

NUMERICAL ANALYSIS OF AN OPEN CELL FOAM STRUCTURE WITH THE USE OF MODELS BASED ON SOLID FINITE ELEMENTS

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Abstract

The paper deals with the numerical analysis of foam materials. Open cell foam is investigated. Numerical simulations allow calculating modes of destruction and assessing effective properties of the model structures.

Metal as well as polyurethane foams show out interesting properties. They are light, have good acoustic and/or magnetic isolation, have ability to absorb energy of vibration and hits. They are used for sandwich panels, hit absorbers (i.e. as elements of buffer constructions in rail vehicles), fillers of construction parts, bodies of vehicles (i.e. floating combat vehicles), dividing walls on vessels and others. Specially prepared open cell foams show out auxetic properties and shape memory effect. Such materials are very good for seats in aircrafts which may protect pilots and passengers during crashes and restrict heavy backbone injuries. Foams are used for filtering purposes. Foams themselves or in combination with different types of fillers (i.e. elastomers) or ceramic reinforcement may be used for hit energy absorbing panels for military purposes (protection against explosion shock wave and splinters).

Presented work is a part of a series of numerical experiments which aim is to investigate the influence of geometry parameters onto effective properties of the foam. Different types of geometries are used for numerical experiments. All the models of single foam cell are based on Kelvin grain geometry.

Numerical compression tests performed with the use of models based on solid finite elements provide studying the process of the structure failure. Effective characteristics of investigated foams show out that such materials would be useful for energy absorbing purposes.

Keywords: FEM modelling, open cell foam structure, effective properties

1. Introduction

For purposes of numerical modelling of foam materials (Fig. 1a) there are used various techniques and methods. Numerical models may be constructed on base of the real structure image that may be a 2D photograph (Fig. 1b) or 3D scan. 3D scans may be obtained by use of X-ray or neutron tomography technique (Fig. 1c). Models may have smooth shape or may be based on a grid technique (Fig. 2) [1, 4, 9]. Also idealized models are used which are suitable for investigations of influence of particular geometrical or material parameters onto global properties of a foam. They may be built on the base of geometrical solids (i.e. Kelvin's polyhedron (Fig. 3)) [2, 5, 6], composition of different polyhedrons (Fig. 4), Weaire-Phelan 8-cell repeatable structure (Fig. 5) [5, 6] or on the way of Voronoi 3D tessellation [2, 7]. Idealized models may represent multi cell structures or may be reduced to repeatable fragment of geometry – single cell or their part (Fig. 6) [2, 10, 3], so they are convenient for fast comparative analysis of long series of differentiated models. There may be found models which deal with the problem of random distributions of shapes and sizes of foam cells [8].

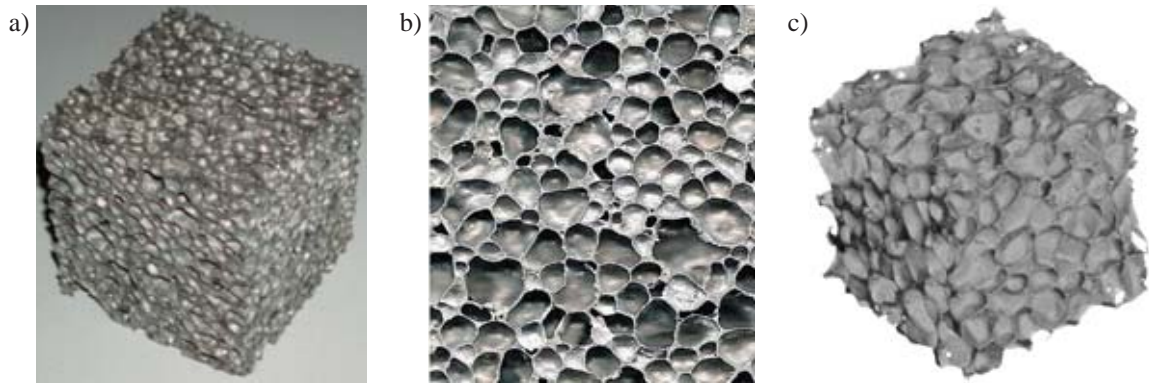


Fig. 1. Aluminum foam with closed cells: a) cubic sample 20×20×20 mm, b) free face of the sample photo, c) visualization of data obtained from X-ray tomography

