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Aluminum Foaming For Lighter Structure

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ABSTRACT:
Aluminum foaming for light weight construction has become an attractive research field both from the scientific viewpoint and the prospect of industrial applications. Various methods for making such foams are available. Some techniques start from specially prepared molten metals with adjusted viscosities. Such melts can be foamed by injecting gases or by adding gas-releasing blowing agents which decompose in-situ, causing the formation of bubbles. A further way is to start from solid precursors containing a blowing agent. Alternatively, casting routes can be used to make such precursors. The properties of aluminum foams promise a variety of applications in vehicle design ranging from light-weight construction, impact energy absorption to various types of acoustic damping and thermal insulation. Aluminum Foaming is not implemented in India. In these seminar a over view of various term like concept, process, properties, advantages, disadvantages and practical applications of it are explained.

Keywords: *Aluminum foam; cellular structure; production; lightweight; incombustible; sound absorption; energy absorption.*

I. INTRODUCTION

Foams are two phase system and thermodynamically unstable. This is new technique to make a material even more ductile, with more shear strength along with light weight by foaming. In the last 40 years many metallic foam structures were produced, but they were not successful, because of their relatively high costs. There are various methods for making foams. Some techniques start from specially prepared molten metals with adjusted viscosities. Foamed aluminum is in stable form. Aluminum foam is very efficient for sound absorption, electromagnetic shielding, impact energy absorption and vibration damping. It is nonflammable and stable at elevated temperature. Aluminum foam is recyclable and thus environmentally friendly. Metallic foams have become an attractive field from the scientific viewpoint and the industrial applications. In many industrial applications, new materials are required for the production of light weight structures. Metal foams with porosities exceeding 50% can meet this requirement. In recent years, there has been a strongly growing demand for the use of metallic foams, particularly aluminum foam for automotive, railway and aerospace applications where weight reduction and improvement in safety is needed. For future industrial applications it is helpful for saving material, energy and environment.

II. MANUFACTURING PROCESS

Aluminum foam produced by following two basic methods:
2.1 Foaming of liquid melt
2.2 Foaming of powder compact.

2.1 Foaming Liquid Metals

Aluminum foam can be produced by creating gas bubbles in the liquid provided that the melt has been prepared such that the emerging foam is fairly stable during foaming process. This can be done by adding fine ceramic powders or alloying elements to the melt which form stabilizing particles. There are three methods of foaming metallic melts: gas injecting into the liquid metal, gas releasing blowing agent's addition into the molten metal.

2.1.1 Foaming Melts by Gas Injection

In this process, Sic, aluminum oxide or magnesium oxide particles are used to increase the viscosity of the liquid metal and adjust its foaming properties because liquid metals cannot easily be foamed by air bubble into it. The drainage of the liquid down the walls of the bubbles occurs too quickly and the bubbles collapse. If a small percentage of these particles are added to the melt, the flow of the liquid metal is impeded sufficiently to stabilize the bubbles. After these, the gas (air, argon or nitrogen) is injected into molten aluminum by using special rotating impellers or air injection shaft, which emerges gas bubbles in the melt and uniformly distributes through the melt. The base metal is usually an aluminum alloy.

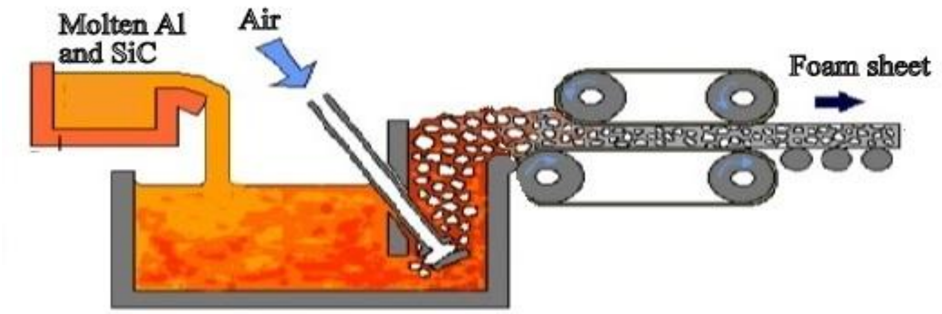


Fig.1 Schematic diagram of manufacturing of aluminum foam by melt gas injection.

The foam is relatively stable to the presence of ceramic particles in the melt. The mixture of bubbles and metal melt floats up to the surface of the liquid where it turns into fairly dry liquid foam as the liquid metal drains out. A conveyor belt is used to pull the foam off the liquid surface and then left to cool and solidify. Foaming of melt by gas injection process is the cheapest one among all others and the only one to have been as a continuous production. Foam panels can be produced at rates of up to 900 kg/hour. They have density 0.069-0.54 gm. /cm3, average size 3-25 mm and cell wall thickness 50-85 μm.
The main disadvantage of this process is the poor quality of the foams produced. The cell size is large and often irregular, and the foams tend to have a marked density gradient.

