Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 04, April-2016

Experimental Determination of Relative Density and Percentage Porosity of Open Cell Aluminium foam Produced from Sand Salt Mould Method

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***Abstract*— Metallic foams have received broad attention due to their potential applications in many different fields, such as sound insulation, heat exchangers, filters, and catalyst carriers. In the last two decades metallic foams, which are porous metals with high porosity and relatively large cells, have been developed and are growing in use as new functional materials because of the unique combination of properties which can be derived from their cellular structure. Aluminium foam is a light weight porous material which appears to be promising metallic foam especially for aerospace applications. Aluminium foam can be produced by different methods like direct foaming with foaming agents in a metal powder mixture, direct foaming with foaming agents in a melt, by using different casting techniques etc., But each process will have its own advantages and shortcomings. There is a need for producing aluminium foam from easily available materials with low cost. In the present work, an attempt has been made to develop open cell aluminium foam from sand salt mould method using NaCl crystal as space holder whose relative density and percentage porosity were determined experimentally.**

Keywords*— Aluminium foam; sand salt mould method; NaCl crystal; relative density; percentage porosity;

I. INTRODUCTION

In the recent decades, open cell metal foams have been widely used because of their diverse properties in various areas including aerospace, electronics and automotive engineering applications [1,2,3]. They are a relative new class of materials with very promising applications in which it's low density and other thermal, mechanical, electrical and acoustical properties make this material an excellent means of performance improvement.

Among their current applications, open cell metal foams are found useful for the construction of light weight structures, energy absorption devices, currently being used by some vehicle manufacturers, and for various fluid flow and thermal applications which is our interest in this work.

Foams are the result of a two phase combination created by various processes most of which include the dispersion of a gas through a liquid without dissolving the gas completely. This is very similar to the emulsion process (combination of two immiscible liquids) but having the difference that a gas phase must exist in the foam. Nine distinct processes have been developed to make metal foams of which four are now used in the commercial fabrication of these materials [1].

1. Bubbling gas through a molten alloy (Al-Al_2O_3, Al-SiC)

2. By stirring a foaming agent (typically TiH_2) into a molten alloy (typically an aluminum alloy)

3. Consolidation of a metal powder, generally aluminum alloys, with a particulate foaming agent (TiH_2) followed by heating into the mushy state when the foaming agent releases hydrogen expanding the material (Al, Zn, Fe, Pb, Au).

4. Manufacturing of ceramic moulds from a wax or polymer foam precursor, following the burning out of the precursor and pressure infiltration with molten metal powder slurry which is then sintered (Al, Mg, Ni-Cr, stainless steel and Cu).

The differences between open cell and closed cell metal foams are mainly how the geometry of the cell is formed (See Figs.1 and 2). In the open cell group the cells are not closed from each other and the flow of other materials through one cell occurs freely to another adjacent cell. In the closed cell arrangement, the cell walls which completely close the cells from one another with the formation of individual cell compartments.

Fig 1. Open cell metal foam sample [5]

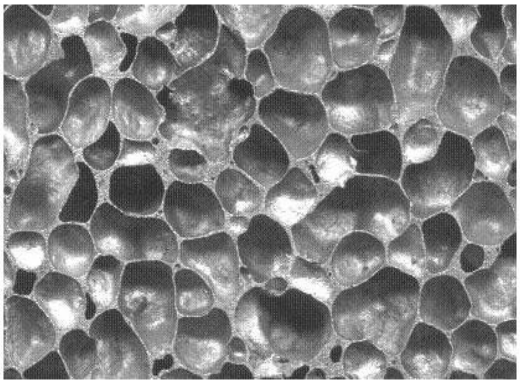

Fig 2. Closed cell metal foam sample

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II. PREPARATION OF ALUMINIUM FOAM SPECIMEN FROM SAND SALT MOULD METHOD

In the present work, an attempt has been made to get uniform porosity of Al foam. First the raw NaCl salt crystals are sieved to a uniform size of 4.2 mm and are filled in to the sand mould to its entire volume. The sieving is done in order to get uniform cell size. The mould is preheated in an electric oven to remove the moisture. The aluminium is melted in a crucible furnace. The Al6061 alloy melt is poured in to mould containing salt through a runner and the molten aluminium is allowed to fill into the space between the NaCl crystals.

Fig. 3. Filling of molten Al in to the sand mould

Then the mould is allowed for cooling and the Al6061 alloy solidifies rapidly. Even though the density of NaCl (2.165 g/cc) is less than the density of Al (2.7 g/cc), the salt crystals will not float in the felt as mould is completely filled with sand to its entire volume, only the molten Al6061 alloy fill into the space between the Al crystals. The solidified part is first washed with hot water and then with pressurized water so that the enclosed salt crystals gets dissolved. Thus open cell aluminum foam specimen is obtained. By following the same procedure, two specimens are prepared as shown in figures 4 and 5.

Fig. 4. Aluminium foam specimen-A

Fig. 5. Aluminium foam specimen-B

III. RESULTS AND DISCUSSIONS

In any metallic foams, the basic aim is to reduce the density the material because the density decides the quality of the foam. In the present work, the density of fabricated foam specimens is determined experimentally. The obtained density values are compared with the density of aluminum and hence the relative density of foam is determined. The following procedure is adopted for the same

1. The mass of the specimen is measured using electronic balance.
2. The average volume of the specimen is measured and hence the density of the foam is calculated.
3. The relative density of foam is obtained by dividing the density of foam with the standard value of density of aluminum.

Porosity also plays the very important role as the density in deciding the foam quality. As the density of the foam decreases, the porosity also increases. But the increase in porosity not helps instead for the foam uniform porosity is the important parameter. In the cast parts actually porosity is a problem, but in the metal foam synthesis main objective is to develop uniform porosity. Simple concept of the evaluating the percentage porosity is given below

$$\text{Percentage porosity} = \frac{\text{Density of Al} - \text{Density of foam}}{\text{Density of Al}} \times 100$$

The table below shows the calculated values of relative density and percentage porosity of the two foam specimens.

TABLE. 1. CALCULATED VALUES OF RELATIVE DENSITY AND PERCENTAGE POROSITY OF THE TWO FOAM SPECIMENS

Sl. No.	Foam specimen	Mass of the specimen (kg)	Average volume of the foam specimen (m^3)	Density of the foam specimen (kg/ m^3)	Standard value of density of Al (kg/ m^3)	Relative density	Percentage porosity
1	Specimen-A	0.994	0.0004700	2114.89	2700	0.7832	21.67
2	Specimen-B	1.785	0.0007952	2244.71		0.8313	16.86

VI. CONCLUSION

Aluminium foam specimens were prepared using salt sand mould method. Though, the process adopted is simple and cheaper, the quality of the foam obtained is not satisfactory. The average relative density obtained is about 0.8. This means instead of using solid Al, if the Al foam specimens are used in the place of Al, the weight of the components are reduced to 80%. This is a very requirement for aerospace applications. Also the average percentage porosity is found to be 19.26%. This means that, 19.26% of the volume of the foam is filled with pores. Since in the recent years, the Al foam finds application in the field of heat transfer, this data is very much required in the determination of effective thermal conductivity of the foam sample.

VII. SCOPE FOR FUTURE WORK

In the present work, the foam is fabricated using easily available materials like NaCl salt. But the quality of foam obtained is not satisfactory. There is a large scope in this area to improve up on the quality of foam by optimising the process parameters of foam fabrication. The value of relative density must be as low as possible. There is wide scope for researchers to work in this area to reduce the value of relative density.

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