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Aluminium Foam: A New Friend of Environment

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Abstract : Metal foam is a highly porous isotropic material with cellular structure. Metal foams are light in weight and have recycling possibility, hence these are environment friendly materials. The pores of metal foam occupy more than 70% of the total volume. Metallic foams exhibit properties like good impact absorption, sound absorption and damping property due to its cellular structure. Metal foams can be prepared by many routes including casting, powder metallurgy etc. For future industrial applications it offers the combination of apparently concurrent properties in one homogeneous material, thus saving material, energy and environment. The aim of this paper is to describe various production techniques of aluminium foams along with their properties.
Keywords: Aluminium, Environment Friendliness, Recyclability, Porosity, foaming,

Introduction:

Ultra light and recyclable materials have always been an interesting and attractive field for research from environmental view point. Metallic foams are new in this field as these are both very light and recyclable. Apart from these, metallic foams have very low mass density, good impact absorption capacity, good vibration damping capacity, non flammability, very high specific stiffness and corrosion resistance. Open cell metal foams are thermal insulators, where as closed cell metal foams are thermal conductors.

There are many methods available for the production of metallic foam. Early attempts were focused on foaming techniques similar to those which were used in plastic technology, using a gas serving as blowing agent. Another technique focuses on casting method which results in interconnected cellular structure. In this technique granules are introduced in the melt for porous structure. Apart from these technologies, powder metallurgical route is also an important technology for producing cellular structures or metallic foams.

1. Production Techniques:

There are various techniques through which metal foam can be produced. These techniques can be categorised according to the initial state of the metal. On the basis of initial state of the metal , there are four categories in which production tech niques can be classified : (i) Production from liquid metal, (ii) Production from solid metal in powdered form, (iii) Production from metal vapour or gaseous metallic compounds, and (iv) Production from a metal ion solution.

Metal Foams made from liquid metal

The methods which fall under this technique are: (i) direct foaming with gases, (ii) foaming with blowing agents, (iii) GASAR method, (iv) melting of powder compacts, (v) casting and (vi) spray forming. In this method metal foams can be produced either by injecting gases directly into the molten metal, or by casting the molten metal around space holder, or by melting the metal powder compact containing the blowing agent. Another possibility of producing metal foam by foaming it indirectly using polymer foam. Alcan Process is shown in fig 1[2].

1.1.1 Direct Foaming with Gases:

Foaming of metals can be done by introducing gas bubbles inside the melt or by generation of gas bubbles inside the melt. These gas bubbles, by virtue of buoyancy force, try to rise to its surface, but this rise is hindered by increasing viscosity of the melt.

A large number of attempts were made to foam metals like aluminium, magnesium, zinc or their alloys by following this route but exceptionally good quality of foam was never achieved [8-15]. Later it was found that control of this whole process of foaming is extremely difficult and hence the quality of foam is not satisfactory. Over past 10 years, numerous developments have taken place to improve the quality of metal foam through this route. Currently, there are two ways of foaming the melt directly: either by injecting the gas directly from the external source or by in-situ formation of gas bubbles by using any blowing or foaming agent.

One of the earliest patents was filed 1940's which suggested the use of second metal as blowing agent, example: use of mercury for foaming aluminium [16].

1.1.1.1 Foaming by direct gas injection.

The patent of this method is originally filed by Alcan International and hence it is also known as Alcan process [17-25]. According to this process as shown in fig.1, addition of silicon carbide, aluminium oxide and magnesium oxide is required to enhance the viscosity of melt. Increased viscosity of melt helps in the stability of gas bubbles. Therefore the first step in this method is the preparation of melt containing either of these materials. The foaming of metal matrix composite (MMC) takes place in the second step by injecting gases like air, nitrogen, argon into the melt by using specially designed impellers to create fine bubbles and distribute them uniformly in the melt. Uniform distribution of very fine gas bubbles in the melt is the important requirement because only fulfilment of this requirement ensures the satisfactory quality of metal foam. The resultant mixture of foam and gas bubbles rises up to the surface of melt which can be pulled off the melt surface using conveyor belt and it is allowed to solidify slowly. The

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semi-solid foam needs to be flattened before complete solidification by rolling operation to form flat slab. Care to be taken, during pulling off and rolling of semi-solid MMC, not to damage the pore structure by shearing the foam too much.