2.1.2 Foaming Melts with Blowing Agents

Addition of blowing agent into the melt is the other way of foaming melts. The blowing agent decomposes under the influence of heat and releases gas. The first stage of the foam production about 1.5 wt. % calcium metals is added to the aluminum melt at 680 °C. Then melt is stirred for several minutes during which the viscosity of the melt continuously forms the oxides like CaAl2O4, which thicken the liquid metal. Titanium hydride is added in an amount typically 1.6 wt. %, which acts as a blowing agent according to the reaction:

$$\mathbf{TiH_2\ (s) \rightarrow Ti\ (s) + H_2\ (g)}$$

The melt starts to expand slowly and gradually fills the foamy vessel. The whole foaming process can take 15 minutes for a typical batch of about 0.6 m3. After cooling the vessel below the melting point of the alloy, the liquid foam turns into solid aluminum foam and can be taken out of the mold for further processing.
BLOWING AGENTS FOR ALUMINIUM FOAMS
Foaming agent entrapped in the metal matrix after densification builds up an internal gas pressure upon heating of the compacts and leads to foam formation. Usually titanium hydride (TiH2) and zirconium Hydride (ZrH2) are used for aluminum foam. But titanium hydride is the best blowing agent for aluminum alloys because strong hydrogen release takes place between 400°C to 600°C which coincides with the melting point of aluminum (660°C). Titanium hydride has been characterized by the thermal analysis to characterize their decomposition temperature and to derive their suitability for foaming.

2.2 Foaming of Powder Compacts

The process starts with the mixing of metal powders - elementary metal powders, alloy powders or metal powder blends - with a powdered blowing agent, after which the mix is compacted. These techniques include compression, Extrusion used to produce a bar or plate and helps to break the oxide films at the surfaces of the metal powders. Foaming agent decomposes and the material expands by the released gas forces during the heating process gives a highly porous structure .A mixture of powders, metal powder and foaming agent was cold compacted and extruded to give solid metal material containing a dispersion of powdered foaming agent. When this solid was heated to the metal’s melting temperature, the foaming agent decomposes to release gas into the molten metal, creating metal foam. During this process, cooling the foam is a problem. For this, after heating the precursor for foaming, the heat source could be turned off quickly. The foam has a closed-cell structure with pore diameters in the range of 1 mm to 5 mm and the process is called baking.

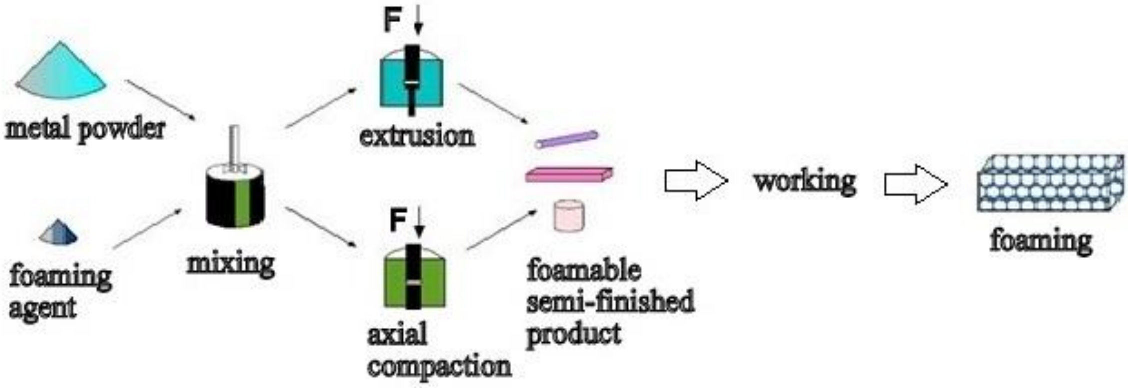


Fig.2 Foaming from powder compacts process.

