FAILURE ANALYSIS OF CHOSEN 3D NUMERICAL MODELS OF AN OPEN CELL FOAM

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Abstract

Metal and polyurethane foams exhibit interesting properties. They are light, have good acoustic and/or magnetic isolation as well as ability to absorb the vibration and impact energy. They are used for sandwich panels, impact absorbers (i.e. as elements of the buffer constructions in rail vehicles) , fillers of construction parts, bodies of vehicles (i.e. floating combat vehicles) and for dividing walls of vessels and others . Specifically made open cell foam s demonstrate auxetic properties and the shape memory effect. Such materials are very good for seats in aircrafts which may protect pilots and passengers during crashes and limit heavy backbone injuries. Foams are used for filtering purposes. Foams or their in combination with different types of fillers (i.e. el astomers) or the cerami c reinforcement may be used in impact ener gy absorbing panels for mili tary aim (protection against an ex plosion shock wave and splinters).

In the paper alumini um open-cell foam structures were investigated for their energy absorption ability. For this purpose a series of numerical 3D models were applied. Geometry of the models was based on Kelvin's polyhedrons. Tests of uni axial compression were simulat ed with the us e of LS-Dyna computer code. Complex contact phe nomena were considered. Preliminary test were performed with the use of single foam cell models. Furt her simulations were conducted using 3x3x3 cell models. The results were analyzed as force/time characteristics.

***Keywords**: FEM modelling, open cell foam structure*

1. Introduction

Various techniques and methods are used for purposes of foam materials numerical modelling. Numerical models may be constructed on the base of the real structure image that is available as 2D photo or 3D scan. The 3D scans may be obtained by use of X-ray or neutron tomography technique. Models may have smooth surfaces or may be based on a grid technique [1, 4, 9]. Idealistic models which are suitable for investigations of particular geometrical or material parameters influence on global properties of foam are also used. They may be built on the base of geometrical structures (i.e. Kelvin's polyhedron [2, 5, 6] (Fig. 1).

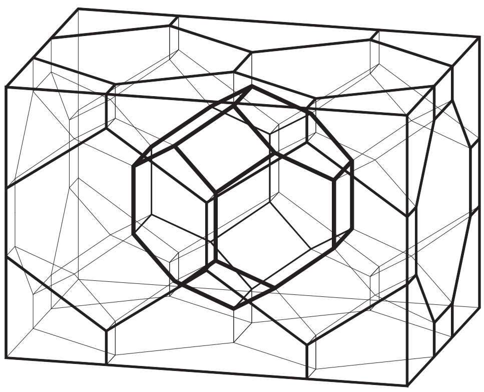

Fig. 1. The structure based on Kelvin's polyhedrons

The model can be built as a combination of different polyhedrons (Fig. 2), Weaire-Phelan 8-cell repeatable structure [5, 6] (Fig.3) or applying Voronoi 3D tessellation method [2, 7]. The idealistic models may represent multi cell structures or may be reduced to a repeatable fragment of geometry – a single cell or its part [2, 10, 3] (Fig. 4), which are convenient for fast comparative analyses of long series of differentiated models. The models which deal with the problem of random distributions of shapes and sizes of foam cells are also described in the literature [8].

