

MANUFACTURING OF COMPOSITE METAL FOAM BY DIRECTLY FOAMING AT SEMI SOLID TEMPERATURE

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Abstract

In this study, closed cell AlMg4.5Mn0.7 / SiCp composite metal foam were produced by direct foaming at semi-solid temperature. Effect of reinforcement size and fraction on linear expansion, relative density and pore distribution were investigated. With increasing fraction of reinforcement and decreasing size of the SiC particle, linear expansion of foam is increased, relative density of foam is decreased, pore size is become smaller and more uniform distribution of pores have been observed.

Keywords: Composite metal foam, SiC, semi-solid, direct foaming

INTRODUCTION

Metal foams keeping a combination of many advantageous properties of metals with low relative density, are cellular materials containing pores filled with gas. If pores insulated by metal walls from each other is referred to as closed cell metal foam. If pores interconnected with each other is referred to as open cell metal foam or metal sponge. Because of consisting different physical and mechanical properties metal foams is become more popular and new applications of metal foams are brought out each passing day. Metal foams are very attractive materials, sound and thermal insulation, impact and vibration damping ability, high specific stiffness, reduced thermal and electrical conductivity with not flammable and light weight for lots of industries such as automotive, construction, aerospace and aviation [1, 2, 5].

Production methods of metal foams to be produced in a variety of methods, mainly in the form of production can be divided into solid and liquid state. At solid state production methods to be used as metal powders and foaming agent powders prepared precursors have a specific shape is compressed by various methods. While precursor is kept at a temperature above the melting point of the metal, in the pore formation of structure is provided with foaming agent gas releases.

Also the production of composite foam carried out that powder mixture prepared initially was added into the ceramic powders. The necessity of precursors compaction and its taking into oven, limits the number and size of the foam product. Compared to the liquid state methods, although control of foam structure is easy in solid-state production method, usually equipments are expensive and the cost higher due to the use of powder metal. [1, 3, 4].

For liquid state production is used several methods such as adding blowing agent into melt or directly blowing into melt [1, 2, 3, 4]. Due to liquid state production methods requires temperature above melting point, occur some problem such as blowing agent release gas earlier, escape the gas into the melt and undesired interfacial reactions. However heat treatment of powder lessens the problems, it cause to increase process time and cost. One of the most important problems of liquid-state production methods is low strength due to the thin wall thickness. Before the addition of blowing agent, with ceramic powders adding into liquid metal can be made a little improvement at strength [7, 8, 9]. Reinforcement powders collected on the cell wall effect to prevent over-growth of cells, mergers and collapse [6, 9]. These methods are relatively low cost and although they are more suitable for continuous production; is not

reaching the desired cell wall thickness and uniform cell distribution is a problem. In direct foaming method with semi-solid stirring; reinforcement and blowing agent stirs into metal melt at semi-solid temperature range of metal [10]. Stirring powders into the high viscous melt and providing uniform distribution of powders become easier. Because of this method requires low temperature, interfacial reactions reduce and blowing agent gas release without need heat treatment will be delayed. Due to the use of reinforcement and the foaming at relatively low temperatures; problems such as cell collapse, cell merge and excess growth of cells can be eliminated [6, 9]. To reach the desired cell wall thickness enables the production of high strength foam. This method is more suitable for continuous production then solid and liquid state methods [6]. In this research, closed-cell composite metal foam were produced by direct foaming method using semi-solid stirring process and was investigated that rate and size of ceramic powder effects on foaming behavior.

EXPERIMENTAL PROCEDURE

A. Material Selection

As matrix material for the production of composite metal foam AlMg4.5Mn0.7 (EN AW 5083) aluminum alloy was used. Due to high corrosion resistance and high fatigue strength of this alloy, are frequently used in the construction of structural element, storage tanks, machinery and vehicle bodies in many sectors such as rail transport, shipping, automotiv [11]. Two different sizes of SiCp powder used in the production of SiCp reinforced EN AW 5083 composite metal foam. 1 μ m and 12 μ m average size SiCp powder were stirred into the matrix at different rates (5%, 10%, 15%, 20%) as received. Also metal foam were produced for understanding effect of SiCp on foam structure.

TiH₂ (98 wt% fine powder, about 44 μ in size, supplied from Merck, Germany) were used as blowing agent without any treatment.