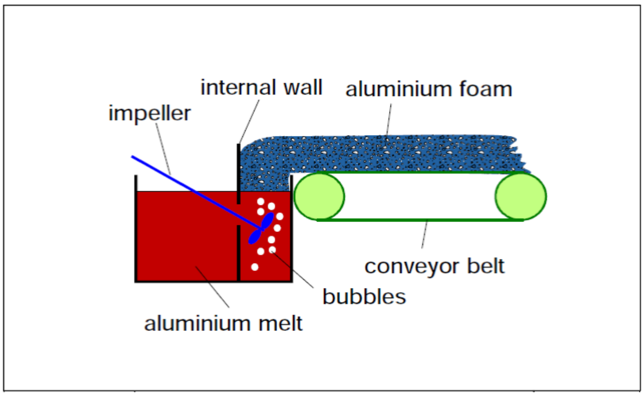
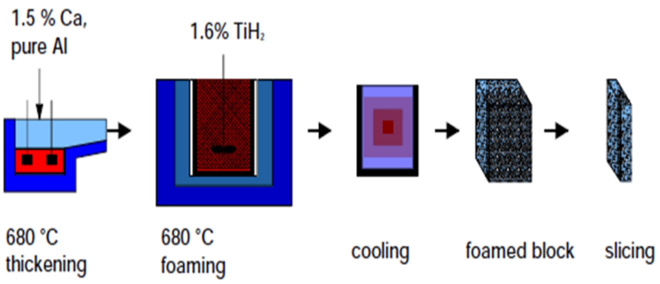


Fig.1. Alcan Process [25]1

1.1.1.2 Alporas Method

Alporas method is quite similar to Alcan method, but unlike Alcan method, Alporas method uses calcium for increasing the viscosity and titanium hydride as a foaming agent. After the addition of foaming agent into the melt, melt is heated up to 700 °C. Foaming agent decomposes under the action of heat and releases hydrogen. This hydrogen is responsible for the formation cellular structure or porous structure. Foam is then cooled down in the moulds to get blocks of the metal foam. The porosity achieved by this method ranges between 89% - 92%.The gas is released instantaneously as soon as the foaming agent comes into contact with the melt, this process is very difficult to control and leads to undesirable large cell sizes.



1.1.1.3 Casting

This method produces interconnected cellular structure by casting aluminium around the granules in the casting mould. These granules must be heat resistant and soluble. The very good example of this is sodium chloride, which is leached out to leave the foam. Other materials like expanded clay, foamed glass spheres, hollow corundum spheres etc can be used as granules. As an alternative to the casting of metal around the granules, granules can also be incorporated into the metal melts. In this process metal is melted in the crucible and thereafter granules are introduced into the crucible. This mass has to be mixed rigorously to disperse the granules uniformly in the melt.

1.1.1.4 GASAR process

The method consists of melting a aluminium in a gas atmosphere to saturate it with hydrogen and directional solidifying under strictly controlled thermodynamic and kinetic conditions. The materials produced by this method, have a monolithic matrix and pores of proper geometric shapes, providing to gasar higher strength, plasticity, thermal and electrical conductivities as compared with those of other porous materials.

1.2 Foams made from metal powders [PM Foams]

1.2.1 Fraunhofer Method

This process of aluminium foam production starts with the mixing of metal powder (pure metal or alloy powder) and foaming agents. This mixture is then compacted to form a dense and semi-finished product. The compaction can be done by any of the available compaction methods according to the required finished product. The next step is the heat treatment of the semi finished product up to the temperature ranging between melting temperature of the matrix metal and decomposition temperature of blowing agent. Blowing agents decomposes at high temperature and releases gas. This gas results in expansion of the material resulting in high porosities in the material ranging between 60% to 85%.

