A Review on Production of Aluminium Metal Foams

Mr. Mahadev¹ Dr. Sreenivasa C.G.² and Mr. Shivakumar K M¹

¹ Department of Mechanical Engineering, Sahyadri College of Engineering and Management, Mangaluru-575007, Karnataka, INDIA
²Department of Mechanical Engineering, University B.D.T College of Engineering, Davangere 577004, Karnataka, INDIA.

* Corresponding Author: mahadev.mech@sahyadri.edu.in

Abstract: Aluminium metal foam has wide applications for lightweight construction has become an attractive research field. In this review paper, the various possible methods for Aluminium metal foams production and other cellulose metallic structures are studied. According to the state of matter the different production processes are classified into three ways solid, liquid and gaseous. Metal foams have a unique property such as light weight in combination with higher compression strength, lower specific weight, high stiffness and better energy absorption quality. Production of metal foams is a very difficult task because of the simultaneous occurrence of solid, liquid and gaseous phase’s at different temperatures. There are number of technologies and methods of manufacturing foamed metals are available but still the foamed metal suffers from deficiencies and non-uniformities. To improve the foam quality, it is necessary to study and understand the foam stability of liquid metals, which will help production techniques of foam metals more reliable and producible. In this review finds the best suitable method for production of aluminum metal foam for mechanical application. It has been experimentally confirmed that aluminum metal foams produced by the Powder Metallurgy method present high pore connectivity hence there is a chances to get good result when we will do the analysis over application.

Keywords: Aluminum foam, cellular structure, Production methods, Properties, Analysis.

1. Introduction

Aluminium metal foams are produced with various methods like powder metallurgy technique, sintering technique, addition of gas in melt injection, using agent in melt foaming, and investing casting. The maximum parameters of every method combination of properties to the material, so there are a unit several samples of optimization of method in literature however due to method complexity and hazard, though all the efforts to develop foams at cheaper procedure. [5] Metal foams are materials that show distinctive combination of physical and mechanical properties like lightweight, high specific stiffness, high strength to weight ratios, and greatly increased energy absorbing capabilities create use within the automotive and aerospace industries. It’s additionally shown to expertise fatigue degradation in each tension and compression.[16] aluminum metal Foam is taken into account as a material that's solid under low stress.
however it flows like a fluid beneath high stress. There’s a precise vary of strain over that foams are elastic in nature and their deformation recoverable.[3] Foams are having distinctive property combination of low density, competitive weight specific mechanical properties and high energy absorption. thence drawbacks of today’s most popular production methodology, the powder metallurgical process, that is predicated on a precursor material incorporating a foaming agent, area unit comparatively high production prices also as attain smart material properties. By this methodology produced a replacement form of closed cell foams by filling the vacancies around a random dense collection of preformed hollow spheres with a solid matrix material, either through casting or through powder metallurgy method with the aim of increasing their energy absorption and strength.[2] Metallic foams made via a powder metallurgy technique by heating a compacted mixture, foammable precursor, of Aluminium alloy powders and a foaming agent, typically TiH2, to keep up temperature slightly on top of the melting point of aluminum. The rotten TiH2 releases hydrogen gas into the liquefied compact of aluminum foam and a cellular structure is created. The PM foaming method is fast with expansion occurring takes place during a few minutes useable cellular structure of foam obtained [24]. In this review paper identifies best suitable production methods for production of aluminium metal foam so that which will give the good result over analysis on mechanical application.

