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High strength tailor-made metallic foams (TMFs): Development and characterization

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ABSTRACT

Advanced tailor-made metallic foams (TMFs) were successfully manufactured by a novel and unique precision manufacturing technique. Different cellular architectures including ordered, disordered and graded dispersion of polymeric spheres in aluminum matrix were prepared and studied under quasi static loading. The results showed high compressive strength of 40–143 MPa for the as-produced foams while exhibiting low density (1.6–2 g/cm^3). Introducing a gradient architecture within the cells led to higher elastic modulus compared to simple cubic architecture. Also, outstanding specific energy absorption range of 4.6–40 kJ/kg was found to be dependent to the relative density, cell size and architecture of the cells. It was also observed that the main factor governing the properties of the TMFs with the same density was the ratio of the cell wall thickness to the cell diameter (t/D).

1. Introduction

Closed cell metal foams possess unique properties that makes them ideal materials for use as energy and impact absorbers such as automotive structural components, sound barriers and vibration dampeners [1]. However, commercially available metal foams do not achieve the predicted properties derived from the scaling relations, which connect the mechanical behavior of the foam to the bulk material they are produced from. These discrepancies mainly are due to the non-uniform shape and size of the cells [1]. Extensive studies have been done to overcome these inconsistencies. Using hollow spheres and syntactic foams are the best ways to have periodic and relatively defect-free structures [2]. However, variation of cell wall thickness (distances between cells) still remains which might lead to inconsistencies of mechanical properties. The present work is, to the best of our knowledge, the first of its kind that focuses on the tailor-made closed-cell aluminum foams manufactured by a novel and unique precision manufacturing technique. The aim of the study is to produce high strength closed-cell aluminum foams with well-tailored arrangement of cells. Furthermore, the quasi-static compressive response of the as-developed foams were studied and compared with properties of metallic foams available in the literature.

2. Experimental procedure

An innovative method was employed based on a deliberate distribution of spherical cells with different diameters in the foam structure. Mixture of 85 wt% silicon rubber and 15 wt% dolomite ($CaMg(CO_3)_2$) with density of 1.1 g/cm^3 was selected as a base material to produce polymeric spheres with 3, 4 and 5 mm in diameters. In order to evaluate the effect of density, cell size and distribution based on spheres with different diameters repeated in *X*, *Y* and *Z* directions, 10 different architectures were studied (Table 1). To ensure uniform dispersion and to prevent redistribution of spheres during casting, aluminum pins (chaplets) with a diameter of 0.2 mm were employed. The 3D preforms placed into the steel mold cavity and liquid A356 aluminum alloy was poured into the steel mold. After solidification, the samples were cut into the dimension of $36 \times 36 \times 80$ mm^3. Axial quasi static loading of samples was performed using a 25 kN Instron 8502 test machine with the constant crosshead speed of 2 mm/min. The specimens were made in triplicate in order to check the reproducibility and reliability of the results. The density of the as-produced foams was calculated by using samples weight and dimensions while modulus of elasticity, compressive strength, and energy absorption of the samples was calculated from the engineering stress–strain curve.

3. Results and discussion

Cross sectional images of the manufactured TMFs, conventional A356 aluminum foam, steel syntactic and composite metal foam

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