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Micro–macro analysis of closed-cell aluminum foam with crushing behavior subjected to dynamic loadings

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ABSTRACT

This paper presents three-dimensional micro-macro modeling of foam structure to investigate the responses of closed-cell aluminum foam subjected to dynamic loadings. The response of the closed-cell Alporas aluminum foam under the low velocity impact is investigated numerically and experimentally. In order to access 3D modeling of the internal microstructure of the closed-cell aluminum foam, computerized tomography and unit cell methods are employed. For macro modeling, a solid continuum model is utilized as the crushable foam material. The effective parameters on the impact response including foam density and velocity of the impactor are considered. In order to show the validity and accuracy of results obtained from finite element methods, low velocity impact tests have been conducted and the results are compared with the experimental data. It is demonstrated that the simulated results agree well with test data. The results of the present paper indicate that the adaptation of experimental results with all three methods of macro and micro modeling is more remarkable for low density foam samples. The crushable foam model has the lowest accuracy. CT scan method is the most accurate and in terms of computational cost, the Kelvin unit cell method showed better performance than other models.

1. Introduction

Metal foams are generally composed of aluminum, but they can also be produced by other metals. Foams are materials that in most cases are produced by trapping gas bubbles in a liquid or solid [1–3]. Closed-cell aluminum foams are used in many applications such as automobiles, trains, airplanes and other vehicles [4–8]. Obtaining foam features only by experimental tests has a high cost and possible human errors. Therefore, applying a numerical method that can predict the desired results is essential. Rajendran et al. [9] carried out numerical simulation of closed cell aluminum foam under axial impact due to free fall of a drop hammer. In order to derive the material properties, quasi-static axial crushing tests carried out on foams of three different densities. Parametric study was carried out on foams of various densities for different impact velocities. They showed that elastic fraction of the foam deformation energy become insignificant as the impact velocity of the hammer increases. Song et al. [10] studied the dynamic crushing responses of three-dimensional cellular foams using the Voronoi tessellation technique. They investigated the effects of the cell shape irregularity, impact loading, relative density and strain hardening on the deformation mode and the plateau stress. They found that the plateau stress, the densification strain energy and the capacity of foams absorbing energy can be improved by increasing the degree of cell shape irregularity. Liu et al. [11] studied the effect of strain rate and porosity on the dynamic behavior of aluminum foam. They showed that the effect of air pressure on static stress and strain rate is negligible. The effect of the strength of the cell wall and the amount of porosity are effective in energy absorption value so Fang et al. [12] numerically investigated these effects. Their model had the ability to consider different thicknesses for the walls of the cell. Li et al. [13] investigated one-degree freedom model of impact in order to estimate the amount of the energy absorption of the metallic foam. They stated that the foam behavior in dynamic loading is similar to quasi-static loading, if the velocity of impact is lower than the critical velocity. Nayyeri et al. [14] studied compressive behavior of tailor-made metallic foams under quasi-static compressive loading by considering a representative unit cell. Their analysis revealed that the ratio of wall thickness to the size of cell has the most significant influence on the compressive behavior of tailor-made metallic foams and there was an adequate agreement between the simulation data and the experimental measurements. Wang et al. [15] studied the effects of strain rate and inertia on the deformation behavior of closed-cell aluminum foam under impact

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