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Numerical simulation of the dynamic processes in metal foams. Part II. Compression tests of open cell copper foams

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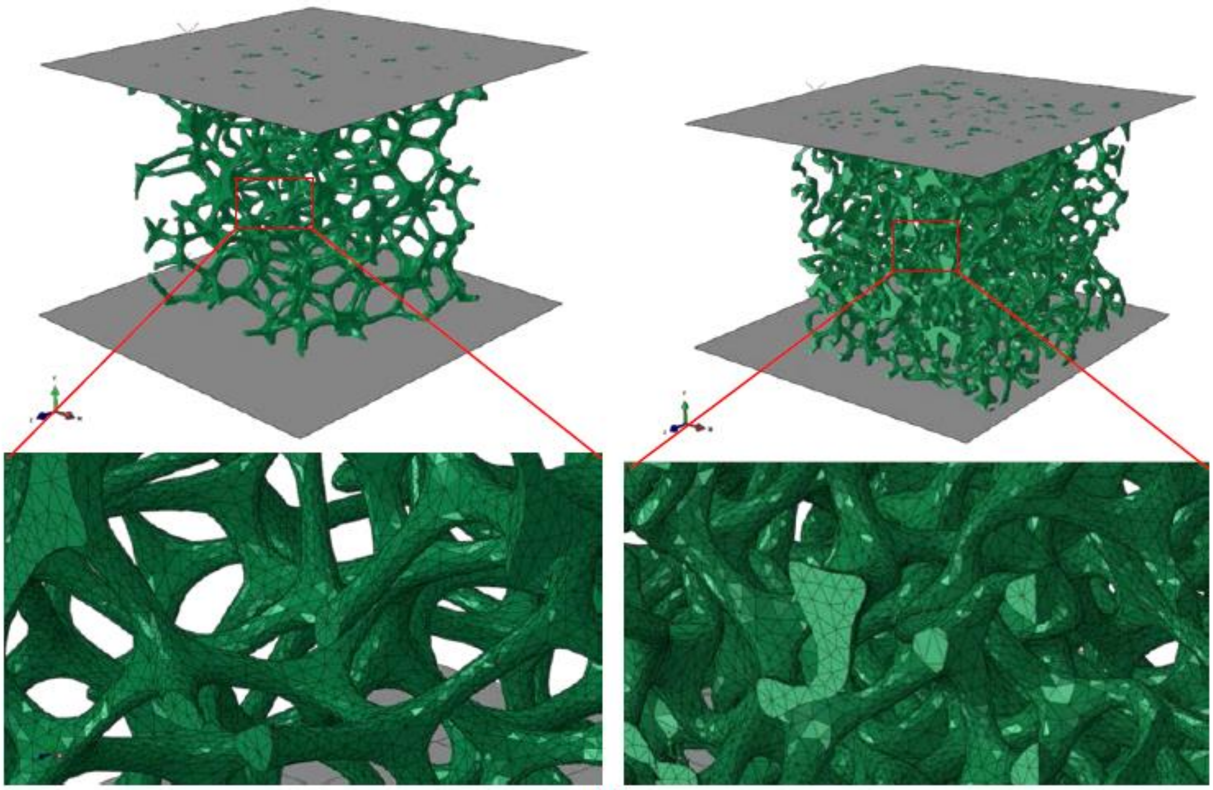
Metallic cellular materials have been widely acknowledged for their multifunctional applications related also with energy absorption capability in addition to their light weight. In recent years, the auxetic materials revealing negative Poisson's ratio have attracted much attention. Up to date, the research of auxetics is mainly concentrating on the cell design [1], [2] and the static response [3], although the auxetic materials also demonstrate potential for energy absorption, fracture retardant, and high-velocity impacts resistance. In the paper, a comparative study is reported on the high-velocity impact responses of two type metallic cellular foams, that is, convex open cell foam [4] and auxetic foam. The impact limits and absorption energy of the two foams are obtained by means of explicit nonlinear finite element simulations using ABAQUS [5]. It has been found that the auxetic foam is superior to the convex cell foam in impact resistance because of the material concentration at the impacted area due to the negative Poisson's ratio effect.

A wide range of impact velocities were considered, which are 5, 10, 20, 25, and 50 m/s, respectively. Finite element simulations have been undertaken by employing ABAQUS program to investigate the deformation mechanisms of cellular skeleton and the high-velocity impacts resistance of corresponding foam materials. The example of virtual foam structures is shown in Fig. 1.



(a) (b)

Fig. 1. The pictures of virtual foams: (a) convex open cell foam of 95 % porosity and (b) reentrant open cell foam of 92 % porosity with generated finite elements mesh using ABAQUS CAE.

To simulate the deformation processes finite element program ABAQUS was used. The computer tomography made the basis for the formulation of computational model of virtual foam and finite element discretization of its skeleton, cf. [6, 7]. The dimension of the finite element corresponds to the dimension of a single voxel equal to 16m. In all numerical calculations the cube-shaped sample of the foam with dimensions of 800x800x800 voxels is considered. Such assumption leads to the representative volume element of the size 2x2x2 mm. The material of the skeleton of the virtual foam is assumed to be isotropic and elastic-plastic. For numerical simulations the constitutive relation is applied which defines the behaviour of oxygen-free high conductivity copper (OFHC) using the experimental data reported in Nemat-Nasser and Li [8] and Rusinek at al. [9]. Finite element calculations are made with use of four node C3D4 tetrahedral elements. The finite elements model consists of 204575 nodes and 670073 elements for the auxetic foam, and 129720 nodes and 506747 elements for convex cell foam. Fig. 1a and 1b represent the virtual foam samples with 92% and 95% porosity. In numerical simulations the bottom surface of the sample is fully constrained and the top surface of this sample is moved parallel to the vertical axis. The resulting force is calculated for each time increment. The comparison of numerical predictions of axial force within the range of velocity (5-50 m/s) are made.

In this work, the impact resistance of auxetic foam is analysed using ABAQUS finite element program. For comparison, the traditional convex open cell copper foam samples of identical dimensions is also included in the numerical study. Using the numerical models, a parametric study has been carried out to examine the effect of impact velocity on the absorbed energy of both types of foams. The main findings from the study can be outlined as follows.
(1) The auxetic foam yields lower final axial displacement for the same compression time and velocity of the impact than the metallic foams with conventional convex cells. The advantage of auxetic foam becomes larger as the impact velocity decreases.
(2) Energy absorption of auxetic foam decreases with increased impact velocity within the investigated range.
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