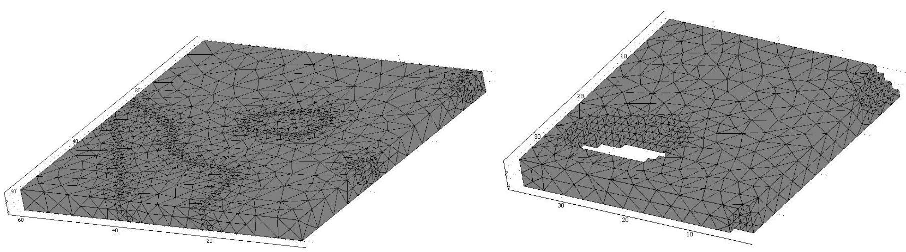

Fig. 1. Virtual 3D models of small slice of human bone identified by μCT method.

The output data obtained from μCT Takes form of three-dimensional 8 bits matrices that represent mass density of material in particular points of the sample. In the case of porous materials the identification of spatial distribution of the skeleton in the sample, such matrices have to be binarized. Next, they are used by specialized software to construct the virtual model of microscopic pore space geometry, enable for import by programs like COMSOL assigned for simulations of physical processes. The exemplary virtual 3D model of small slice of human bone identified by μCT method is shown in Fig. 1.

3. Determination of macroscopic parameters of pore space structure

Three kinds of pore structure parameters are determined in the paper: volume porosity permeability and tortuosity of pores and skeleton. The volume porosity is calculated directly from geometrical relations given by 3D scans of samples whereas the permeability parameter and its directional characteristics are determined applying simulations of microscopic fluid flow in virtual model of porous material and Darcy law,

$$\mathbf{v} = -\frac{k}{\mu}\, grad(p),$$

describing this process at the macroscopic level.

To determine the value of the pore tortuosity parameter, the numerical simulations of an electric current passage through perfect conductor (e.g. electrolyte) filling pores of a non-conductive skeleton have been applied. It corresponds to the standard conductometric method of the tortuosity measurements in porous materials ([1], [2]).

These simulations enable calculation of formation factor,

$$F = \frac{\rho}{\rho_0},$$

that is the ratio of effective resistivity ρ of the conductor filling porous sample to specific resistivity ρ_0 of the bulk conductor. Due to relation, [3],

$$\delta^2 = f_v F,$$

the determination of volume porosity f_v and formation factor F, gives directly the value of pore tortuosity δ. The similar approach have been used for determination of the skeleton toutuosity and its directional characteristics.

References

[1] Mac Carter W.J., Desmazes P. (1997). *Soil Characterization using Electrical Measurements*, Geotechnique, 47, 1, 179-183.

[2] Łukowski J., Kaczmarek M. (2002). *Laboratory Methods of Determination of Pore Structure Parameters Formation Factor and Tortuosity of Permeable Media by electric Methods,* Engineering Transactions, 50, 4, 267-286.

[3] Cieszko M. *Extended Description of Current Passage in Perfect Conductors Occupying Anisotropic Pore Space of Non-Conducting Porous Materials. Generalization of the Ohm's Law*, Engineering Transactions, (in the press).