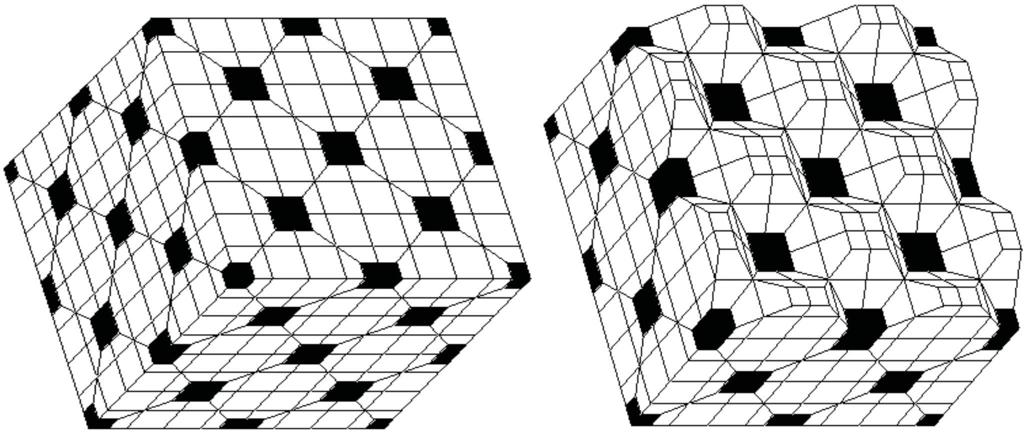

Fig. 2. The model of the ceramic composite based on cubes and 18-faced polyhedrons –geometry that can be adapted for building foam models

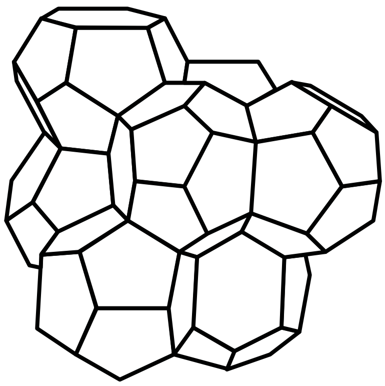

Fig. 3. The Weaire-Phelan repeat able structure consisti ng of 8 cells- difficulties in closing such a structure i n cuboidal volume

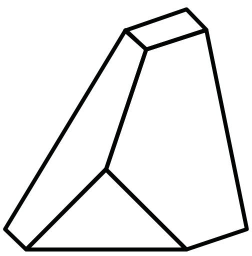

Fig. 4. The model of closed cell foam which is the fragment of Kelvin's polyhedron

2. Open cell foam models

Two models of the open-cell foam structures were taken in considerations. Model A is built for the foam of 0.42 g/cm^3 density (Fig. 5). Model B is built for the foam of 1.98 g/cm^3 (Fig. 6). They consist of 27 foam cells. Dimensions of the models are 10x10x10 mm. The influence of the rest part of a foam structure was simulated by locking the perpendicular degrees of freedom at two neighbouring external model side walls. Such a boundary conditions were defined to simulate ¼ part of the structure sample. A dynamic numerical analysis was carried out with the use of LS Dyna computer code. The compression test was performed numerically with two rigid plates (LS Dyna rigid walls) –a stationary and a moving one (velocity v=0.1 m/s). Friction in the model was not considered.

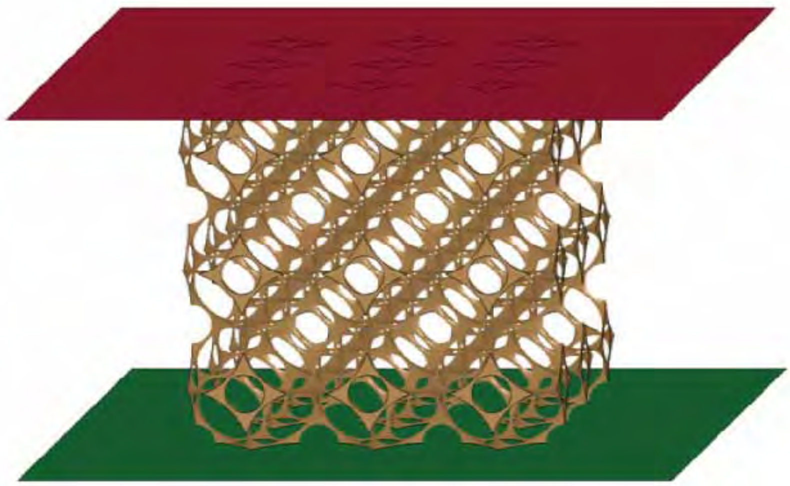

Fig. 5. Model A – 3x3x3 cell structure of 0.4 g/cm3 density based on Kelvin's polyhedron geometry