III. PROPERTIES

3.1 Physical Properties and Values

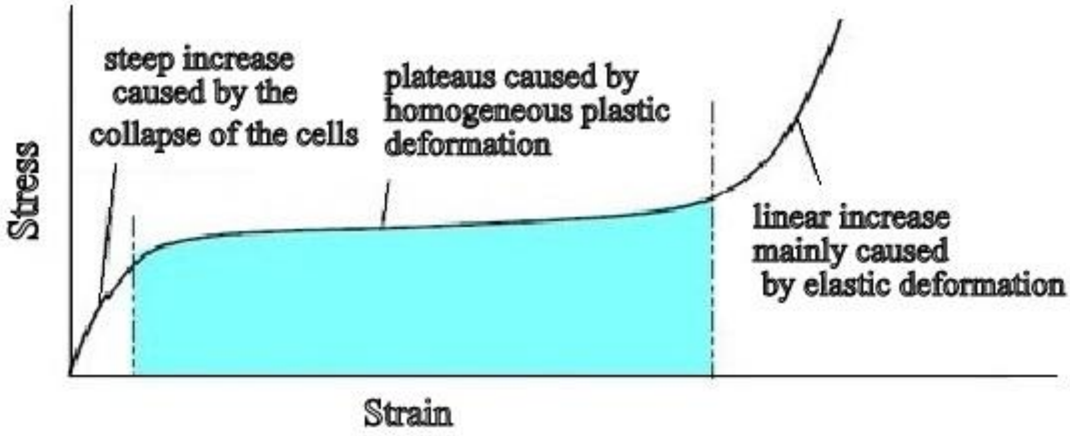
Sr. No.	Physical Property	Value
1	Compression Strength	2.53 MPa
2	Tensile Strength*	1.24 MPa
3	Shear Strength	1.31 MPa
4	Modulus of Elasticity (Compression)*	103.08 MPa
5	Modulus of Elasticity (Tension)*	101.84 MPa
6	Shear Modulus	199.95 MPa
7	Specific Heat	0.895 $^{J}/_{g\text{-}C}$
8	Bulk Thermal Conductivity	5.8 $^{W}/_{m\text{-}C}$
9	Coefficient of Thermal Expansion (0-100°C)	23.58×10^{-6} $^{m}/_{m\text{—}C}$
10	Bulk Resistivity	7.2×10^{-5} ohm – cm
11	Melting Point	660°C

Table 1. Physical properties and their values.

These values were obtained from small samples. Larger samples having a minimum of 10-15 bubble diameters produce more general test results which are in better compliance with the equations.

3.2 Mechanical properties

The cellular structure of foams behaves differently in testing when compared to metal. Therefore conventional testing methods cannot be used, like tensile testing. The behavior was found for compressive stress-strain diagram with a division into three parts.

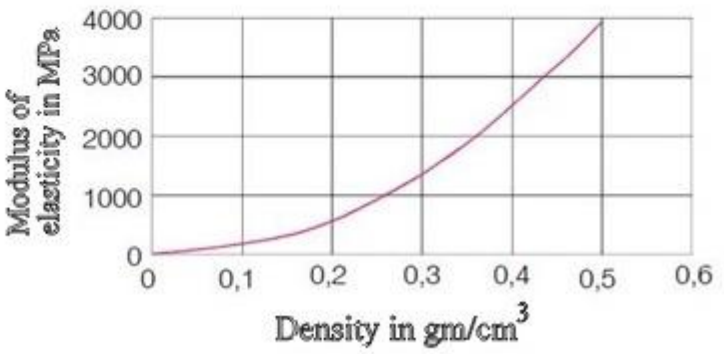


Graph 1 Stress-strain diagram for compressive test of aluminum foam.
It shows a linear increase of stress at the beginning of deformation. The first stage is caused by an elastic deformation. In foams plastic deformations can occur at low stresses.

A plateau region nearly constant stress in the middle. It is followed by a steep increase in flow stress at the end. The tensile strength of foams is nearly the same as the stress at which the plateau occurs. That's why this "plateau stress" is used as the main property value of foams.

3.2.1 Modulus of elasticity

The modulus of elasticity is, in combination with the geometry an important characteristic for the estimation of the stiffness of a finished metallic product. The specific modulus of aluminum foams is much lower than that of dense aluminum.



Graph 2 Modulus of elasticity of aluminum foams of several densities.

As shown in graph, the modulus of foams increases with increasing density. Therefore the modulus can be adapted to a special application by controlling the density of the foam.

3.3 Chemical properties

Aluminum foam is incombustible. Under the influence of heat foams do not release toxic gases. The corrosion behavior is comparable to that of dense aluminum alloys.

IV. ADVANTAGES

- Foam blocks can floats in Water.
- Foam blocks can saw drilled, cut and bend.
- By screwing & riveting foam blocks can join to dense material.
- Welding of foam blocks is possible, mainly laser welding.
- Foam blocks can paint with organic or inorganic paint.

V. DISADVANTAGES

- They are difficult to manufacture as precision manufacturing is required.
- High cost.
- Difficultly in manufacturing high temperature metal.
- Once damaged it cannot be repaired, the whole metal foam has to replace by new one.

VI. APPLICATIONS

- AUTOMOTIVE INDUSTRY:
  Firewalls, Energy Absorbing Bumpers, Door side impact bars, Floor panels, Helmets.
- MILITARY:
  Lightweight armor, mine blast containment.
- AEROSPACE INDUSTRY:
  Due to lightweight Al foam sheets could replace the expansive honeycomb structures.
- BUILDING & CONSTRUCTION:
  Good possibilities due to good fire penetration resistance & thermal insulations.
  Used as sound absorbing material in railway tunnels, under highway bridges or inside of building.
- HOUSEHOLD & FURNITURE INDUSTRY:
  Used for lamps, tables or household articles & accessories.

VII. CONCLUSION

Aluminum foam has high potential for various applications but there use is limited because of its cost and lack of uniformities in properties. But it is expected that the price of foams will decrease in the coming years as the volume of production increases. Recent technological advances in the field of metallic foams have led to the development of a wide range of processing techniques for the open as well as closed cell morphologies.

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