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Effect of processing parameters on cell structure of an aluminum foam

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Abstract

A closed cell aluminum foam with the same composition but different cell sizes and structures was prepared by changing air injection rate and impeller speed during foaming process to study the influence of air injection rate and impeller speed on cell structure. The foams prepared under the foaming conditions are characterized as roughly equiaxed polyhedral cells with density range of 0.1–0.22 g/cm^3 and cell diameter of 4–11 mm with different cell wall thickness and Plateau border size. Cell size of the aluminum foam is increased with increasing air injection rate, and higher impeller speed results in a much smaller cell size at given air injection rate. Cell wall thickness and Plateau border size of the aluminum foams are decreased with the increase in cell size. Moreover, the higher impeller speed produces smaller size of the foam cells with thicker cell wall and Plateau border size, resulted in higher density foam in contrast to the foam with the same cell size prepared at lower impeller speed.

Keywords: Aluminum foam; Air injection; Impeller speed; Cell size; Foam density

1. Introduction

Closed cell aluminum foam offers a unique combination of properties such as low density, high stiffness and energy absorption [1–4]. Through design of microstructure, the properties of aluminum foam can be made to vary greatly for the demands of specific engineering applications. Closed cell aluminum foam can be manufactured by introduction of air into molten aluminum composites [5,6]. The injected air causes bubbles to rise to the surface of the melt, forming liquid foam which is stabilized by the presence of solid ceramic particles on the gas liquid interfaces of the cell walls. The stabilized liquid foam is then mechanically conveyed off the surface of the melt and allowed to cool to form a solid slab of aluminum foam. With the development of the technologies for the production of aluminum foams, researchers have long realized that the physical and mechanical properties of aluminum foams are not only governed by cell wall material and the volume fraction of the solid [3], but also affected significantly by geometry of the cell structure [7,8]. In the case of the closed cell aluminum foam by air injection, the cell structure (size and wall thickness) is controlled by the process variables including the shape and dimensions of foaming chamber, size and volume fraction of the solid particles, foaming temperature, air injection rate, impeller design and impeller speed during foam production [9].

Aiming at structure and property control of the closed cell aluminum foam, the current authors prepared a closed cell aluminum foam with the same composition but different cell sizes and structures by changing air injection rate and impeller speed during foaming process. This paper reports the work on the influence of air injection rate and impeller speed on cell structure of the closed cell aluminum foam.

2. Experimental procedure

The closed cell aluminum alloy foams were prepared at constant foaming temperature by injecting compressed air into an aluminum alloy melt with solid SiC particles as a foam stabilizer. The setup of the foaming experiments is published elsewhere [9]. The air injection rate was varied from 0.5 to 2.0 l/min at a constant pressure with a rotation speed of the impeller at 400, 600 and 800 rpm, respectively.

For cell size evaluation, the specimens with a cross-section of 90 mm × 90 mm and height of 40–80 mm were cut from foam slabs with different foaming conditions. The height of the spec-

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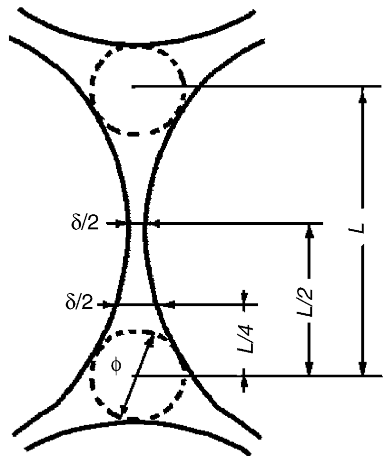


Fig. 1. Schematic description of cell wall and node geometry.

imens was at least seven times of the cell size. The shape of the foam cells was observed visually, and the densities of the aluminum foams were calculated by weight and dimensions of the specimens. Cell size was measured for at least 400 cells for the foams processed at different conditions by using mean intercept length technique. A sketch of the cell wall and Plateau border (node) geometry is shown in Fig. 1 where the cell wall thickness, $\delta/2$ and $\delta/4$ at $L/2$ and $L/4$ of the chord length, L were measured for 20 cells using a digital caliper with 1 μm resolution, and the node size ϕ, was measured under microscope (avoiding distortion caused by the angle of sectioning). The cells for the measurement of wall thickness and node size were chosen from mean-sized cells in order to reveal the relation between the cell size and dimension of the cell structure.