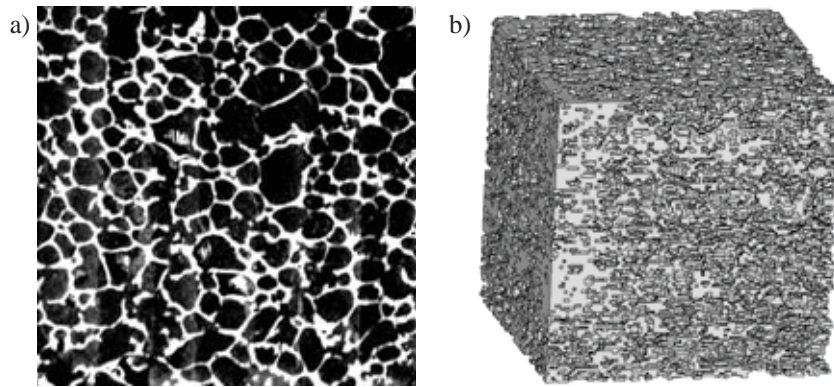


Fig. 2. Scan data and the grid model: a) single 2D scan of the sample (one from series of cross sections of a sample), b) 3D grid model built on the way of digitalization of series of 2D scans

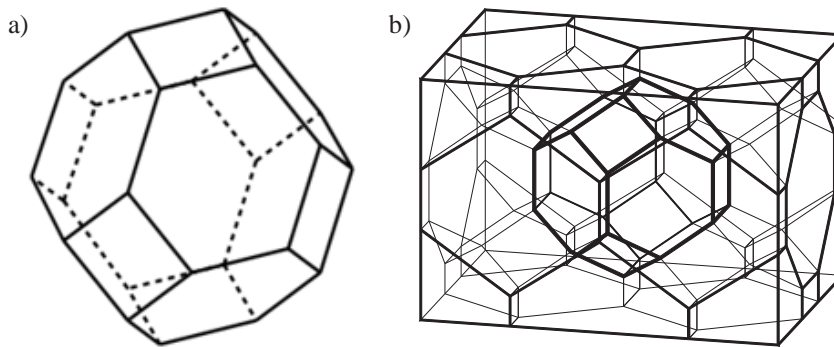


Fig. 3. The use of Kelvin polyhedron (14 faces) for model building: a) polyhedron, b) cuboidal model containing one entire Kelvin cell and fragments of adjacent ones

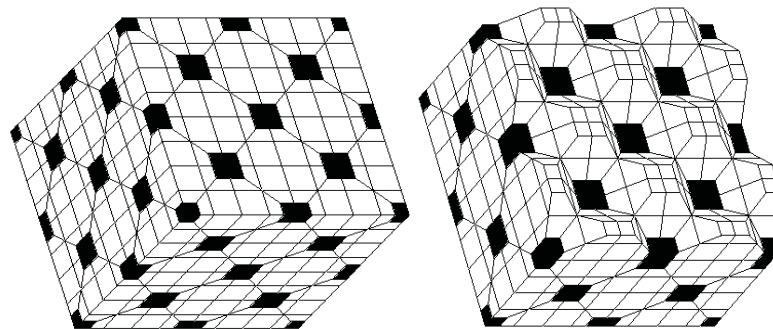


Fig. 4. Model of ceramic composite based on cubes and 18-faced polyhedrons – their geometry may be adapted for building of foam models

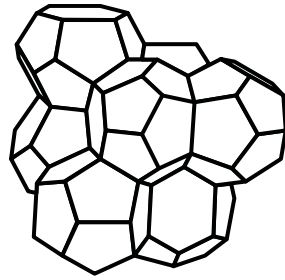


Fig. 5. Weaire-Phelan repeatable structure consisting of 8 cells – it is difficult to close such structure in cuboidal volume

