A New Method for Production of Porous Aluminum Castings

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Received: 10 November 2011, Revised: 1 Mars 2012, Accepted: 2 August 2012

Abstract: Porous materials are commonly found in nature and as industrial materials such as wood, carbon, foams, ceramics and bricks. In order to use them effectively, their mechanical properties must be understood in relation to their micro-structures. Foam made from non-flammable metal will remain non-flammable and the foam is generally recyclable back to its base material. Metallic foams mainly have physical properties of their base material This research work is mainly concentrated in producing porous aluminum castings by melt route using soaked Precursors, steel net, and aluminum net with casting around granules technique. Additionally the properties like density and % Porosity was calculated as well.

Keywords: Density, Metal Foams, Porous Castings, % Porosity, Rotating Die

Reference: Shaik Dawood, A. K. and Karuppusami, G., ‘A New Method for Production of Porous Aluminum Castings’, Int J of Advanced Design and Manufacturing Technology, Vol. 5/No. 3, 2012, pp. 9-13.

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1 INTRODUCTION

Metal foams (MF) are porous metal manufactured using state-of-the-art production technologies [1]. Open pore metal foams generally have a cellular structure made up of 3-D interconnected network of solid plates that form the edges and faces of the cells. In metal foam, typically 60-98% of the structure is made of pores. It may have many interesting combinations of physical and mechanical properties, such as high stiffness to weight ratio and high gas permeability combined with high thermal conductivity [2].

MF is applied in many areas of engineering such as mechanical, chemical and medical applications. Although some of the metal foams have been manufactured for decades, new foams with enhanced properties are continuously being introduced in the market and their use in new applications is expected to grow in the near future. Their light and stiff structure offer performance gains such as efficient absorption of energy, thermal management, acoustic control, and perhaps more specialized applications in the near future. They are recyclable and nontoxic [5]. In this research paper, aluminum is selected for conducting experiment. It is a light weight, low melting point metal which is easier to process through melt route. Melt route, is the most attractive and cheapest method for producing porous castings, compared to other processes like powder metallurgy.

2 LITERATURE SURVEY

In recent years, there has been a strongly growing demand for the use of metallic foams. Metal foams are a special class of porous materials with novel physical, mechanical, thermal, electrical and acoustic properties [6]. Presently metallic foams are finding application in automotive, railway and aerospace industries where weight reduction and improvement in safety is needed. Metal foams have considerable applications in multifunctional heat exchangers [3].

Metal foam heat exchangers have substantial advantages compared to commercially available heat exchangers under nearly identical conditions. They provide substantially more heat transfer surface area, more boundary layer disruption and mixing leading to larger heat transfer rate [4]. The development of new porous material structures will be a thirst for material researchers.

Generally foams can be produced by three techniques. The first method, called The Replica Technique, can be defined as packing a soluble salt in a mould to have a pattern, casting the molten metal around these granules and finally removing the pattern. A more recent method is defined as using a reactant and foaming agent or injection in the melt. The foaming agent and the reactant are mixed after pretreatment in to the melt through mechanical stirrer, and are allowed to dissociate. The foaming agent to releases gases so that metallic foam is formed.

In the second method, called sintering and dissolution process, the powders have been used to produce a dense two-phase precursor where one phase is water soluble. The powders are mixed and compacted, forming double connected structures of both phases as purging gases during solidification. After furnace sintering by dissolving the leachable phase, foam is produced [7]. The third method uses pre-shaped cores. Fig. 1 shows Melt route methods for production of metal foams.