2. Literature Survey on Aluminium Metal Foam

M. Paknezhada, et.al. (2017), investigated experimentally the effect of inclination angle on the temperature of a heated surface with and without metal foam in the case of free convection heat transfer conditions. Experimental modeling has been conducted using an electrical resistor on an aluminum plate with and without aluminum metal foam in different angles with respect to the horizontal direction. The results show that the temperature variations have a linear dependency to the sine of inclination angle up to 45° and 60° for plate with and without metal foam, respectively. The highest thermal efficiency of aluminum foam is in the vertical position and is about 17%. Aluminum foam heat sink reduces the surface temperature up to 16 °C which is in the vertical position of the surfaces. [1]M. J. Mirzaalia, et.al. (2016), in this study, using a manufacturing method of foaming by expansion of a blowingagent, he prepared 2 types of closed-cell aluminum foams with identical distribution of cells on length and foams with gradient of pores on its length. He hypothesized that such variation of pores will induce small structural radial asymmetryon the length of foam samples and improves their mechanical properties. For this aim, he studied the small structural properties by micro-CT imaging and found their relevance macroscopic mechanical properties of foam samples by conducting monotonic compression tests. He also conducted numerical analyses and valid them for the elastic part based on our experimental work. His results showed that gradient variation in porosity in closed-cell aluminum foams have a minor effect on their macroscopic mechanical properties. The conferred results are considered as a preliminary study for improvement of mechanical properties of closed-cell aluminum foams. [4]Oronzio Manca et,al,(2016), In this paper an experimental investigation is carried out on impinging jets in porous media with the wall heated from below with a uniform heat flux. The fluid is air. The experimental apparatus is made up of a fun systems, a test section, a tube, to reduce the section in a circular section. In this work an energy performance ratio is employed to compare the performances of surface with and without foams in terms of heat transfer coefficients and pressure drops. Preliminary experimental results have confirmed that the use of the porous medium improves the heat transfer promoting the heat dissipation of the surface with high efficacy but determines an increase in pressure drops. [6] S.F. Aida et,al(2016), studied varies quantity of sodium chloride (NaCl) particles as an area holder to fabricate the aluminium foam using Gravity die casting is that the technique that allows fabrication of open-cell A356 aluminium foam as a suitable absorbent material with smart quality performance. because
the addition of the NaCl spaceholder will increase, porosity will increase resulting in decreasing density of the foam. Aluminium foam with 30% NaCl showed moderate porosity among the others foam A356 aluminium alloy. Microstructural analysis, porosity and density were investigated.[8] Tizian Bucher, et. al (2016), This study was targeted to determine what quantity geometrical accuracy is required to get a good agreement with experimental information on the thermal aspects of laser forming of closed-cell aluminium foam. Associate infrared camera was used to measure the transient temperature response of aluminium foam to stationary and moving laser sources. of geometrical complexness were used, as well as an easy solid geometry, a Kelvin-cell based mostly geometry, associated a highly accurate porous geometry that was based on an X-ray computed tomography (CT) scan Moreover, three completely different numerical models were developed completely different levels. Therefore the performances of the numerical models were compared, the numerical results were valid with the experimental information. [13]

3. Review on Methods of Producing Aluminium Metal Foam

From the last decade technologies has been improved in the production of metallic foams or similar porous metal structures. From the production process it has been observed that some the process is suitable for the production of aluminium foam. The technology requirement will be divided into liquid molten metal and metallic powder.

3.1 Foams Made From Metallic Melts
3.1.1 Foaming Melts by Gas Injection

In this process the gas injection is used to melt foaming aluminum and aluminum alloy. By the addition of SiC, aluminum oxide or magnesium oxide particle are used to alter the foaming properties. The volume fraction of the particles obtained from the gas injection varies from 20% to 100% and mean size of the particles will vary from 5 μm and 20 μm. A closed cell foam production is about 1m wide and 0.2m thick slabs with diameter ranges from 5mm and 20mm and relative density of foam is 0.03-0.1kg/m3.

![Fig 1](image)

Fig 1. Schematic diagram of manufacturing of aluminium foam by melt gas injection method.(52)

3.1.2 Foaming Melts with Blowing Agents

In this process we have to use add blowing agent into the aluminium melt. Under influence of heat and releases gas the blowing agent decomposes. The process is shown s in the Figure 2. The aluminum melt at 680 °C the primary stage of the foam production about 1.5wt%.calcium metals adds to. Titanium hydride is add in a quantity usually 1.6 wt. %. The blowing agent used in the subsequent reaction:

\[ \text{TiH}_2 (s) \rightarrow \text{Ti} (s) + \text{H}_2 (g) \]

After the reaction the melt starts to expand gradually and suddenly fills the foaming vessel. This foaming process it will take around 15 min to complete foam produce. The liquid foam turns into
solid aluminum foam cooling the vessel below the melting point of the alloy.