3. Experimental results and discussion

3.1. Microstructure

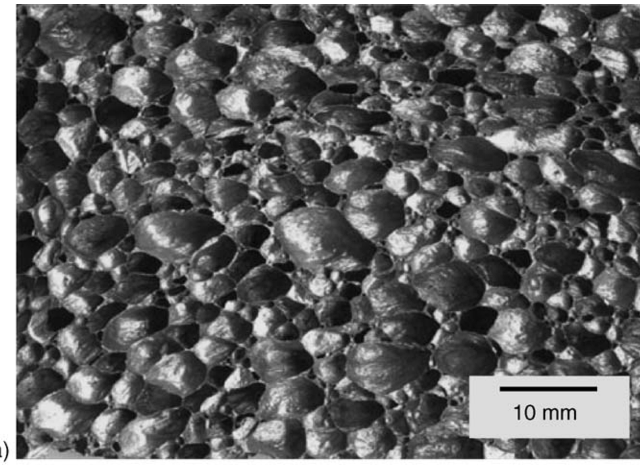
The representative morphology of the aluminum foam is shown in Fig. 2. Macrostructurally, all the foams with large or small cell sizes prepared under the foaming conditions are characterized as low density foams consisting of roughly equiaxed polyhedral cells which differ from the more spheroidal ones of Alporas foams of higher density [10]. The foam cells contain approximately 12–14 cell faces and 5 edges per face, and the cell sizes of the closed cell foams span from 4 to 11 mm in diameter for all the preparation conditions.

3.2. Cell size

The relation of cell size, Φ as a function of air injection rate at different impeller speeds is shown in Fig. 3. Obviously, the cell size of the aluminum foam is increased with increasing air injection rate and impeller speed. The stirring at 800 rpm results in a much smaller cell size at the range of air injection rates, compared with the larger cell size produced at 600 rpm impeller speed.

An impeller speed of 400 rpm did not produce a sufficiently strong vortex to break up the injected air by shear force. Consequently, most of the air bubbles formed in the melt were large and unstable, and they burst on reaching the melt surface. A few stable bubbles ascended to the top surface of the aluminum melt and formed an initial hull of two or three layers of roughly ellipsoidal foam cells. The ensuing foaming caused the shape of

(a)



(b)

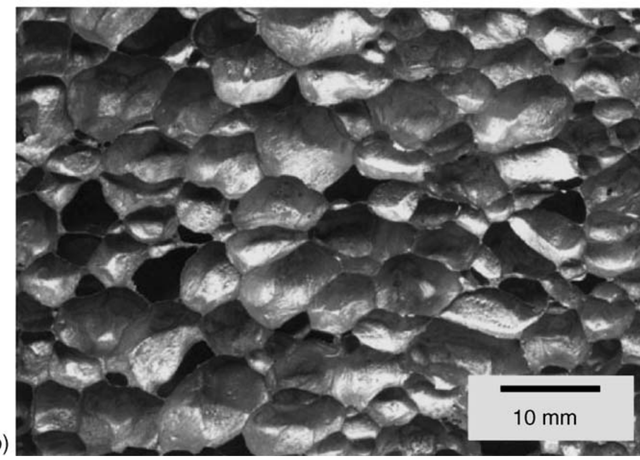


Fig. 2. Macrographs of the aluminum foams with cell sizes of (a) 4.3 and (b) 9.0 mm.

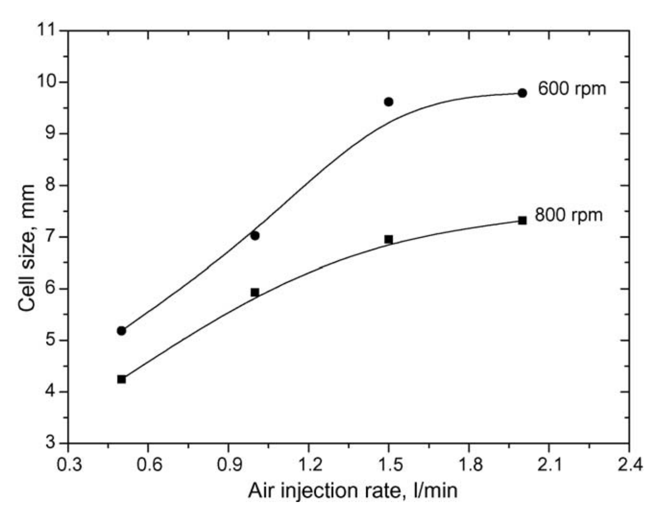


Fig. 3. Cell size of the aluminum foam as a function of air injection rate at different impeller speeds.