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ON THE ENERGY ABSORBTION IN OPEN CELL FOAMS UNDER DYNAMIC LOADING

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Abstract:

Metal foams in view of their structural strength and mechanical energy absorption capability under high speed impact can be utilized as energy absorbers. Most commercially available metal foams with the open-cell or the closed-cell microstructure are made of aluminium, nickel, copper, and metal alloys. Many papers in literature provides several examples of metal foams solutions for energy absorption applications, dealing with both experimental, numerical and analytical studies e. g., [2], [3].

The subject of the study are the models based on digital microstructures, in particular open cell metallic foams characterized with the skeleton formed of convex cells. The goal of the presented investigations is to study the impact limits and absorption energy of the convex open cell metallic foams. To simulate the deformation processes the finite element program ABAQUS is used, [4]. The computer tomography made the basis for the formulation of computational model of the foam and the finite element discretization of the skeleton, [5]. From each reconstructed volume, a representative cubic volume element was extracted. The numerical simulations of uniaxial compression test have been performed. For numerical simulations the constitutive elasto-viscoplasticity model is applied that defines the dynamic behaviour of oxygen-free high conductivity (OFHC) Cu using the experimental data reported in the literature. The chosen material model for the numerical simulation is the Cowper-Symonds model in order to investigate and describe problems such as ballistic impacts or problems in which the strain-rates component is relevant. In numerical simulations the cellular specimen in the impact scenario is sandwiched between two rigid walls to impose a velocity compression condition. One wall is fixed and the other wall travels at an initial velocity V0 compressing the cellular specimen and general contact (steel wall-Cu foam and self contact Cu foam) with the friction coefficient 0.35 is assumed. Numerically, the same specimen can be used in different simulations. This ensures that the microstructural randomness of the specimen does not influence our main conclusions. Using the numerical models, a parametric study has been carried out to examine the effect of impact velocity on the absorbed energy of convex type of foam. The numerical predictions with the velocities of 50 and 300 m/s are discussed.

To assess the mechanical performance of cellular material as energy absorbers, the specific energy absorption capacity (SEA) is chosen as evaluating indicator, [1]. The SEA is a dimensional indicator and is defined as the ratio of total energy absorbed up to the densification strain to the mass of foam. The energy absorption efficiency characterizes the variation of effective specific energy absorption with strain during uniaxial compression of cellular structures. A critical criterion of crushing resistance assessment is determined by crushing force efficiency (CFE) and it can be defined as the ratio of peak crushing force (PCF) which can be directly obtained from the load displacement curve and the mean crushing force (MCF) represents the average force during the crushing process.

The energy absorption indicator was resulted from the final step of displacement in simulation of the investigated open-cells copper foam with porosity 96%. The energy absorption is mostly dominated

by the long stress plateau stage, leading to a low loading transmission to the protected structures. From experimental impact tests during impact loadings the collapse of cells and localized deformation crushing zone was observed at the top side of the specimen (see Fig. 1). The difference in velocity between the crushed region and uncrushed region plays a dominant role in energy absorption. The maximum velocity of front-wall increases with increasing impact velocity. The total energy absorption increases with the crushed distance and the dynamic enhancement which is velocity dependent. The cells in the crushed zone may not be fully compressed during the front end moving forward. Cells in this zone were partially deformed, obtaining comparable loading capacity with uncrushed ones. The energy absorption capacity increases with the impact loading, but when the full crush is reached the energy will be maximally enhanced.

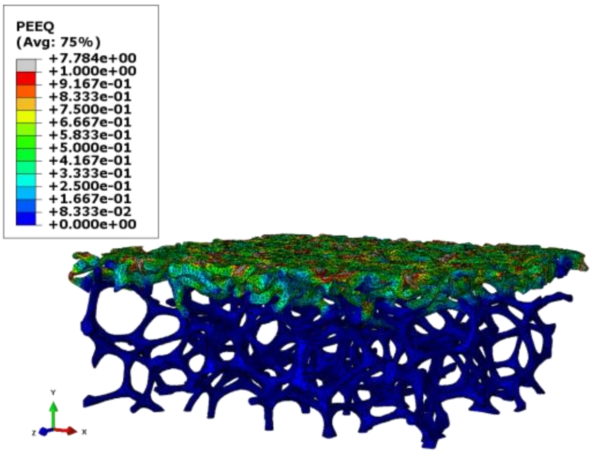

Fig. 1.Equivalent plastic strain distribution for convex open-cells copper foam for wall impact velocity 50 m/s.

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