Fig 2. The process steps of aluminium foam forming by gas releasing agent.(54)

3.2 Foams Made From Metal Powders (PM Foams)
Alloy powders and metal powder blends with a powdered blowing agent the process starts with the blending of metal powders. In heating method (350°C–450°C) therefore an extremely porous structure is formed and then Foaming agent added and also the foaming material expands due to the addition of gas forces. The cold compacted to provide to the solid metal material containing a composition of powdered foaming agent. The foaming agent reaction takes place after adding gas into the liquid molten metal and then starts to form the foam once this solid material was heated up to the metal melting temperature. the strategy is shown schematically in Figure 3.

Fig 3 Foaming from powder compacts process.(54)

The process starts with mixture metal powders (either pre-alloyed metal powders or blends of elementary powders) with little quantity of foaming agent. When the foaming agent is uniformly distributed inside the matrix powders, the mixture is compacted to yield a dense, semi-finished product with none residual open porosity (Fig.3).
The foamed elements created by this powder technique feature a comparatively solid closed-cell microstructure with a fractional density as low as 200th of fully dense aluminium (2.7 g/cm³). Case of steel foam, a down density as low as 400th of totally dense steel (7.8 g/cm³) was obtained. Figure 3.1 shows the optical micrograph of typical aluminium foam. This kind of cell structure is answerable for the high specific stiffness-to-weight quantitative relation (SWR) of the foam. Throughout deformation, localized cell collapse and fast compaction energy dissipation offer the energy absorption capability within the material [56].

3.3 Casting Methods

Investment casting with polymer foam might be produced from liquid metal while not straightforwardly foaming the metal. This can be shown in the schematically Fig. 4. Steady with this strategy, polymer foam, e.g. polyurethane foam, is utilized as a beginning stage. In the event that the polymer froth has shut pores, it's to be changed into an open permeable one by a reticulation treatment. The subsequent polymer foam with open cells is then loaded with a slurry of adequately warm safe material, e.g. a blend of mullite, phenolic gum and calcium carbonate or simple mortar. when hardening the polymer foam is evacuated by warm treatment and liquid metal is fashioned into the subsequent open voids that reproduce the main polymer foam structure. Utilization of weight and warming of the shape could likewise be important if no filling of the thin depressions with the fluid metal might be accomplished in straightforward gravity throwing. after evacuation of the form material (e.g. by pressurized water), a metallic structure is acquired that is a specific imitate of the original polymer foam.

3.4 Electrodeposition Method

The base materials utilized as a part of this investigation were open-cell Al foam manufactured with Al 6101-T6 composite with a pore size of 40 PPI (pores per inch, 1 in. = 25.4 mm) and a relative (thickness of foam over thickness of strong). The Al/Cu cross breed foam were produced by covering the Al foam
with nanocrystalline Cu utilizing the electrodeposition method. Quickly, pre-treatment as indicated by ASTM standard B 253 was connected to the froth examples before store to yield a superior covering result. a blurb, that essentially contained copper pyrophosphate in light of the fact that the copper supply was utilized a pH size of 7.5. A blending bar was connected all through the entire statement technique at 180 rev to lessen the inclination of arrangement fixation. (18)

3.5 Fabrication of Aluminium Metal Foam by Sand Ball

The Porous aluminum leaf spring is made by throwing metal around granules procedure. The silica sand with bentonite blend and silica oil is utilized for making sand balls. The prepared balls are dried inside the temperature, the picture of sand balls is appeared in fig 5. At that point the aluminum metal is liquefied over the dissolving temperature by utilizing the heater. The liquefied metal is filled the example that comprises of sand balls stuffed. The poured form was knocked off, isolated from the gating framework and shot impacted. a comparable method is followed up for the readiness of required aluminum foam. The prepared aluminium foam piece is shown in fig 6.

