NUMERICAL SIMULATION OF REAL FOAMS MICROSTRUCTURE BEHAVIOUR SUBJECTED TO UNIAXIAL LOAD

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Introduction

Metal foams are cellular structures consisting of solid metal - frequently aluminum - containing a large volume fraction of gas-filled pores. They are still quite new and unknown structures that are used as an impact-absorbing material [2,3,4].
In this paper the creation process of a real foam microstructure model and its numerical analysis is presented.
In the literature on this subject a quite similar model but based on an ideal microstructure is shown. It considers a three dimensional cube composed of cubical cells of two types: “material” (labeled 1) and “void” (labeled 0). In the porous medium of the first generation, the material cells are made of ice, while the voids may actually contain gas. In the second generation medium the material cells are cubes of the first generation; similarly, the material cells of the third generation are cubes of the second generation., what is illustrated in fig. 1.

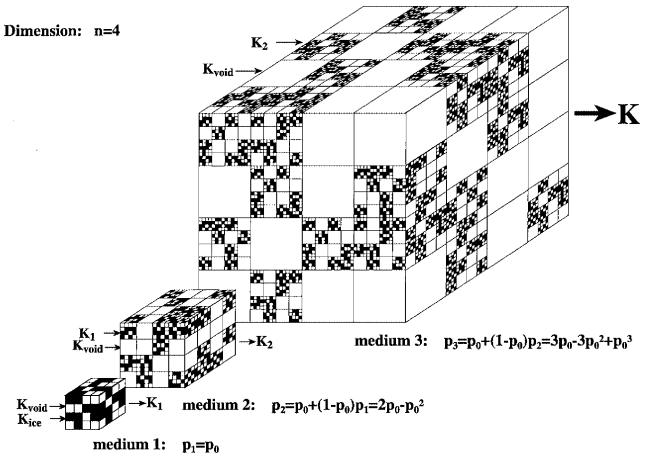


Fig.1: Schematic representation of the hierarchical (fractal) model of a porous medium [1].

Experiments

An uniaxial static compression test for aluminum foam sample was carried out. The results are presented in fig. 2.

Numerical model

A numerical model was created on the basis of destructive experiments of real foam structure.

Fig. 2: Experimental results from uniaxial compression test.

The thin slices of 0,35mm were removed one by one from a top surface of a foam cube (35×35×35mm) and then the pores were filled with red wax. Then a picture of every slice was taken (fig. 3a). With the use of graphic processing software the pictures were converted to 100 bitmaps of 100×100 pixels in black and white (fig. 3b).

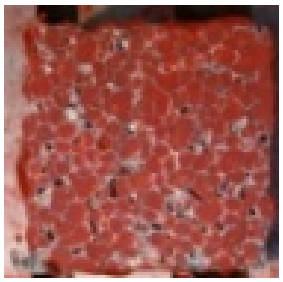
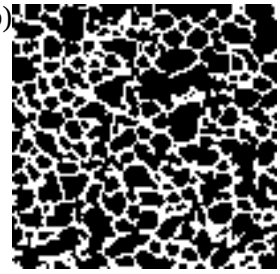
a)  b) 

Fig. 3: a) Picture taken from the real foam, b) bitmap of this picture.

Thanks to applying solid elements Hex8 [2], a numerical model based on a position of pixels in each bitmap was built. Each white pixel representing the material was transformed to a finite element. The reconstructed cube had a dimension of 35×35×35mm consisting of 100×100×100 cubes, from which 345168 represented the material elements (fig. 4). Porosity of the numerical model was 65% in comparison to porosity of a real foam of 80%. The difference was caused by the limits of graphical software (e.g. a size of pixcels).
A dynamic numerical analysis was carried out with the use of LS Dyna computer code [5]. A compression was performed with two rigid plates - stationary and moving (v = 50 mm/s) one. A piecewise linear plastic material model was used for aluminum (Young modulus E=71000 MPa, Poisson ratio ν=0,33, yield

stress R_e=250 MPa). Although a numerical analysis was dynamic, small differences between static and dynamic compression processes for foams allow to compare it to experiments.

