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Heat Treatment of Closed-Cell A356 + 4 wt.%Cu + 2 wt.%Ca Foam and Its Effect on the Foam Mechanical Behavior

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In this investigation, aluminum-silicon alloy foam is developed by adding certain amounts of copper and calcium elements in A356 alloy. Addition of 4 wt.%Cu + 2 wt.%Ca to the melt changed bubbles morphology from ellipsoid to spherical by decreasing Reynolds number and increasing Bond number. Compression behavior and energy absorption of the foams are assessed before and after aging. Solid solution treatment and aging lead to the best mechanical properties with 170% enhancement in yield strength and 185% improvement in energy absorption capacity as compared to non-heat-treated foams. The metallographic observations showed that bubbles geometry and structure in the A356 + 4wt.% Cu + 2 wt.%Ca foam are more homogeneous than the A356 foam.

Keywords aging heat treatment, aluminum-A356 foam, energy absorption, mechanical properties, solidification and casting

1. Introduction

Metal foam is an advanced engineering material which is gaining more importance in high-tech applications due to its interesting properties such as improved mechanical properties to weight ratio, excellent impact energy dissipation, low thermal conductivity, and acoustic properties (Ref 1). Previous investigations have focused on the mechanical properties of foam upon uniaxial compression, both through experimental work and numerical simulations such as finite element method (FEM) (Ref 2). Based on their structure, metal foams are categorized into two major types being the open-cell and the closed-cell foams. Potential applications of closed-cell foams are in mechanical energy absorption, sound and heat dissipation. But open-cell foams are used in batteries, filtration, and heat exchanger industries. Several process-routes have been developed to make metal foams (Ref 1, 3, 4). The process employed to fabricate foams from molten metal by using a foaming agent is known as ALPORAS process-route (Ref 4). Basic steps for producing foams through ALPORAS route are similar to make bubbles in water by stirring washing powder in water and froth it up. However, in molten aluminum, foaming agents such as TiH_2 or $CaCO_3$ produce gases like H_2 and CO_3 (Ref 1, 5). Literature review shows that after melting and addition of blowing agent, time and temperature of stirring for obtaining a foam with very fine bubbles (nucleation of bubbles) are deterministic (Ref 6-8). However, after rapid casting of the molten foam in the hot mold and its transfer to a furnace, time and temperature of foaming (growth of the bubbles) are two essential factors in obtaining homogenous solid foam with arbitrary density (Ref 9). Bubbles homogeneity in the cross section of a metal foam sample is dependent on the stirring- and foaming time which in turn depends on furnace temperature (Ref 3, 10, 11). Another important factor to be taken into account (before addition of the blowing agent) is the viscosity of the melt (Ref 9, 10, 12, 13). Generally, viscosity is controlled by adding some materials like Ca granule, Si, and SiC powder (Ref 7, 14). The majority of the researches on compressive properties of metal foams have reported mechanical properties including Young's modulus, yield strength, densification strain, and deformation energy absorption that obtained from stress-strain curve during ASTM E9 standard test (Ref 15-18). However, there is a serious need to develop technology that improves mechanical and metallurgical properties of metal foams especially energy absorption capability (EAC). Heat treatment process can improve the EAC of metal foams by aiding modification of microstructure (Ref 19, 20). In contrast, foams produced by powder metallurgy, effect of heat treatment on the EAC of cast aluminum alloy foam is not fully understood (Ref 12, 21). In this respect, introducing new foam materials with the ability of aging is considered as a great progress in the field of advanced materials.

In this paper, a systematic attempt is made to investigate the EAC and the mechanical properties of A356 aluminum alloy foam and a new closed-cell foam (A356-4 wt.%Cu + 2 wt.%-Ca) under different heat treatment cycles.

First, an innovative closed-cell Al alloy foam was produced by TiH_2 decomposition in the molten alloy, casting in a metallic mold, foaming in a furnace, and then quenching in water. Then, obtained foams were cut and aged followed by compressing under uniaxial loading. Finally, microstructure, mechanical properties, and the EAC of all samples were investigated.

2. Experimental Methods

2.1 Materials

A356 aluminum alloy ingot with nominal composition according to ASTM standard (UNS: A03560) was used in this

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