Composite Structures 159 (2017) 316–326

Contents lists available at ScienceDirect

Composite Structures

journal homepage: www.elsevier.com/locate/compstruct

Numerical evaluation of the stacking effect of spheres on the mechanics of tailor-made aluminum foams

Mohammad Javad Nayyeri, Seyyed Mohammad Hossein Mirbagheri *, Davoud Haghshenas Fatmehsari

Department of Mining and Metallurgical Engineering, Amirkabir University of Technology, Tehran, Iran

ARTICLE INFO

Article history:
Received 13 July 2016
Revised 8 September 2016
Accepted 24 September 2016
Available online 26 September 2016

Keywords:
Aluminum alloy
Syntactic foams
Tailor-made Metallic Foams
Finite element
Response surface method
Mechanical property

ABSTRACT

The effect of different stacking of simple cubic (SC), body centered cubic (BCC) and face centered cubic (FCC) on the compressive characteristics of tailor-made aluminum foams (TMFs) was evaluated by the use of both response surface methodology and finite element technique. Quadratic polynomial models for describing the mechanical characteristics in terms of cell size (D), cell wall thickness (t) and height of cell layers (h) were developed. The statistically developed models revealed that t/D ratio has the most significant effect on the compressive characteristics of TMFs while the cell size showed a complex effect on the structural stiffness. Furthermore, despite the negligible importance of D, h is directly related to the strain hardening leading to an increase in plateau stress at higher value of t/D and h/D. Moreover, it was indicated that FCC arrangement has higher densification while SC arrangement absorb more energy during deformation.

1. Introduction

Metal matrix syntactic foams (MMSFs) were introduced as a class of composite materials in which hollow/porous spheres are embedded in a continuous metal matrix [1]. The mechanical properties and energy absorption capability of MMSFs are the decisive factors in their application as the energy and sound absorbents, collision dampers and as the material of hulls and shells in the deep-sea applications, aeronautics and automotive industries [2–4]. Many researchers have focused on enhancement of mechanical properties and energy absorption capability of MMSFs [2,5–10]. The MMSFs can effectively provide opportunities for further tailoring the energy absorbing properties of the material [11–13]. This can be accomplished by the appropriate selection of matrix and heat treatment regimen as well as the reinforcement composition, wall thickness, diameter and volume fraction [14,15].

A survey of previous literature provides some information about the modeling/simulation of MMSFs. Most of the modeling/simulation works have focused on the evaluation of elastic behavior of the MMSFs. Marur [16] studied the elastic behavior of hollow microsphere filled composite by using analytical and numerical approach; also, the influence of particle distribution on the elastic moduli properties was evaluated using 2D and a full 3D finite element method. Although his analytical and numerical results had a good agreement, there was a slight incompatibility in moduli due to different particle distribution. Bardella et al. [17] developed a micromechanical model employing finite element technique for the prediction of the effective elastic moduli of syntactic foams. Besides, Marcadon and Feyel [18] quantified the contributions of both the stacking architecture of hollow spheres and the constitutive material's mechanical properties on the mechanical behavior of metallic hollow-sphere structures under quasi-static compressive loads. In addition, Gao et al. [19] showed that the hexagonal close packed (HCP) arrangement is the best choice for the energy absorption purpose because of its highest plateau stress; however, the difference in the specific energy absorption of the various regular packaging arrangements implies the crucial role of the relative wall thickness h/R rather than packaging pattern. Santa Maria et al. [3,5,20] proposed a model based on both theoretical and experimental approaches for the prediction of mechanical properties of metal matrix syntactic foams. The main advantage of their work is the consideration of mechanical and physical properties of the matrix together with the ceramic hollow spheres and volume percentage of the hollow spheres. Moreover, Orbulov and Májlinger [21] and Antunus et al. [22] employed a multi-phase model to predict the compressive behavior of MMSFs. Their results indicated that the rigidity of the matrix is the most influential factor on the mechanical properties of the MMSFs. Also, they reported that the mechanical behavior of the samples is related to the size and volume fraction of the hollow spheres, elastic properties of both spheres and matrix and thickness of the hollow spheres.

* Corresponding author.
E-mail address: nayyeri@aut.ac.ir (S.M.H. Mirbagheri).

http://dx.doi.org/10.1016/j.compstruct.2016.09.072
0263-8223/