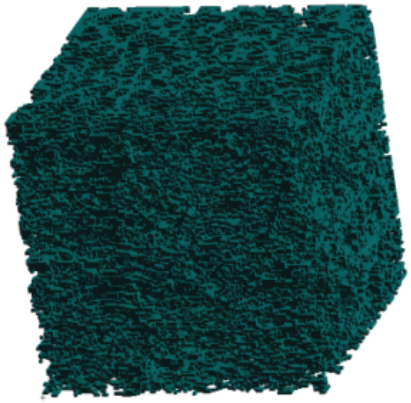


Fig: 4: Numerical model.

Results

During the analysis the relation between load and displacement was studied. The results is presented on a chart below (fig. 5). Also, the deformations of the whole structure and the microstructure were presented in table 1.

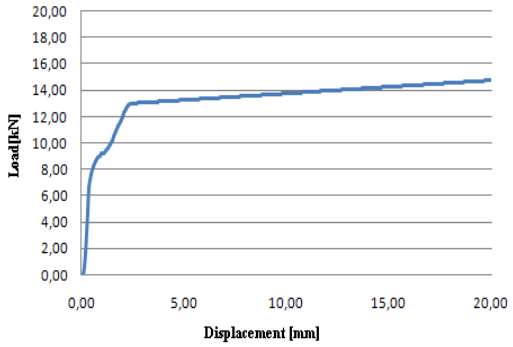


Fig.5: Load-displacement chart from numerical simulations.

It is noticeable that the numerical structure has a larger stiffness than the real foam. It is caused either by higher porosity of the numerical model comparing with real foam, or by inertia of the hitting plate.
The value of absorbed energy per mass unit was calculated for experimental and numerical results what is shown in table 2.
It is shown that the model absorbed more energy than real foam, because of the difference between character of both processes (static and dynamic). The difference between numerical and experimental analysis was 11%. Then the energy absorber by sample groups of 10 elements representative for the whole elements population was measured to assess the microstructural behavior. A result of absorbed energy per mass unit was 7998 kJ/kg what responds to macrostructure behavior. It is in good accordance to experimental results.

Table 1: Global and local views of deformations for some selected stages taken from numerical simulation for compression test.

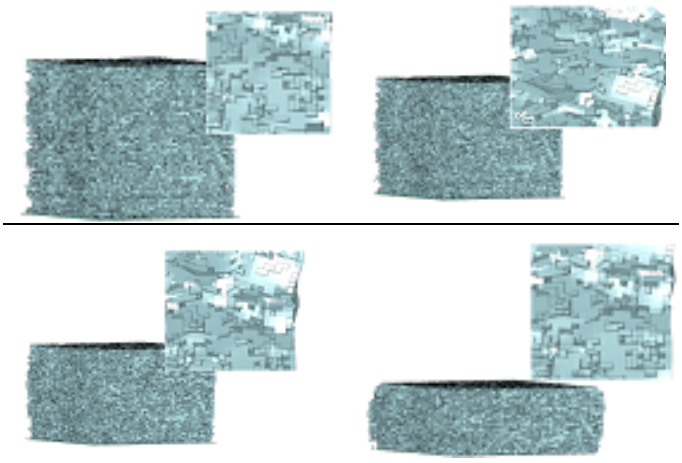


Table 2: Absorbed energy per mass unit.

Experiment	FE Analysis
7374 kJ/kg	8186kJ/kg

Conclusions

1. Despite noticeable difference in porosity between the model and the real foam, the analysis describes the character of the compression process with a high level of accuracy.
2. There was only a slight change in a lateral dimension of the cube.
3. Also the value of absorbed energy per mass unit allows to apply this model in estimations of impact absorbing behavior of closed-cell metal foams.

References

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