Low Cost Method for the Production of Aluminum Metal Foams

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Abstract- *Metal foam production is being very challenging process due to the problems incurred while processing. Commercialization of metal foam in many applications is very difficult aspect as it possesses many problems; after the process the foams obtained are of inconsistent properties, high cost of production for good quality foams, non homogeneous distribution of pores. Obtaining the near net shape (NNS) is another problem in the metal foam production. In midst of all these problems metal foams especially aluminum (Al) gained a significant attraction from research because of its attractive properties like acoustic damping, bomb mitigation, light weight etc. Especially, the research on developing Al foam has become more because of its potential application in many engineering fields. The attempt has been made in this work to develop a near net shape of Al foam using NaCl as the space holder in the Al matrix and melt gas injection (MGI) method. The problems associated in the process and its effect on the density and porosity of the foam were discussed.*

Keywords- Al foams, Density, Melt Gas Injection, NaCl, Porosity, Space holder.

I. INTRODUCTION

Metals intentionally fabricated with high degree of porosity are called metal foams [1]. Metal foam is a cellular structure consisting of a solid metal, usually aluminum, containing a large volume fraction of gas-filled pores [2]. Aluminum foams have a good combination of properties such as high specific stiffness, high strength and good energy absorption. These characteristics make aluminum foams a potential material for absorbing impact energy during the crashing of a vehicle either against another vehicle or any obstacle [3]. Metal foams are a subgroup of cellular metals, usually having polyhedral cells, but shapes may vary in cases where directional solidification creates different morphologies. Metal foams are either open cell, closed cell, or a combination of the two. Open cell foam forms a network of interconnected solid struts. Closed cell foam is made up of a network of adjacent sealed pores, all sharing walls with each other. The difference between the closed and open cell configuration is clearly seen in pores.

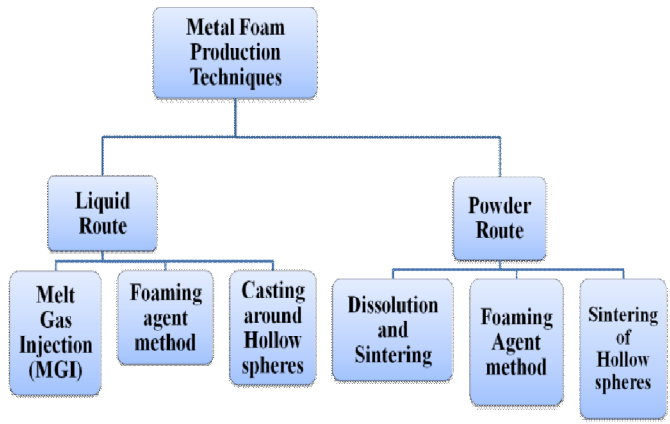

Fig.1.1. Common methods followed for the producing Al metal foams

Metal foam production techniques can be generally classified as Liquid route and powder route. It is shown in the fig.1.1. Various parameters are involved in the process are responsible for the quality, size and shape of the metal foam to be produced. The parameters involved are different from process to process like type of process selected, type of foaming agent, temperature at which foaming process starts etc. Controlling these process parameters is difficult and thus understanding the process concept is difficult, particularly in liquid route controlling process parameters is a big task. Hence the methods developed for the production of metal foams are still in incipient stage[5-7].

The attempt has been made in this work to develop the low cost aluminum metal foam by incorporating two different methods,

i. Aluminum foam production using Melt Gas Injection (MGI).
ii. Aluminum foam production in Space holder technique in bottom pouring concept.

II. EXPERIMENTAL PROCEDURE AND DISCUSSION

2.1. Aluminum foam production using Melt Gas Injection (MGI)

2.1.1. Materials used: Pure Aluminum as starting material, CO_2 gas cylinder, flexible hose, steel pipe (0.4mm inner diameter), resistance furnace for melting purpose.

2.1.2. Procedure: 200 grams of Aluminum was taken in crucible and melted in a resistance furnace. The melt temperature was maintained around 750°C. The melt was added with 5 wt% of Silicon carbide particles to make the melt high viscous. High viscous melt assists in holding the gas bubbles created in the melt. The melt was continuously stirred to achieve uniform mixing of SiCp inside the melt. Slag is floated at top and it removed. Then melt was transferred to another crucible which is shown in fig 1.4. The CO_2 was released from the cylinder which was injected into the melt through the flexible pipe and stainless steel pipe as shown in fig.1.5. As the gas injected into the melt, the bubbles creation takes place inside melt, there by gas bubbles are try to entrap in the melt which leading to creation of the foam as shown in fig.1.5.

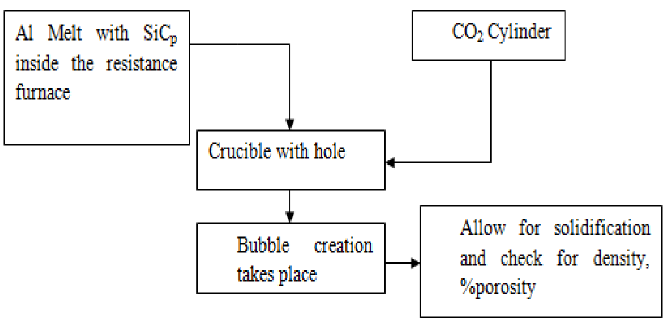

Fig.1.1. Block Diagram of MGI process

A-Crucible, B- CO_2 Cylinder, C- Flexible hose
Fig.1.2. Experimental setup

Fig.1.3. Melt stirring using SS pipe 4mm inner diameter

Fig 1.4. Transferring melt into another Crucible

Fig.1.5. The bubble created in the melt through gas injection

Fig.1.6. The Foam structure obtained by MGI

Discussion: The experimental observations indicate that the use of MGI method for the production of aluminum metal foams results in the formation of poor quality of metal foams.. From the Archimedes principle the density of the prepared samples were measured. The density of foam obtained in this method is about 2.15 to 2.39 g/cc. where the % porosity is calculated by using %Porosity= $\frac{\rho Al - \rho f}{\rho Al} \times 100$ and it was obtained around 20 to 22% of the theoretical density of the Aluminum.