3.6 Al Foam Production using NaCl as a Space Holder

The gadget grants to control its interior environment with a latent gas to shield the metal from the brisk oxidation, staying away from the utilization of a costly controlled air heater (a controlled climate heater consolidates the warming and air control frameworks itself). The gadget is inside formed by a metallic holder gave of a gap in its base half and a metallic shape. Fig. 7 demonstrates the compartment/form framework, in which the metallic holder with the aluminum is put on the metallic shape containing the NaCl particles bed, and each emphatically changed in accordance with one and unique. From that point forward, the framework compartment/form is put inside the gadget with controlled latent gas climate. At last, the gadget with controlled dormant gas environment is fixed and it's put inside a customary vertical electrical furnace opened in its best side to strategy the metal foam.
4. Consolidated Information on Al Metal Foam Production Methods

| Sl. No. | Production method                                      | Paper                                      | Parameter Studied                                                                 | Observation                                                                                                                                 |
|---------|-------------------------------------------------------|--------------------------------------------|-----------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------|
| 1       | Foaming Melts by Gas Injection                        | Sunil M Mahajan et al.[52]                  | Different cellular structure, production methods, sound absorption capacity        | The possibility of price for foams can decrease in the coming back years because the volume of production will increase.                     |
| 2       | i) Foaming Melts with Blowing Agents
          | John Banhart et al.[54]                             | Properties of Porous metals, Manufacturing techniques, Application,                | Open and closed foam has wide applications in structural, industrial sectors, automotive, aerospace.                                      |
|         | ii) Foams Made From Metal Powders (PM Foams)          |                                            |                                                                                    |                                                                                                                                              |
| 3       | Sandwich panel Methods                                | Hao Qingxian et al.[55]                    | Aluminum foam, sandwich panel, preparation process, properties                      | The production method of AFS panels was reviewed, and the advantages and limitations of different processes were discussed in this paper.    |
| 4       | Electrodeposition Method                              | Yi Sun et al.[18]                          | Open cell structure, Electrodeposition method, Energy absorption capacity           | Stress–strain compressive response of aluminium metal at the macro-scale foam using multi-cell models.                                    |
| 5       | Fabrication of Aluminium Metal Foam by Sand Ball      | S. Venkatesh et al.[39]                    | Aluminium foam, Sand balls, Foamed Leaf spring, FEA                               | The aluminium foam produce by the sand ball method withstand the utmost static load of 7000 N.                                            |
| 6       | Al Foam Production using NaCl as a Space Holder       | S. Bácz–Pimientoa et al.[35]               | Open–cell structure, Infiltration technique.                                       | There is a chances to get high interconnectivity between the cell that is cused by NaCl contact metal foams will be produced with the container. |
5. Experimentation and Analysis on Al Metal Foam
Based on the literature review after referring many papers researchers are conducted the following experiments on Aluminum metal foam that is produced by the various methods
- Density Evaluation of the Aluminium Foam
- Percentage Porosity Evaluation of the Aluminium Foam
- Detection of Crack Generation
- Flow Pattern by CFD
- Analysis through SEM on AL Metal Foam
- Acoustic Test on Aluminium Foams
- Modulus of Elasticity of Aluminum Foam [30-40]

6. Research Gap Identified/ Scope For Present Investigation
The study of these papers has indicated that, there are around several methods for producing aluminum metal foams.
- The researchers are focusing on developing newer methods for producing aluminum metal foams. However, there is absence of comparing and optimizing the available methods for producing aluminum metal foams and producing aluminum metal foams from the scrap of aluminum.
- Due the non uniformities in properties and production cost, it is not widely used in the Engineering applications
- Powder metallurgy technique is used to produce aluminium foam, because high porous structure and uniform foams can be develop for the FEM analysis for any mechanical component.
- It was also observed from one of the literature that powder metallurgy foaming process can prevent effectively the spread of cracks in panels and keep the shape of preformed blanks complete with an uniform density [55].

7. Conclusion
- A detailed review on the production of Aluminum metal foam is studied. To produce aluminum metal foam, there are several methods such as liquid metal process, powdered metal process and electrolyte method. Each process has their unique advantage and limitation on the production of aluminum metal foams.
- Depending on the various applications such as automotive, aerospace, machine construction etc., properties is an important parameter in the selection of the manufacturing of the aluminum metal foams.
- A detailed literature survey, emphasis that the aluminum foams produced by the powder metallurgy method, resulting high pore connectivity which gives better result for the analysis of mechanical applications.

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