Metals and Materials International
https://doi.org/10.1007/s12540-019-00502-0

Micro-Structure Analysis of Quasi-Static Crushing and Low-Velocity Impact Behavior of Graded Composite Metallic Foam Filled Tube

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Received: 30 August 2019 / Accepted: 10 October 2019

Abstract

Foam filled tubes (FFT) are novel structures with high energy absorption, enhanced strength to weight ratio, and tailoring capability. In the present paper, we have analyzed quasi-static uniaxial compression and low-velocity impact behavior of FFT with closed-cell metallic foam cores and functionally graded densities both experimentally and numerically. Alporas foams were manufactured using liquid state method with TiH_2 blowing agent. We prepared Specimens with graded composition and densities by stacking of several layers of pure aluminum and A356 alloy Alporas foams with cubic geometry. We conducted several standard uniaxial compression experiments to determine the non-linear mechanical properties and hardening. Square aluminum tubes are manipulated to enhance the performance and tailoring specification of the structure. We generated microstructural models using a hybrid 3D Voronoi diagram and CT-scan images to predict mechanical behavior numerically. Computed tomography is used to determine the inner cells morphological characterization. Also, the modified Kelvin cell with a beam element in edge regions is manipulated to enhance accuracy. Comparing the quasi-static experiment and FEA results show good accordance, and hence, we achieved the calibrated model. Finally, we used the numerical model in FFT tailoring and mechanical properties design.

Keywords Microstructure · Foam filled tube (FFT) · Voronoi diagram · FEM · Graded cellular solid

1 Introduction

Cellular solids, especially metal foams, have rather irregular microstructure [1]. So generating a micro-model is essential for mechanical behavior analysis. There are several methods for geometrical modeling of cellular structures such as Kelvin and other unit cells, Voronoi diagrams, CT scan images geometric reconstruction, stochastic placement of voids, and soap froth. Furthermore, there are several standard methods for material properties characterization, such as uniaxial compression and tension, microhardness, and Nanoindentation. Microstructural damage investigation with SEM and optical microscopes has done by Yuan. They model microstructure using Kelvin unit cell with thin shell faces and simulate uniaxial compression and effect of cell edges material properties by FEM and experiments [2]. Kadkhodapour et al. present an approach bridging micro-deformation to macro-mechanical properties in closed-cell metallic foams using FEM and experiments. They used several unit cells such as spherical and elliptical, to model micro-structure and investigated the effects of relative density and topology [3]. A comprehensive study is conducted on Alporas foam mechanical properties by Jang et al. they analyzed foam specimen shape and dimensions and their effects on uniaxial compression behavior. They employed various unit cells in the numerical modeling of cellular structure [4]. Nammi et al. are also worked on closed-cell lattice numerical modeling using unit cell approach. They used spherical-cubic and cruciform cells

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Published online: 04 December 2019