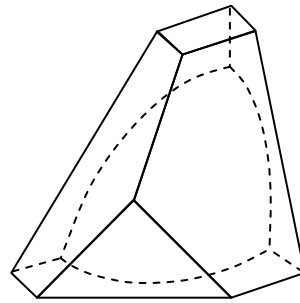


Fig. 6. Model of a closed cell foam which is the fragment of Kelvin's grain

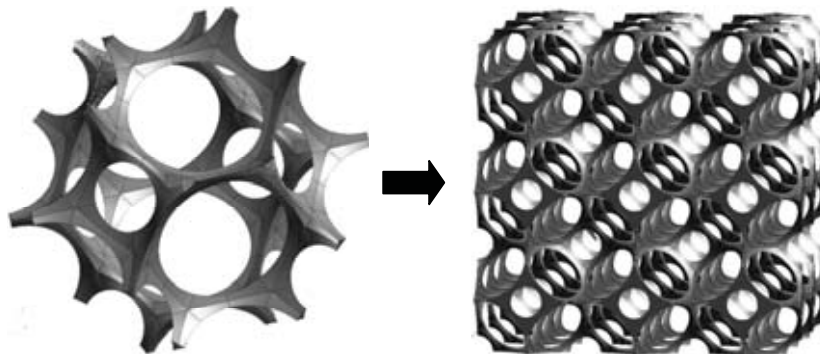


Fig. 7. 3D solid geometry based on Kelvin's polyhedron and the multi cell model of open cell foam

2. Simulations

The model of a single cell of open cell foam is shown in the Fig. 8. It bases on Kelvin's polyhedron geometry. The edges of base geometry are normalized to 1 mm. It is the one of the series of models of different geometry involving differentiation in density (Fig. 9). Material properties taken for quasi-static tests is shown in Fig. 10. Planar sections of "square faces" of the model were constrained due to assumption, that the foam is closed in a stiff profile element (cylinder or cuboid). The effect is that these faces are forced to remain planar. Calculation were performed in the MSC.Marc system.



Fig. 8. Single cell model of open cell foam taken into considerations

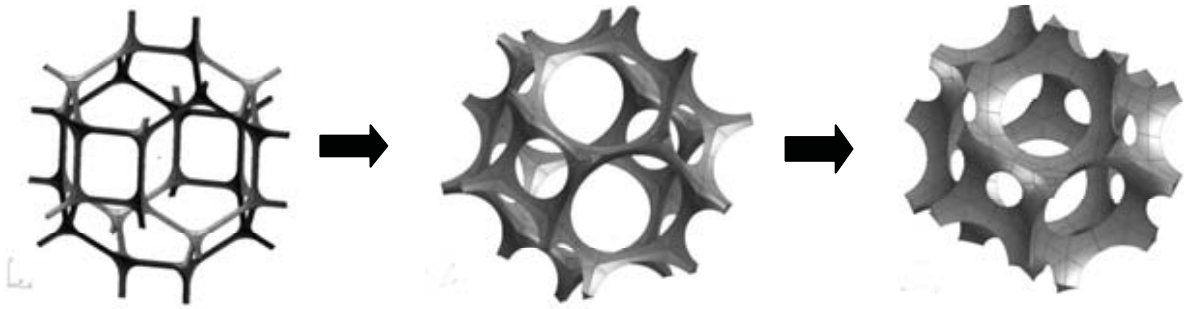


Fig. 9. Series of base geometries of foam structure of different density obtained thanks to change in dimensions of cross sections of connections between nodes