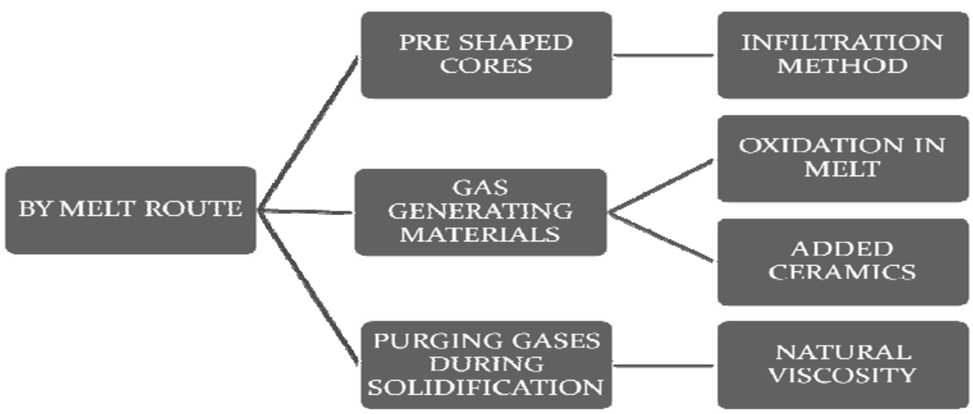

Fig. 1 Melt route methods for production of metal foams

Transport vessels made of aluminum can carry more cargo with the same amount of fuel than vessels made of other materials as the aluminum itself it so much lighter. These relatively low thermal points help aluminum to be reshaped, and welded quite easily. Hardness is the ability of not being easily scratched and is measured in Pascal’s or force per unit area. Aluminum’s hardness is relatively low due to its low density. This means, it is easier to be scratched than other metals like steel [8]. Aluminum is extremely reflective, when polished. It is the most reflective material, (71% unpolished and when polished 97%), for this reason it is now frequently used in lights. It is also very heat reflective and because of this people use it in their car windscreens to reflect the heat, and to keep the car cool on sunny days.

3 EXPERIMENTATION

In this work Aluminum is heated in an electrically heated crucible furnace as shown in Fig. 2. Aluminum is held with a special metallic alloy heating element in a crucible furnace and electrically heated. Here in this research work, a special metallic alloy heating element is used which provides more surface area, in turn radiating more heat. Thus, heat is better utilized and energy is saved. It can hold 50 kg aluminum, with 32KW connected load. It provides homogenous temperature all through the inside cavity of the furnace, achieving thermal balance and prolonging the operational life of furnace linings, heaters & crucibles. The furnace is connected & operated at lower voltage; it is connected with 60-80-100V, using Step down Transformer with three tapings.

Fig. 2 Electrically heated crucible furnace

Fig. 3 Picture of Rotating die

In this experiment two types of dies were used for mixing the cores with aluminum after melting the aluminum at various temperatures namely an open die and a rotating die. Here the open die was made of Ms plate 4 mm thick with dimensions of 200 X 200 X 40 mm. Then the rotating die was made up of Ms plate 10 mm thick with dimensions of 175 X 160 X 50 mm. The rotating die is depicted in Fig. 3. Experiments were conducted with Soaked Precursors at 850ºC as shown in Fig. 4; then again Soaked Precursors at 850ºC by using aluminum net as shown in Fig. 5 and steel net as shown in Fig. 6.

Fig. 4 Soaked Precursors at 850ºC

Fig. 5 Soaked Precursors at 850ºC (using aluminum net)

Fig. 6 Soaked Precursors at 850ºC (using steel net)

Using open die, experiments were conducted with Soaked Precursors at 950ºC as shown in Fig. 7 then by using Soaked Precursors at 910ºC as shown in Fig. 8.

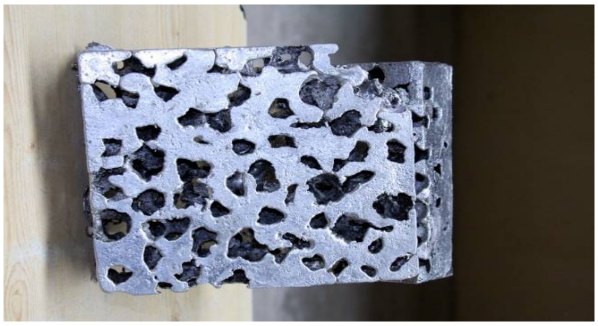

Fig. 7 Soaked Precursors at 950ºC

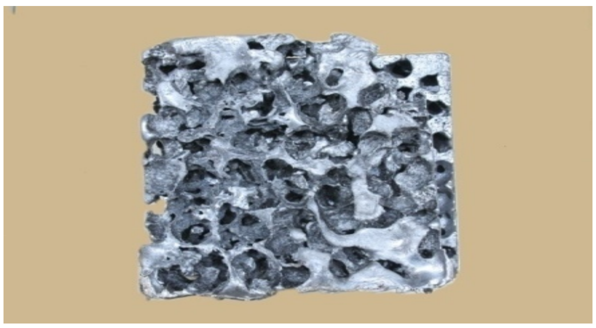

Fig. 8 Soaked Precursors at 950ºC

Here pre-shaped core metal foams are produced. This method produces an interconnected cellular structure or sponge metal by casting metal around granules introduced into the casting mould. These granules can be soluble (but heat-resistant), such as sand balls. In this work sand balls are used to create porous foams. However, the surface tension of most metals, especially aluminum, prevents the metal melt from immediately flowing into the interstices. This can be overcome by producing a slight vacuum in the bulk or by exerting a slight external pressure upon the melt. In addition, some superheating of the melt or preheating of the granules can be used in advance. This process has been used not only with aluminum, but also with magnesium, zinc, lead, tin and cast iron, and it allows casting of parts with intricate shapes. The picture of porous aluminum castings is shown in Fig. 9 at 950ºC and in Fig. 10 at 910ºC.

