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Development of aluminum metal foam using blowing agent

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Abstract: This paper describes the complete manufacturing process for production of the aluminium foam with its achieved important physical properties and its uses in various industries. The production process of aluminum metallic foam includes high purity molten aluminium in which a small amount of calcium carbonate powder is continuously faded and stirred thoroughly. The decomposition of calcium carbonate release gases, which are entrapped in high viscous mixture of the molten aluminium and calcium residues and create low density porous aluminium foam as shown in figure no. 7 and figure no. 8. The aluminum foam is collected and cooled in the mold. Afterward foam is removed from the mold and cut to the desired sizes. The foam with low density 848 kg/m³ is obtained and density of which is 0.342 times of pure aluminum.

Keywords: Aluminium; blowing agent; Calcium Carbonate; Foam

1. Introduction

The history of metal foams dates back to the 1940s. Many patents were issued from the late 1950s to the 1970s and many variants of foaming processes were proposed. As hardly anything was ever published beside these patents, it is difficult to assess whether all the ideas suggested actually worked. A second surge of scientific activities starting in the late 1980s led to the re-establishment of some of the old techniques and to a much higher publication activity. Nowadays the operability of some of the proposed metal foaming processes has been shown and commercialization has begun. Much of the research and development work on metal foams in the past seems to have been carried out on a mainly empirical basis without a detailed knowledge of the underlying mechanisms of the foaming process. This procedure quickly led to limits when applied to a very complex area such as metal foaming and no real scientific understanding was ever developed [1,2,3]. Casting and PM are common techniques used to manufacture larger quantities of foams made from steel, titanium and aluminium, whereas electro deposition, CVD and PVD are used to produce more exotic foams such as those using refractory metals.

The development of metal foams introduced improved properties when compared to non-metal foams and solid metals. Compared to non-metal foams, metal foams offer higher stiffness, better strength to weight ratios, increased impact energy absorption, and a greater tolerance to high temperatures and adverse environmental conditions. In comparison to solid metals, metal foams offer higher specific stiffness (stiffness to weight ratio) and by altering the size, shape, and volume fraction of cells, mechanical properties can be engineered to meet the demands of a wide range of applications [4,5]. The characteristic properties that define metal foam include its cellular structure and relative density. Metal foams are either open cell, closed cell, or a combination of the two [6,7].

Metal foams are generally light weight metals flourished with a combination of several properties like very low specific weight, high stiffness, good energy absorption quality and high compression strength [8].
2. Experimental Setup
In-house facility is developed to production of the aluminium metallic foam by using blowing agent. Figure 1 shows the aluminium metal is melted in pit furnace up to the 700°C. Figure 2 shows the view of stirring mechanism. In figure 3 mould is made with the use of a clay pot and green sand to withstand the mould at high temperature. When the aluminum is fully melted, the impurities is removed from the mould and one half amount of calcium carbonate is put on the empty mould before pouring molten aluminum and remaining amount of calcium carbonate is added after pouring of molten aluminum as shown in figure 4. After adding calcium carbonate on molten aluminum, it is stirred properly for 67 seconds for batch 1 and 60 seconds for batch 2 as shown in the figure 5. Stirrer was taken out from the mould, due to the formation of gases, hollow cavities are formed in aluminum metal. From the lower part of the mould the sand cap is opened, so that remaining amount of molten aluminum is taken out from the mould, after the solidification metallic foam is generated as shown in figure 6. A photo-graph of trimmed aluminium metal foam is shown in figure 7. Microstructure of foam shown in figure 8.

Figure 1: Aluminum is melted in pit furnace
Figure 2: Aluminum Stirring Mechanism
Figure 3: Mould for producing aluminum metallic foam
Figure 4: Molten aluminum is poured in to the mould
3. Production Process
The production process includes a pre-heated mould with vent hole in which high purity molten aluminium is poured and small amount of calcium carbonate powder is dispersed in three stages. First stage one third amounts sprayed in empty mould; afterward another one third is mixed while pouring the molten aluminium metal and finally remaining part mixed while stirring operation. The decomposition of calcium carbonate release gases, which are entrapped in high viscous mixture of the molten aluminium and calcium residues and create low density porous aluminium foam. This low density foam float on the top of molten aluminium metal. Left out metal is drained though vent hole and remained foam is allowed to be cool-down in the mold. Afterward foam is removed from the mold and cut to the desired sizes by EDM. Microstructure of the typical sample is given in figure 8.
With the above mentioned procedure, six samples with different ratio of metal and blowing agent by weight were produced and various physical properties analysis was carried out. A detail of successful two batches is as following:

3.1 Batch-1
Ratio of aluminium and CaCo3
By weight (in grams) 900/30
Ratio 30:1
Stirring time: 67 seconds

3.2 Batch-2
Ratio of aluminium and CaCo3
By weight (in grams) 969/20
4. Physical Properties
The most important parameter characterizing a foamed material is its relative density, $\rho_R$. This is defined as the quantity, $\rho_R = \rho^*/\rho_s$, where $\rho^*$ is the density of the cellular solid itself, and $\rho_s$ is the density of the parent material from which foam is made.

Density of pure aluminium is 2319 Kg/m$^3$ whereas the Density of parent aluminium metal measured was, $\rho_s = 2480$ Kg/m$^3$.

It shows that there are some impurities in the aluminium that used.

4.1 Density of Metallic Foam,
Dimension of piece = 67×14×11 mm
Volume of piece = 1.0318×10$^{-5}$ m$^3$
Weight of metallic foam piece = 8.75 gm = 0.00875 Kg

$$\rho^* = \frac{m_f}{v_f} = \frac{0.00875}{1.0318 \times 10^{-5}} = 848 \text{ Kg/m}^3$$

4.2 Relative Density of Aluminium Metal Foam

$$\rho_R = \rho^*/\rho_s = 848/2480 \text{ or } 0.342$$

4.3 Pore Size
The Lieca microscope was used to measure the pore sizes of the foam. This facilitates to take the photograph of cut section as well as provides the dimension with marking. A typical result is shown in photograph given below. Microscope directly gives the values of pore size and wall thickness. The red color arrows shown in figure are the pores that were measured. Typical values are follows:
1. Maximum size of pore = 1 mm
2. Minimum size of pore = 500 µm
3. Average size of pore = 750 µm
4. Wall thickness = 50 µm to 85 µm
5. Volume of solid aluminium = 45%
6. Volume of foam = 55%

5. Conclusions
The aluminium metal foam was successfully developed using the blowing agent technique. It shows the desired properties as demanded by the user industries. It needs some more effort to produce at mass scale production as well characterization of the product to be included in the list of standard materials.

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