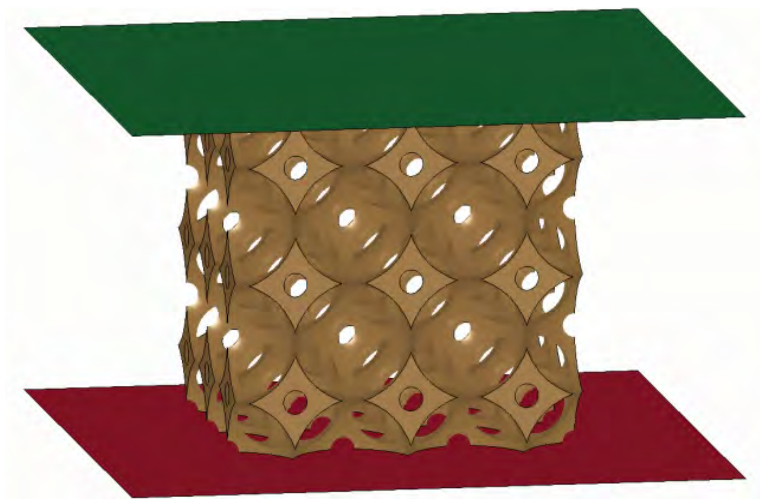

Fig. 6. Model B – 3x3x3 cell structure of 1.98 g/cm3 density based on Kelvin's polyhedron geometry

The material characteristics for pure aluminium used for calculations are shown in Fig. 7. The Young modulus was E = 71000 MPa, the Poisson ratio - $\nu = 0.33$.

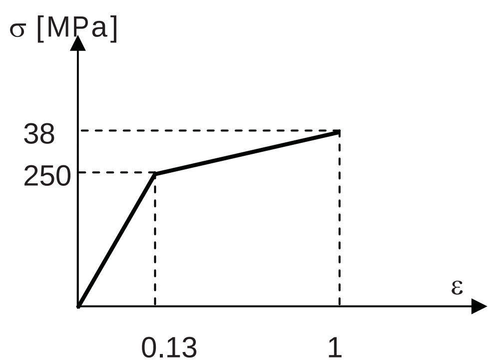

Fig. 7. The material characteristics for aluminium

3. Results

The stages of the foam structures failure obtained from the FE analyses are presented in Fig. 8 and 9.