1.2.2 Gas Entrapment Method:

In this method, aluminium powder is filled in a lockable container and then argon is pressed in the powder. Gas is filled in the spaces between the powder particles. Container is heated up to the melting temperature of the matrix metal. Aluminium powder melts and entraps the gas. Semi-finished metal block so obtained after this step is rolled and heated, entrapped gas expands and delivers the metal foam.

2. Properties

2.1 Mechanical Properties

2.1.1 Compressive Property: Due to cellular structure of metal foams, they behave differently from conventional materials under compression loading. A typical compression stress strain curve for metal foams is shown in figure 3[2].

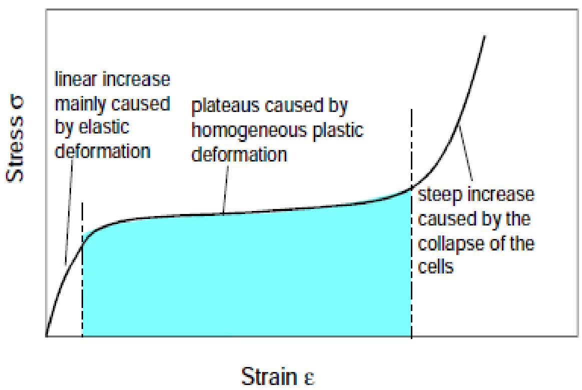


Fig 3. Compressive stress strain curve

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This type of behaviour is common for both open and closed cell walls. The compressive stress strain curve is divided into three regions as shown in fig 3. The compression behaviour of the Al alloys depends on several parameters such as (i) Al-alloy composition (ii) cell size range (iii) density (iv) defects of cellular structure (v) characteristics of the external skin surface. It has been observed that tensile strength of the foams is nearly as same as the stress at which plateau occurs. That's why this "plateau stress" is used as the main property value of the foams. Foamed aluminium can be compressed as much as 65% of its original height.

2.1.2 Energy Absorption: The area under the curve shown in fig 3 is the energy absorbed by the material during compression testing. Metal foams possess good energy absorption capacity due to their cellular structure. Due to special shape of curve, especially the long plateau, metallic foams are capable of absorbing enormous amount of energy at relatively low stress values. Clearly, the potential for absorbing energy increases with an increasing area under the plateau.

2.1.3 Elastic Modulus: Modulus of elasticity is an important parameter for the estimation of stiffness of the finished metallic foam. The specific modulus of metal foams is lower than the specific modulus of dense material. Elastic modulus of the metallic foam relates linearly with foam density and this relation stands for both open cell and closed cell metal foam. Elastic modulus of the foamed material can be altered by controlling the cell size or pore size of the metal foam.

2.2 Physical Properties

2.2.1 Conductivity: Electrical and thermal conductivity of aluminium foam is generally lower than the dense metal. The reason behind this is share of the foam volume. Cell walls have very low share in foam volume as compared to the gas or air in foamed material. Apart from this oxide layer over the cell walls is also one of the reasons for low conductivity of foamed metal.

The thermal conductivity of the foamed metal can be estimated as $1/10^{th}$ of the same dense metal. Coating of the oxide layer over cell walls can decrease the conductivity further.

2.2.2 Sound Proofing Properties: Another advantage of foams is their excellent sound and vibration absorbing. The dissipation factor is lower than this of dense aluminium. In the foam sound waves are reflected by the irregular porous structure. The vibrational energy causes minimal deformations of the cell walls and is converted into heat energy. Therefore the intensity of the reflected sound decreases. The sound absorbing capacity can be further increased by producing very fine and homogeneous pores.

3. Application

The existing applications of foamed metal cover a wide area related to engineering and environment and its applications are continuously arising in various different fields. Currently, metal foams are used in the manufacture of silencers, flame arresters, impact energy absorbers, filters, heaters and heat exchangers, construction material. Metal foams can also be used as chemically adsorbent in chemical industries, as electrodes fir alkaline batteries, as an abradable seal in turbine construction etc.

4. Conclusion:

Aluminium foams are very light weight advanced materials with recycling possibility. Introduction of Aluminium foam as new construction and structural material can bring a revolution in the engineering fields. Although there are some challenges regarding the manufacturing cost of the metal foam which we have to cut down. This would permit a more large scale industrial use of these materials.

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