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Modern Applications of Aluminium Foams

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Abstract. The implementation of aluminium alloy foam has more and more attention. Application of closed cell aluminium foam has made an impact in automobile and aerospace applications where crash energy absorption, vibration and weight reduction are obligatory [1,2,3]. The aluminium alloy foam is an advanced lightweight material providing high strength and stiffness at relatively low density. The technological use of aluminium alloy foam is difficult with the currently available technologies. In the case of open cell aluminium foams, the most common research areas for application are heat exchanger components, filters and sound damping elements [3]. The manuscript focuses on the manufacturing techniques of the aluminium alloy foams according to the application areas. First step is the investigation of the requirements for the application: what are the loads and the circumstances and why can we use aluminium foams. Second step is the knowledge of the producing methods of the foam or the component. And the last step is the investigation of the possible testing methods.

Introduction

Nowadays metal foams, especially aluminium foams are getting more and more attention. We can prove this easily if we investigate the number of results with the aluminium foam searching term on one of the biggest scientific online web page (ScienceDirect) which contain scientific books, articles and journals (Figure 1).

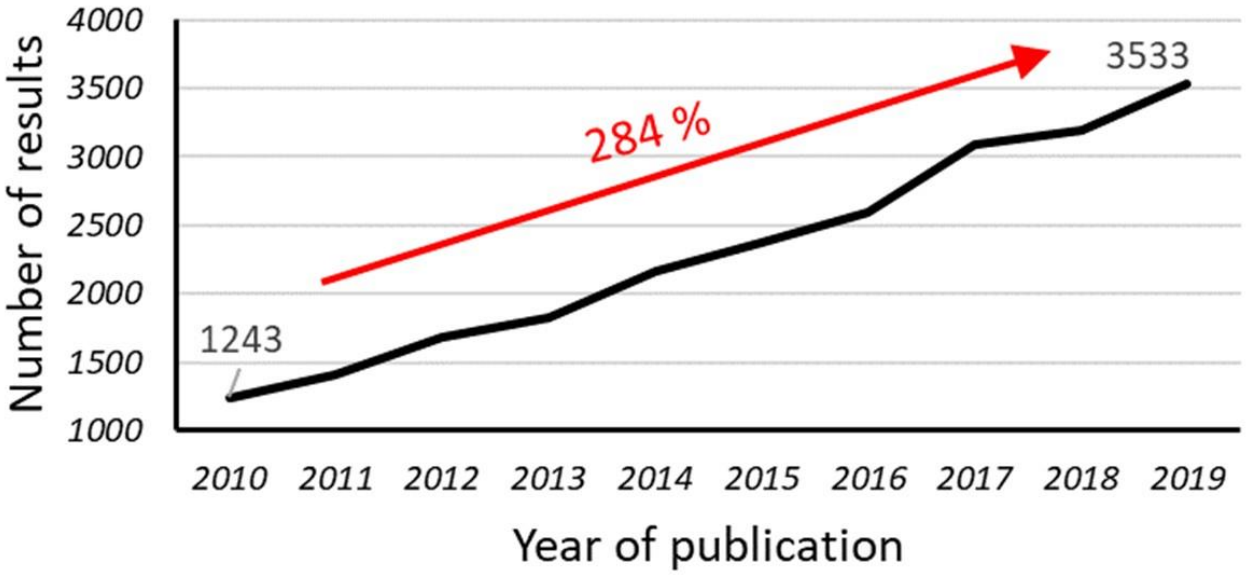

Figure 1. Number of articles about aluminium foams according to year of publication

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We can conclude the increase of the popularity of aluminium foams from the Figure 1. Why is the application of aluminium foams becoming more and more popular? Because metal foams have very unique properties and these properties are the results of the cell structure. Metal foams are porous structural materials and these materials are special composites where the base material is the matrix material and the “reinforcing” material is “oxygen”.

Enhanced research activities can be divided into two major groups: the production of foams that can be more effectively influenced and reproduced, and the application areas of recently produced metal foams [3-18]. Application areas are affected by the type of the metal foams. Aluminium is the most important and most used base material of metal foams due to its density and mechanical properties.

The paper is a major literature review of the applications of different aluminium foam structures.

1. Aluminium foam properties and applications

Aluminium foams are cellular, low-density materials that have unique mechanical, thermal, electrical, and acoustic properties. Aluminium foams can be divided into two large groups based on their structure: closed cell foams where the hollow structure is separated by cell walls, while the open cell foams have continuous hollow structure and the frame is made by interconnected cell edges [3,19,20].