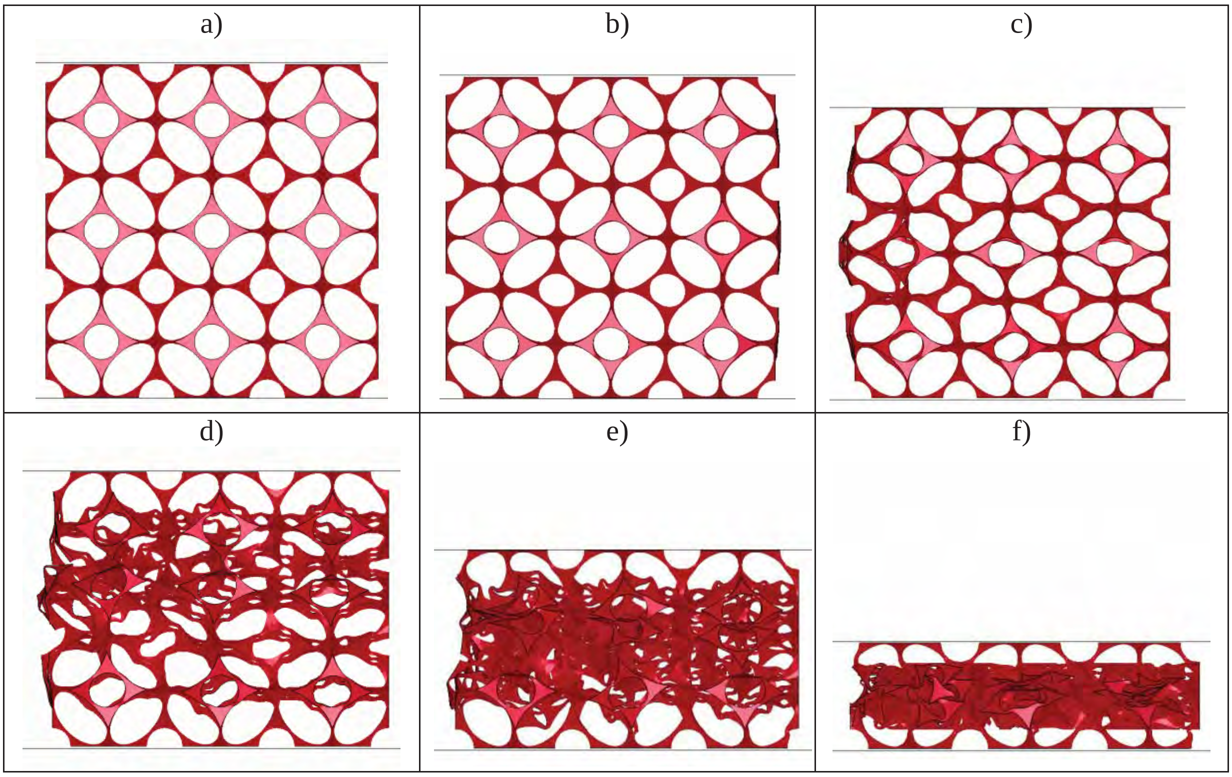

Fig. 8. Model A – the stages of the foam structure failure

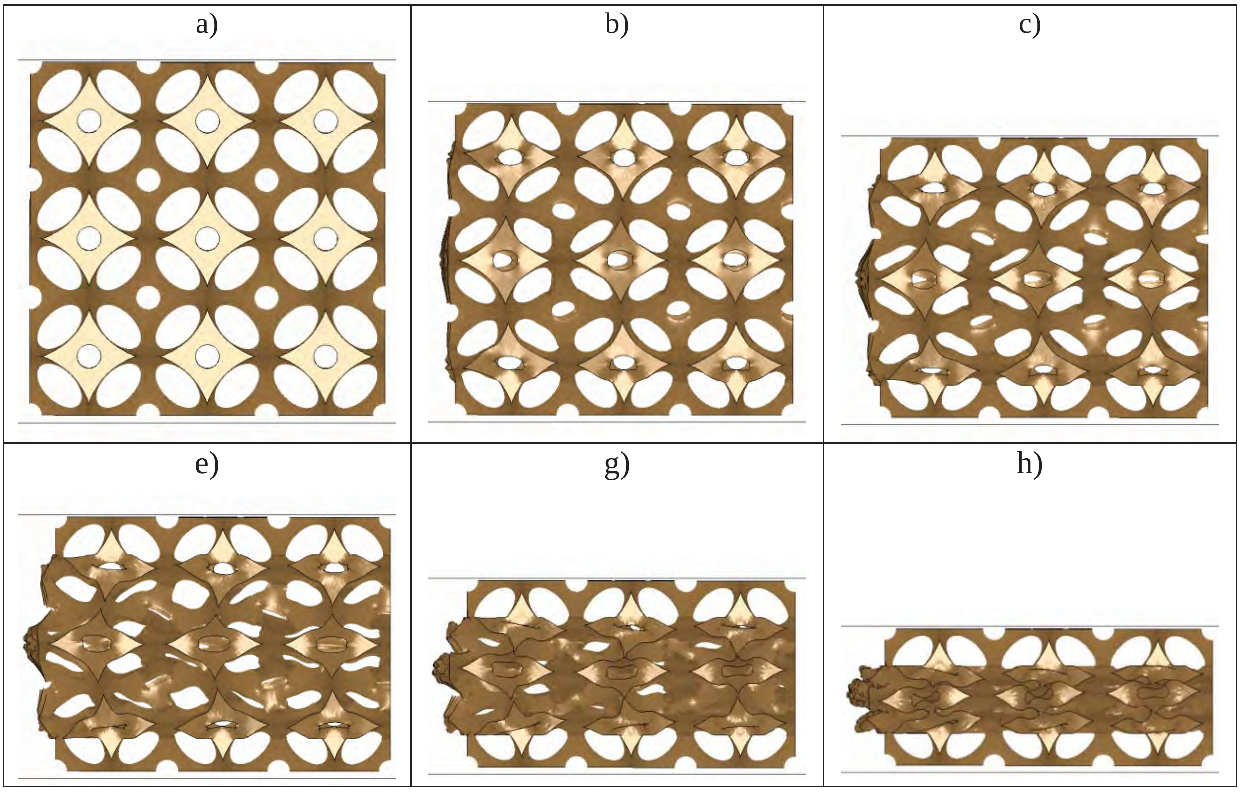

Fig. 9. Model B – the stages of the foam structure failure

The difference between the considered structures is in the final stage of failure process. The lighter structure collapsed and the heavier one expanded in the direction perpendicular to the direction of compression.

The results in the form of the force/time characteristics are presented in Fig. 10.

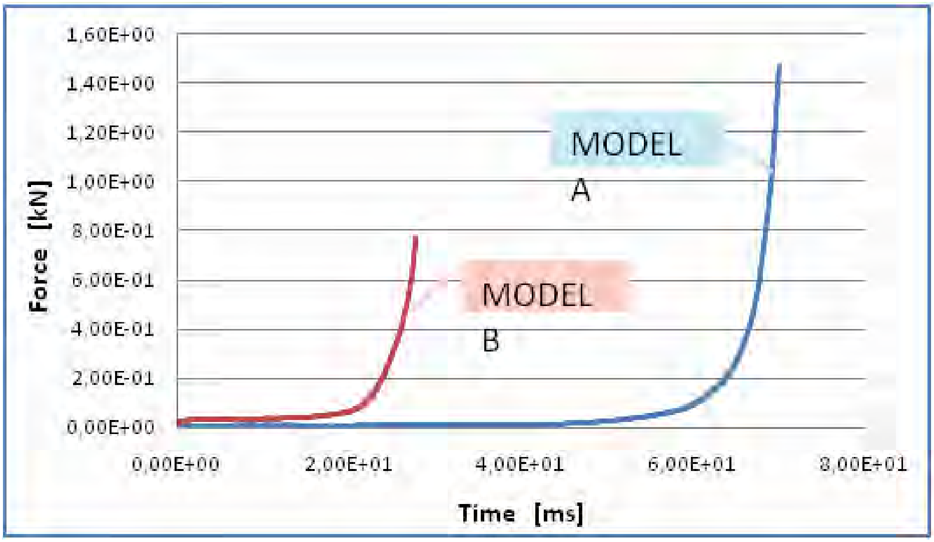

Fig. 10. The characteristics of force/time for both models

4. Conclusions

The failure of both foam models originated in the midplane between supporting and hitting plates. Then buckling of the foam cells edges continued until contact of internal free surfaces of the structures occurred (earlier for model B). This structure (with density greater that for model A) is also stiffer in the buckling stage. Another difference between the behaviour of the modelled structures was that the lighter one (density 0.4 g/cm^3) tended to collapse at the end of failure process after the initial stage of expansion in the directions perpendicular to the direction of compression and the heavier one continued its expansion until the test ended. Model A showed the semi auxetic type of behaviour but not as evident as in the case of typical auxetics. Typical auxetic foams structures models need to be specifically modified to enable such an effect. It is reached by cutting some edges in the model. It was not necessary for a light structure in model A.

References

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