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Evaluation of failure mechanisms of high strength tailor-made metallic foams (TMFs)

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ABSTRACT

Deformation and failure mechanism of A356 matrix tailor-made metallic foams (TMFs) with variety of sample aspect ratio (H/D), cell wall thickness to the diameter (t/D) and density was studied under quasi-static compressive loading. Four distinct deformation sections were characterized in the stress strain curves; elastic, initiation of plastic, plastic and densification. The plastic deformation of TMFs before crack initiation increases with increase of t/D ratio and density of the TMFS. Likewise, stress drop due to formation of cracks shows a direct relation to the t/D and density. Crushing of spheres, shear fracture and Griffith rupture were observed as main failure mechanisms in A356 matrix TMFs. It was seen that the H/D ratio of the samples is the main governing factor that favors rupture or shear fracture while t/D controls crushing of cells or shear fracture of A356 matrix TMFs.

1. Introduction

Metal matrix syntactic foams were introduced as a class of composite materials consisting of a continuous metal matrix embedded with hollow or porous spheres [1]. Due to their periodic and relatively defect-free structures, metal matrix syntactic foams (MMSFs) are promising materials for applications in lightweight structures and energy absorbers against impact [2]. Despite the attempts for enhancement of mechanical properties and energy absorption capability of MMSFs, there are fewer researches which have been focused on deformation and failure mechanism of syntactic foams [3–5]. During compressive deformation of MMSFs, different compressive behaviors and failure mechanisms have been observed [4,6,7]. Although ductile failure, brittle fracture or rupture are common, there are no comprehensive criteria available to predict the failure mode of metal matrix syntactic foams under compression. Recently, tailor-made metallic foams (TMFs) have been introduced as a new generation of metallic foams based on tailor making cell architecture which exhibit superior mechanical properties due to their controllable and ordered structure [8]. The aim of this study is to investigate the compressive behavior along with effect of designing parameters on deformation and failure mechanisms during quasi-static compression.

2. Experimental procedure

A mixture of high temperature resistant polymer and dolomite, with density of 0.9 g cm^{-3}, was selected as a base material to produce spheres with 5 mm diameter in this study. In order to evaluate the effect of density, cell wall thickness and aspect ratio of the specimen, different architectures (t/D ratio of 0.33–1) were designed. The 3D preforms placed into the steel mold cavity with aluminum chill and liquid A356 aluminum alloy was poured into the mold. After solidification, the produced foam was removed and samples were cut into the desired dimension of 35×35 mm^2 and aspect ratio of 2–2.6. To evaluate the compressive behavior of as-produced foams, axial quasi-static loading was performed using 25 kN Instron 8502 test machine with the constant crosshead speed of 2 mm/min.

3. Results and discussion

A typical compressive stress strain curve of A356 matrix TMFs sample is illustrated in Fig. 1, where four distinct deformation sections can be identified. These sequences from initial elastic region to complete densification, can be linked to five stages of the deformation, and are summarized as follows:

1. Elastic region in which the materials experience only elastic deformation (up to the point a) and the spheres remain intact and undamaged (Fig. 2(a)),
2. Initiation of plastic deformation (point a). At the end of this

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