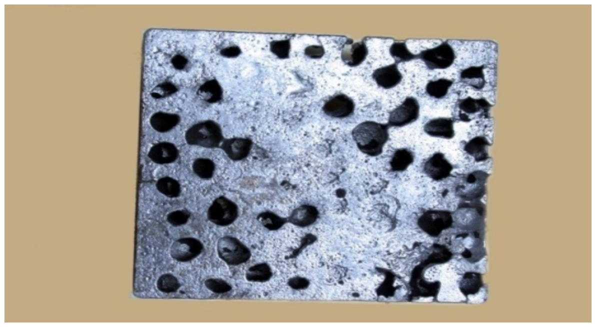

Fig. 9 Porous casting at 950ºC

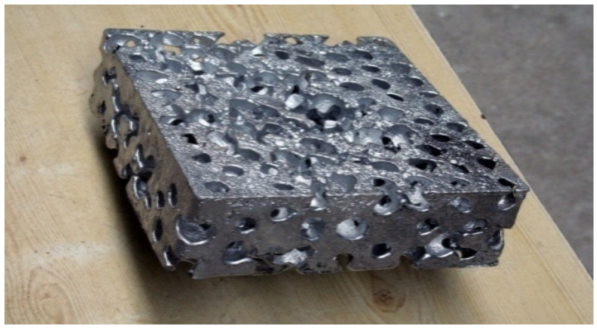

Fig. 10 Porous castings at 910ºC

The sand balls were prepared with 6-10% of bentonite and 2-6% of moisture with silica sand as the normal clay. The AFS content required is 6-10% in the foundry for green sand system. Sand balls of various sizes ranging from 15 mm – 45 mm were made manually by hand, where the picture of sand balls is shown in Fig. 11**.**

Fig. 11 The picture of sand balls

The poured mould was knocked off, after four hours of cooling then shot blasted. Cleaning of porous casting is done using the conveyor hook type shot blasting machine. It is a granular media were it is propelled against the surface of the casting to mechanically knock away the adhering sand.

4 TESTING OF POROUS ALUMINIUM

Density is a physical characteristic and is a measure of mass per unit of volume of a material or substance. The density of the porous specimen was determined by weighing the samples using a digital balance and their dimensions were measured. Multiplying the mean value of the measured dimensions, the volume is thus obtained. By dividing the weight of the sample on its volume, its density is thus determined. The density is calculated using the formula shown in Eq. (1). Aluminum has a low density of 2700 kg/cubic meter. This gives aluminum its unique lightweight property and extends its applications vastly. Really this is the key property that sets aluminum apart from so many other metallic elements.

$$Density = \frac{Weight\ of\ the\ porouscasting}{Volume\ of\ the\ castingproduced\ sample} \quad (1)$$

Percent Porosity is a rough measure of the open volume equal to 100% minus the part density. The total open volumes of interconnected and isolated porosity are normally found, it is calculated using the Eq. (2).

Here experiments were conducted initially with non porous sample and with porous models. In Fig. 10 maximum % porosity of 41.5 of aluminum porous sample at 950ºC is shown. Table 1 shows the Porous sample, its weight, density and % porosity of porous aluminum.

$$\%\ Porosity = \frac{(Bulk\ castingdensity\ -\ Produced\ casting\ density)}{Bulkcasting\ density} X\ 100 \quad (2)$$

Table 1 Porous sample, its weight, density and % porosity

Type of Casting	Sand balls size, mm	Pattern size (l x b xw) mm	Weight, kg	Density, kg/cu m	% porosity
Porous aluminum	15	180 X 170 X 65	3.23	1600	41.5

5 RESULTS

- Porous casting can be produced in aluminum.
- Porosity was created using steel net, aluminum net and soaked precursors at different temperatures.
- Aluminum porous castings were produced by melt route using castings around granules method.
- Percentage porosity level up to 42% can be produced in aluminum.
- Aluminum, with a minimum density of 1600 kg/m^3, weighting 3.2 kg and percentage porosity of 42% was obtained.

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