Table 1. Material specifications

Powders	Grids	Size (μ m)	Purity
TiH ₂	F325	< 44 μ m	98 wt%
SiCp	F500	12.8 μ m	99 wt%
SiCp	F1200	3 μ m	99 wt%

B. Experimental Setup

Heating EN AW 5083 alloy at semi-solid temperature and SiCp with blowing agents adding to alloy was performed into silicon carbide crucibles. Internal temperature of furnace was set 750°C and kept at this temperature during production. During production after the addition of reinforcing and foaming agents, for a straight volume progression of the formation of foam, melt which taken from crucible were transferred to the molds. Autoclave cellular concrete (ACC) molds were designed as open top face for is not limiting foaming [6].

During production, melting and stirring processes was carried out under protective nitrogen gas. Its known that if not provided protective environment, due to oxidation of matrix and reinforcement material, create a mixture will become difficult, clumping will formed and will not achieve desired reinforcement ratio [10].

C. Production

Crucible with solid Al pieces was placed into furnace when internal temperature of furnace was 750°C. Aluminum alloy is heated until semi-solid temperature and it were kept at semi-solid temperature by the addition of solid aluminum pieces throughout the process. Various proportions of SiCp powder was added into semi-solid material while suitable viscosity has been obtained. Until ensured that uniform distribution of SiCp, 4-6 minutes stirring process was performed. Stirring period was prolonged; stirring process was become relatively hard with increasing proportion of SiCp. 0.5 wt. % TiH₂ was used as a foaming agent was added into melt and 2 minutes stirring process was performed after homogeneous distribution of reinforcement powders was established. Foamable melt was transferred into mould.

For releasing H₂ gas from blowing agent and forming pores in melt moulds was kept by 9 min at 750°C then taken out of the furnace was left to cool in the open atmosphere. In order to determine changing foam forming with time, to obtain best distribution and size of pores different foaming time (7, 9, 11 min) was tried.

For micro-structure analysis of composite metal foams, Jeol JSM-6335F Field Emission Scanning Electron Microscope device was used.

Archimedes principle was used for measuring density. Foams was coated with a thin film layer, the weights was measured in the air and water by using a precision weighing with 1 / 1000 g accuracy.

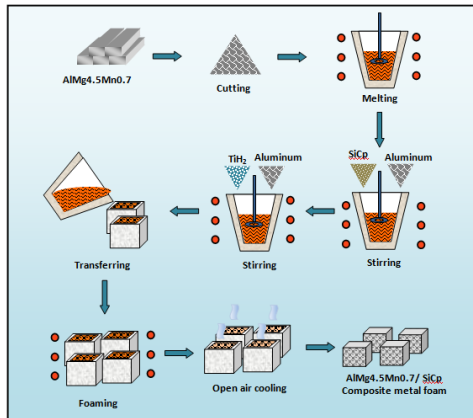


Fig. 1. Composite metal foam production stages [6]

RESULTS AND DISCUSSION

In this study, AlMg4.5Mn0.7 alloy reinforced with SiCp composite metal foam was produced. Effect of reinforcement size and fraction on linear expansion, relative density and pore distribution were investigated.

Density of composite foam varied depending on the amount of linear expansion, cell structure and distribution, porosity the ratio was realized. At the same time the temperature and foaming time of production, is very effective on the foam density.

With increasing fraction of reinforcement, density of composite metal foam decreased and porosity was increased. Depending on the fraction of reinforcement, relative density of foams was varied between 0.44 - 0.87 g/cm³. 65-85 % porosity was achieved.

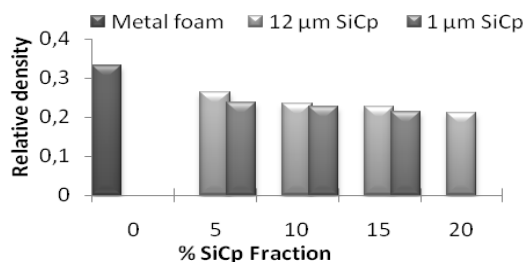


Fig. 2. Changing of relative density with different fraction of SiCp

It's known that in composite materials production reinforcement ratio increases with increasing density of the material [10]. For this reason, changing relative density with reinforcement ratio was examined. It was found that reinforcement ratio is directly proportional with porosity and porosity increase with increasing reinforcement ratio.