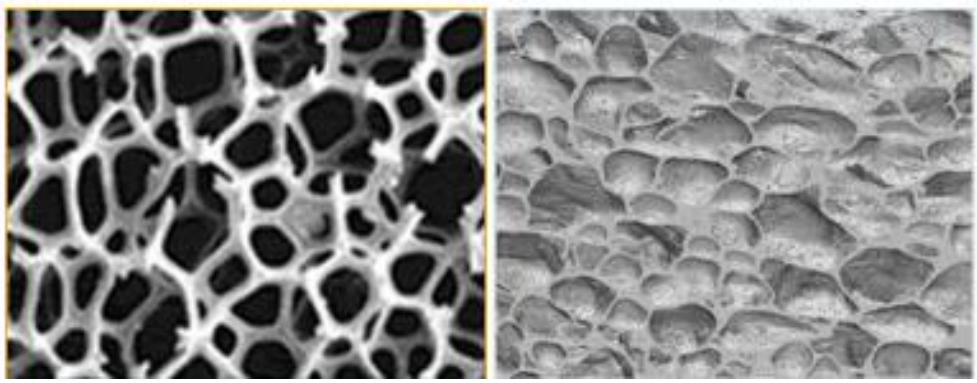

Figure 2. Open cell (left) and closed cell (right) aluminium foams [21,22]

Their applications are greatly influenced by their mechanical, electrical, chemical, acoustic properties.

Possible application areas of aluminium foams [3]:

- Lightweight structures: Excellent stiffness to weight ratio when loaded in bending.
- Sandwich cores: Aluminium foams have low density with good shear and frature strength.
- Strain isolation: Aluminium foams can take up strain mismatch by crushing at controled pressure.
- Mechanical damping: The damping capacity of aluminium foams is larger than that of solid metals.
- Vibration control: Foamed panels have higher natural flexural vibration frequencies than solid sheet of the same mass per unit area.
- Acoustic absorption: Reticulated aluminium foams have sound-absorbing capacity.
- Energy management: Aluminium foams have exceptional ability to absorb compact or light energy at almost constant pressure.

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- Artificial wood: Aluminium foams have some wood-like characteristics.
- Thermal management: Open-cell foams have large accessible surface area and high cell-wall conduction giving exceptional heat transfer ability (heat exchangers, refrigerators).
- High thermal conductivity of cell edges together with high surface area quenches combustion (flame arresters).
- Excellent filters be made from aluminium foams.

1.1. Closed cell aluminium foams

The cavities of closed celled aluminium foams are separated by cell walls, making them more stable than open celled aluminium foams. Due to their structure, they are more machinable and have better mechanical properties. It follows that closed-cell aluminium foams can be used as reinforcing and strengthening elements for machine components and structural elements.

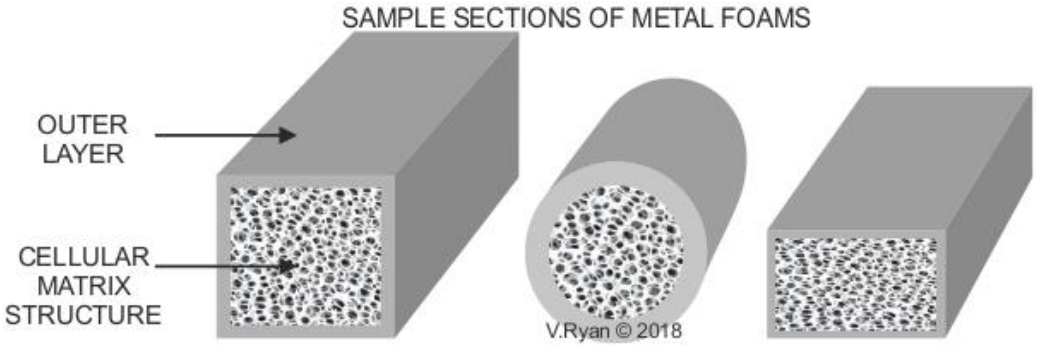

Figure 3. Geometries filled with al. foam as strengthening element [23]

Figure 3 represents that closed cell aluminium foams are essential structural elements, especially as filler element of a base component. The production of these elements is not considered in this paper.

1.1.1. Manufacturing routes

Several foaming methods were developed in the last century. Table 1 contains the most common foaming routes of closed cell aluminium foam production.