Following are some of the problems associated with the use of MGI method for the synthesis of aluminum metal foams.

a. By using the MGI for producing Al foam the results are not satisfactory, as it leads to the rapid solidification of the melt.

b. MGI method used here for the development metal foams

2.2 Aluminum foam production in Space holder technique in bottom pouring concept:

2.2.1. Materials used: Pure aluminum as starting material, NaCl Crystals, sand mold, crucible.

2.2.2. Procedure: Other method developed for Al foam production was based on the concept of bottom pouring. The schematic of the method was shown in fig.2.3. This concept helps in producing foam with good structure and porosity. The mold as shown in the fig.2.2 was prepared and above that the crucible with small hole was placed and packed with the sand to avoid leakage. The mold was half filled with NaCl crystals and the set up was placed in the resistance furnace. Required quantity of Al was placed in the crucible. As the melting starts, the melt starts flowing slowly inside the mold and fills the mold cavity, where the NaCl particles floats due to density difference between NaCl and liquid Al. Set up was maintained in the furnace for about 2hrs to ensure complete filling of the mold cavity. Fig.2.3. shows the foams obtained in this method.

Fig.2.2. Bottom pouring concept of producing Al foam

(a) Top view **(b)Lateral view**

Fig. 2.3. Foam structures from bottom pouring concept

Discussion: Bottom pouring concept somewhat helps in getting the NNS, but the problem is that large components can't be produced and main drawback associated with this method is that prediction of volume of metal required for filling mold cavity, it is difficult to predict is molten metal completely fills the cavity or not. From the Archimedes principle the density of the prepared samples were measured. The density of foam obtained in this method is about 2.16 g/cc. where the % porosity is calculated by using %Porosity= $\frac{\rho Al - \rho f}{\rho Al} \times 100$ and it was obtained around 20% of the theoretical density of the Aluminum, where ρ_{Al} is density of Al in g/cc, ρ_f density of foam obtained.

III. CONCLUSION

Aluminum metal foams were synthesized using two different techniques. Though methods help in the formation of metal foam the quality of the foams produced were not satisfactory. Bottom pouring in sand + salt mold mixture helps in getting the good foam structure with low density of 2.16 g/cc. This method was very helpful and it can be promising method for getting the foam with near net shape. By observing and summarizing the points it can be concluded that processing may be easy to carry out, but controlling the process parameters is very difficult. Hence the production of Al foams in general, metal foams is a continuous challenging and innovative process. More experiments and trials are needed to develop a sophisticated method for producing good quality foams at lesser cost, because of the present sophisticated methods available are of very of high cost and also production is not yet commercially approved.

The authors declare that there is no conflict of interests regarding the publication of this paper.

REFERENCES

[1] V. GERGELY, H. P. DEGISCHER, T. W. CLYNE, Recycling of MMCs and Production of Metallic Foams, Volume 3; (ISBN: 0-080437214); pp. 797-820,

[2] Rossella Surace and Luigi A.C. De Filippis, Investigation and Comparison of Aluminium Foams Manufactured by Different Techniques, Advanced Knowledge Application in Practice.

[3] LI Da-wu. Et al. Preparation and characterization of aluminum foams with ZrH2 as foaming agent, Trans. Nonferrous Met Soc. China 21(2011) 346-352.

[4] Takashi Nakamura, Development of a new foaming agent, Material Transactions, Vol.43, No.5. (2002), page no.1191-1196.

[5] M.F. Ashby, A.G. Evans, N.A. Fleck, L.J. Gibson, J.W. Hutchinson and H.N.G. Wadley, “Metal Foams: A Design Guide”, Butterworth-Heinemann publications.

[6] Young-Hwan Song, Hwan-Goo Seon, Soo-Han Parka, Min-Jae Jeong, “Fabrication of Near Net Shape Metallic Foam via Plaster Mould”, J. Mater. Sci. Technol., Vol.24 No.3, 2008.

[7] A K. Shaik dawood, S. S. Mohamed Nazirudeen, “ A Development of Technology for Making Porous Metal Foams Castings”, Jordan Journal of Mechanical and Industrial Engineering, Volume 4, Number 2, March. 2010 ISSN 1995-6665 Pages 292 – 299.

[8] Dennis Weaire, “Foam Physics”, Advanced Engineering Materials 2002, vol 4, p10. John Banhart, “Metallic foams: challenges and opportunities”, Eurofoam2000, Editors: P. Zitha, J. Banhart, G. Verbist (MIT-Verlag Bremen, 2000), pp. 13-20.

[9] C.C. Yang, H. Nakae, “Foaming characteristics control during production of aluminum alloy foam”, Journal of Alloys and Compounds 313 (2000) 188–191.

[10] J. BaumeisterU, J. Banhart, M. Weber, “Aluminium foams for transport industry”, Materials & Design, Vol. 18, Nos. 4/6, pp. 217-220.