In order to determine effect of foaming time on pore size and distribution, different time interval was tried. Pore size and distribution are closely related to the duration of foaming was observed. The growth of pores and porosity were increased with increasing waiting time of melt in the furnace. While prolonged time of waiting melt in furnace, increasing porosity of foam and growing sizes of pores was found out (Fig.3).

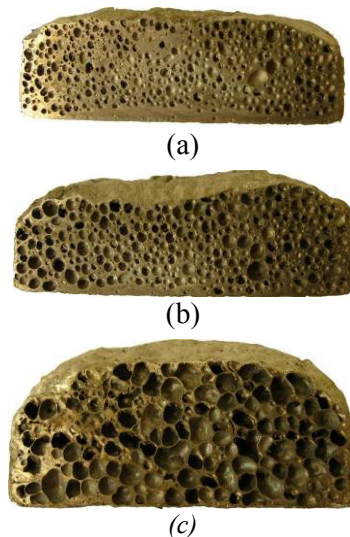


Fig. 3. [6] Formation of pore with different foaming time, a) 7 min, b) 9 min, c) 11 min

It was achieved that composite metal foam produced with different fraction of reinforcement by direct foaming at semi-solid temperature. Controlling pore distribution of metal foam was not been achieved and non-uniform pore distribution was observed. SiCp reinforcement was helped to obtain cell stabilization. Stirring problem of reinforcement and blowing agent powders into melt was overcome by viscous melt at semi-solid temperature. With increasing fraction of SiCp, pore size becomes smaller and more uniform structure was obtained. Increasing SiCp positively effect on linear expansion of foam was observed (Fig. 4). Decreasing the amount of drainage in foam was seen with increasing

SiCp fraction. Reinforcement powders were collected on the cell wall and were affected to prevent over-growth of cells, mergers and collapse.

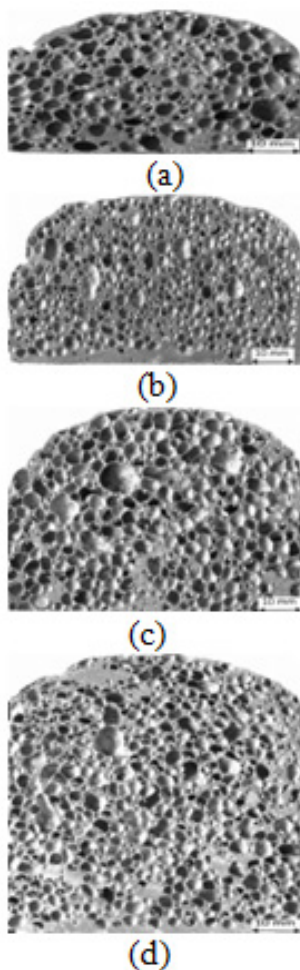


Fig. 4. Product of foam with different fraction of SiCp (12μm) a) %5, b) %10, c) %15, d) %20

Micro structural analysis of composite foams shown that SiCp powders spread homogeneously on cell wall (Fig.5.a) and sink in matrix material (Fig.5.b) .

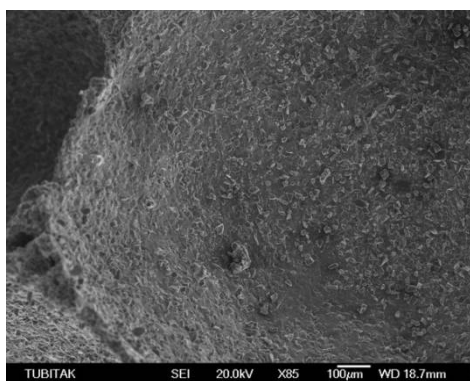


Fig. 5. a) 20% wt. SiCp (12μm) composite foam

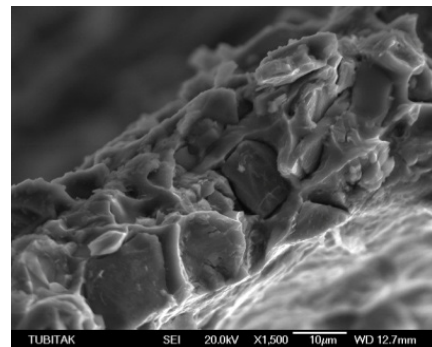


Fig. 5. b) 15% wt. SiCp (12μm) composite foam

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