Foaming route	**Direct foaming of melt**			**Indirect foaming via re-melting of precursor**	
Process name	Alcan	Alporas	Gasar	Alulight/ Fominal	Formgrip
Dominant stabilization factor	Ceramic added to the melt	Oxide formation in melt	Viscosity of eutectic melt	Oxides in compacted powder	Ceramic added to the melt
Gas source	External gas source	Blowing agent	Dissolved gas	Blowing agent	Blowing agent

Table 1. Most common production methods of closed cell aluminium foams [20]

Closed cell aluminium foams of 0.03-1 g/cm^3 density ratio and cell diameter of 0.5-20 mm can be produced generally [3,19,20].

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1.1.2. Applications

The most powerful application areas for closed cell aluminium foams are the automotive industry, aerospace industry, space industry and machine industry. In machine industry, it can be used as reinforcement element, can be used for mechanical damping (Figure 4) and vibration control [3].

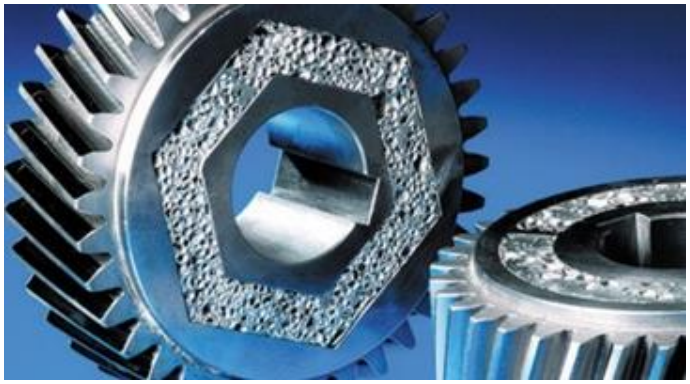

Figure 4. Gears filled with indirect foaming [24]

Lightweight structures can be used in space industry very well and the closed cell aluminium foams could be used for thermal management. Energy management, strain isolation and mechanical damping abilities are essential in the case of automotive and aerospace industries. Passive safety systems of automobiles have great potential to be one of the main development trends [14,15,17,18]. Other vehicles can benefit from the aluminium foam properties, Figure 5 shows us a reinforced train-frame.

Figure 5. Aluminium foam panels on a train [25]

1.2. Open cell aluminium foams

Open cell aluminium foams don't have closed, cell wall bordered cavities, they only have cell edges. Because of this property, the foam has a high surface to volume ratio. This type of foams has excellent thermal conductivity and good electrical conductivity as a result of their cell structure and the air in the system. Furthermore, since very high-density foams and consequently small bubble-sized foams can be produced, the mesh-like structure of open cells is well suited for filtering off impurities in liquids and possibly gases [3,20].

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1.2.1. Manufacturing routes

Open cell foam production requires more specific routes than closed cell foams.

Routes to produce open cell foams [3,19]:

- Production of open cellular metal foam using granules
- Precision casting after sample or template
- Sintering of sponge filled with casting paste
- Manufacture of metal foam by plating
- Sintering Dissolution Process (SDP)

3D metal printing is getting more attention in the case of open and closed cell foams either.

1.2.2. Applications

The four main target of the open cell aluminium foam applications are sound damping elements, heat exchanger elements, filters and design elements. Sound damping has very high potential and these elements are already used by transport sectors [8-13].

Heat exchangers (Figure 6) and design elements can be used very well in building industry. Open cell aluminium foams can be applicated on the walls, giving a very exciting look and it can be very good for the thermal maintance of the building too.

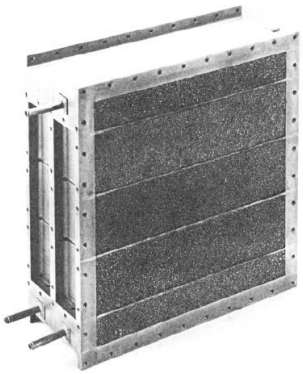

Figure 6. Aluminium foam heat exchanger [3]

Open cell aluminium foams are very good base materials for filters (Figure 7). Their density and bubble-size can be varied in broad limits and their corrosion resistance is essential too. Aluminium foam filters

Figure 7. Aluminium foam filters [26]

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Conclusion

Aluminium foams can be used in many different ways. They can be used as structural elements, light-weight structures, energy-absorbing elements, mechanical, vibration and sound damping elements, filters, design elements, reinforcing components and heat exchanger elements.

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