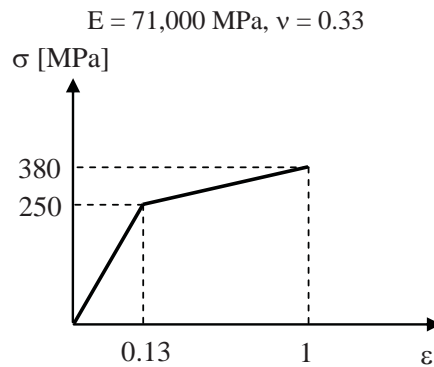
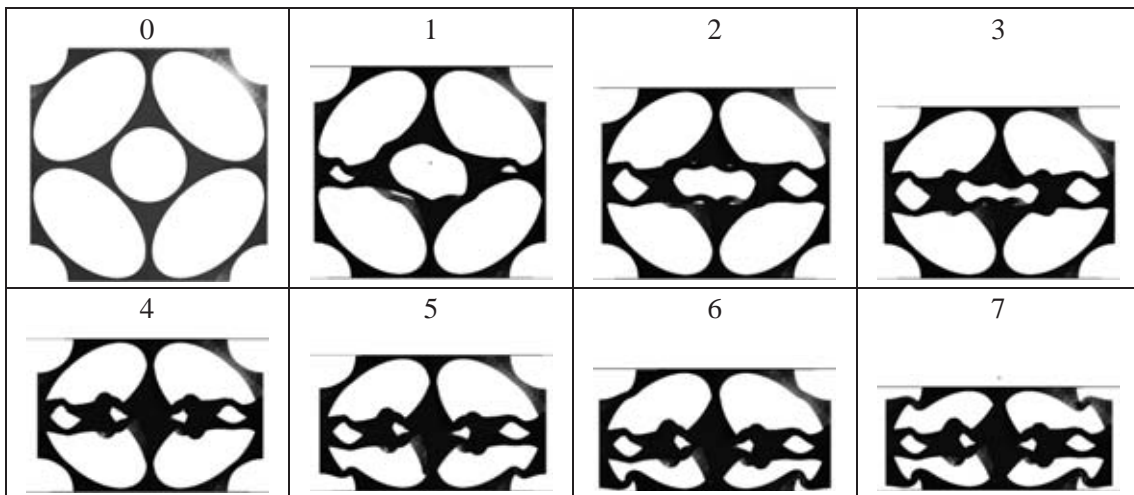


Fig. 10. Material characteristic – aluminum

In the Tab. 1 are represented sub sequential stages of destruction process. Particular parts of the structure of model cell (connections between the nodes) are destroyed step by step. Passages from one stage to another are visible in the obtained characteristics force/displacement (Fig. 11).

Tab. 1. Subsequent stages of single model cell deformation during quasi-static compression test



During the passage it may be observed local stiffening of the characteristics. It is in opposition to typical experimental characteristics which are more smooth.

4. Conclusions

Partial models based on idealized geometry may be effective in investigations of structural materials like foams. But they may produce distorted results. It depends on possibility of proper

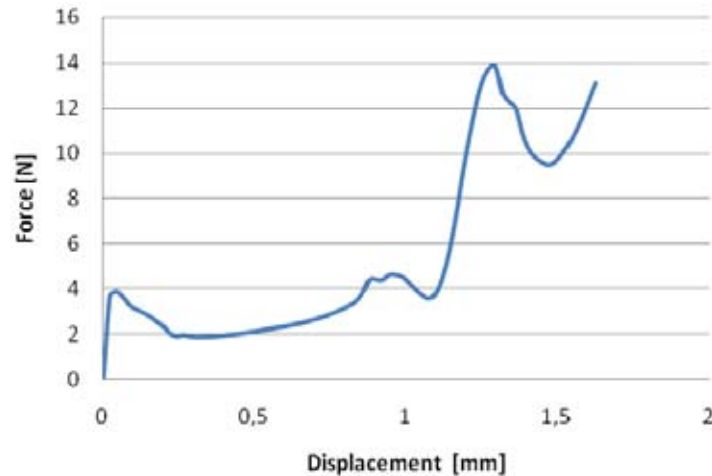


Fig. 11. Characteristics force versus displacement

definition of boundary conditions. In comparison to real materials geometries idealized models show out privileged directions and planes which are responsible for characteristic calculated mode of destruction (step by step). This phenomenon exists also in models built by multiplication of partial geometries. Distortions oscillate around the real material characteristic which is smooth due to their irregular structure and distribution of dimensions and random orientation of particular cells.

Acknowledgements

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