Application of X-ray micro-computed tomography for numerical simulation of auxetic foam fabrication

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The design of new multifunctional foams as well as metal-ceramic and polymer-ceramic composites of ceramic foam structure, which can be applied as lightweight wear resistant elements, fire resistant or fire retardant parts, piezoelectric actuators etc., requires the solution of the following questions:

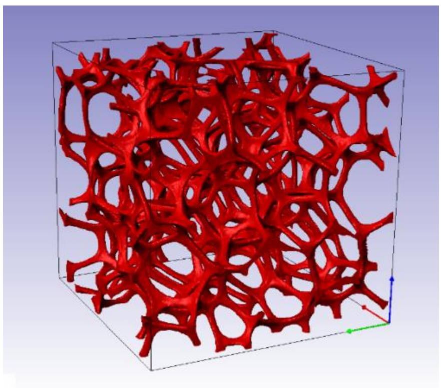
- in what way to fabricate polyurethane, metallic or ceramic foams and preforms of assumed skeleton structure,
- how to produce *tomograms*, i.e. 3D virtual volume reconstructions of real foam structure [1],
- how to elaborate methods of numerical simulations of fabrication processes of auxetic foams with use of the *tomograms*.

Depending on manufacturing method the cells obtain convex or concave shape. The materials with convex cell structure reveal positive value of Poisson's ratio, that is if a sample is stretching, then its cross-section is getting thinner. The complex structure of the foam related with reentrant cells produce the opposite effect during stretching of a sample, i.e. its cross-section is increasing. Then the negative Poisson's ratio is observed and such foams become auxetic.

The aim of the study is to tackle the third question. The motivation can be found in the following statement: *„Ideally, in an attempt to reduce laboratory expense, one would like to make predictions of a new material's behaviour by numerical simulations, with the primary goal being to accelerate the trial and error laboratory development of new high performance materials."*, [2].

Accordingly, numerical simulation of fabrication process of auxetic foam is developed. The subject of the study are metallic open-cell foams, in particular the foams of Cu skeleton. To simulate the deformation processes of such a material the finite element program ABAQUS was used. Finite element discretization was derived from real foam specimen with use of computer tomography images implementing the procedures described in [3], [4]. The initial cube of convex open-cell skeleton is subjected to three-axial compression applied as uniform displacements normal to the surface of cube faces, Fig. 1. The dimension of a finite element corresponds to the dimension of a single voxel and is equal to 2.52 10^{-6} *m*. In all numerical calculations the material of the skeleton was assumed as isotropic Cu: Young modulus: 126 GPa, Poisson's ratio: 0.3 and yield limit: 20 MPa. The computational methods and procedures applied in the analysis of the micro tomography observations and numerical simulations of deformation process are presented in detail.

a)



b)

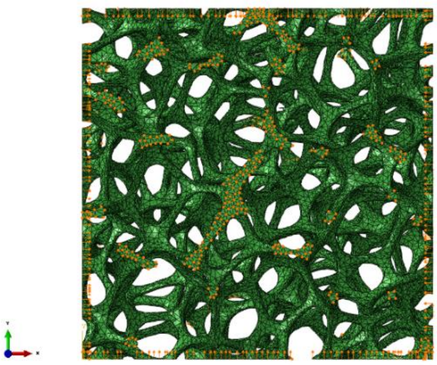


Fig. 1. a) Initial configuration of the skeleton of the convex open-cell Cu foam of 94% porosity, b) finite element model of the convex open-cell foam cube of the edge of 800 voxels, 1 voxel = 2.52 10^{-6} *m*, created with use of ABAQUS/CAE with the scheme of displacement boundary conditions.

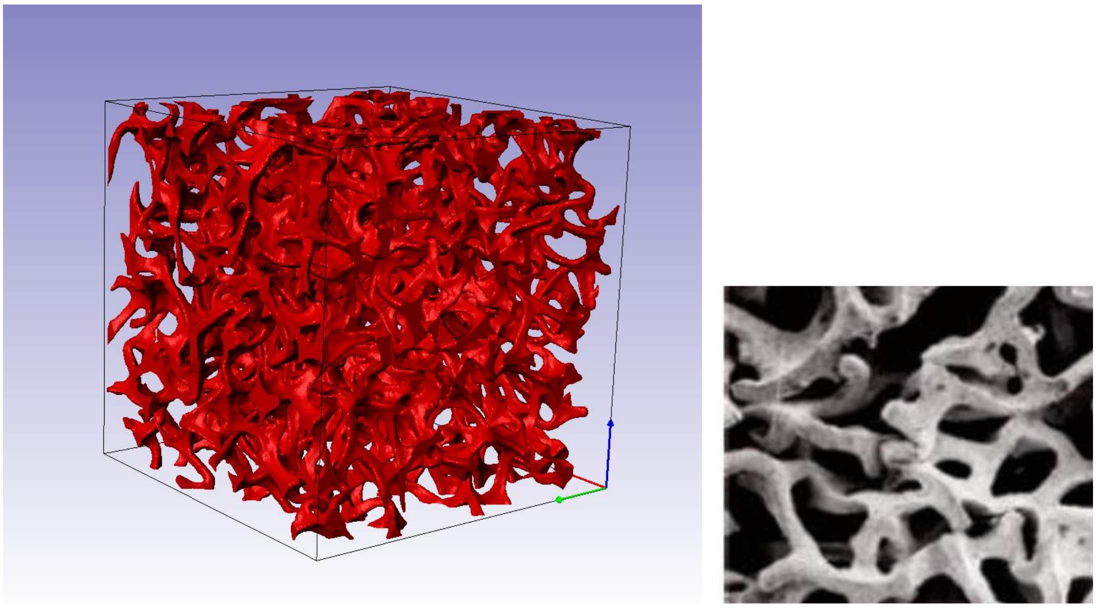


Fig. 2. The resulting structure of the virtual auxetic foam with the estimated Poisson's ratio: - 0.3 in comparison with the picture of real Cu skeleton with reentrant cells obtained in [5].

The results of the above analysis can be applied for the prediction of manufacturing requirements. In Figure 2 an exemple of the structure of the virtual auxetic Cu foam resulting from numerical simulations is compared with the picture of Cu skeleton obtained experimentally by Lakes [6]. The both pictures reveal similarity of topology and geometry of the skeleton. The results presented in [6] show that the similar re-entrant skeleton structure can be obtained also for polyether foams.

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