A SHORT OVERVIEW ABOUT STABILIZED ALUMINIUM FOAMS

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Abstract: *The paper will presents some manufacturing processes of Stabilized Aluminium Foams (SAF), (such as sheet casting, low pressure casting, precursor technology) and some SAF's characteristic properties. Finally, the various application fields for cellular metals are discussed. They are divided into structural and functional applications and are treated according to their relevance for the different industrial sectors.*

Stabilized Aluminum Foam (SAF) is a unique material in which the base material is a metal matrix composite (MMC), composed of metallic alloy base with added ceramic particles. The particles are necessary to stabilize the foam bubbles, since without the particles the formed bubbles will immediately collapse. The stabilizing particles slow the drainage of the metal in the cell walls and increase the apparent viscosity. Liquid metals are mostly made foamable by Ca additions followed by a thickening period. There is a need for an additive that can be easily admixed to an aluminium alloy melt and makes this melt foamable. Foams were successfully produced using SiC, TiB_2 and TiC particles. Ex-situ characterization of the foams by SEM showed that the particles segregate to the surfaces of the cell walls and lead to almost dense coverage there.

Keywords: *manufacture metal foams, stabilized aluminium foams, porous metals, cellular materials.*

1. Introduction

Stabilized Aluminum Foam is a unique material. The base material is a metal matrix composite (MMC) composed of aluminum alloy with ceramic particles added. The particles are necessary to stabilize the foam bubbles, since without the particles the bubbles would form but then immediately collapse. The stabilizing particles slow the drainage of the aluminum in the cell walls and increase the apparent viscosity.

Aluminium foams are a new class of materials with low densities, large specific surface and novel physical and mechanical properties. Their applications are extremely varied: for light weight structural components, for filters and electrodes and for shock or sound absorbing products. Recently, interesting foaming technology developments have proposed metallic foams as a valid commercial chance; foam manufacturing techniques include solid, liquid or vapour state methods. The foams presented in this study are produced by Melt Gas Injection (MGI) process starting from melt aluminium [1, 2]. The injected air causes' bubbles to rise to the surface of the melt, forming a liquid foam which is stabilized by the presence of solid ceramic particles on the gas liquid interfaces of the cell walls. The stabilized liquid foam is then mechanically conveyed off the surface of the melt and allowed to cool to form a solid slab of aluminum foam. The aluminum foam structure (cell size and cell wall thickness) is controlled by the process variables such as the volume fraction of the solid particles; foaming temperature, airflow rate, and impeller design the foam making process. Unfortunately, no publication has been found in the work on the influence of the process in variables on the cell structure of aluminum foam. The present study is aimed at investigating the effect of the concentration of SiC particles on the cell structure and mechanical properties. [1, 2].

2. Structure and properties of aluminium stabilized foams

The term "foam" is usually reserved for dispersion of gas bubbles in a liquid. [3]. The morphology of such a foam can be preserved by letting the liquid solidify thus obtaining what is called "solid foam" (often just called foam or sponge) [4]. The expression "metal foam" [5] strictly valid only for the liquid phase, is often used to describe the solid product thus the liquid counterpart is defined as liquid-metal foam [6].

The term “structure” is used for the description of cellular materials at different levels of observation: the geometric architecture of the solid (skeleton) in the individual cells and their 3D arrangement, the variation of that architecture within a considered sample or part (degree of uniformity), and the microstructure of the solid itself and its surface [5]. Equal size bubbles form a monodisperse foam. The foam is polydisperse if the bubbles show a wide variety in size [7].

We can say that practically foam structure can be in a open cell shape or in a closed one. The open cell metal foams are those that consist of cells connectable to each other through open faces. The solid material is contained in cell edges consisting of struts and rods rather than in solid faces. This form of foam is open to fluids passing through and so it is useful as a filtering medium, part of a heat transfer system [7] or cores in sandwich structures.

Closed cell metal foams contain non-interconnected cells with solid material faces. These foams have been investigated for potential uses where the structural properties are desired in combination with one or more of the foam’s other properties. The variation in cell size, wall thickness, constituent wall materials, and defects will all affect the mechanical properties of the bulk structure.

No matter the different processing routes for obtaining metallic foams, the complete foaming process is concerned with foam genesis where the blowing agent decomposes, its evolution and growth of spherical pores, further foaming that leads to thinning of cell wall and thus to change of pore shape from spherical to polygonal and pore coalescence due to surface tension and gravitational forces. The main convict for the destruction of foam is the instability of cell walls under the pressure differences or gravity. As we can see from the third and fourth steps, the death or collapse of foam occurs at the peak of third and start of the fourth step [8]. The strengthening the cell walls can inhibit this phenomenon. This can be accomplished in several ways, e.g., by enhancing the viscosity of melt, using different alloying elements in the melt or employing ex- or in-situ particles that stabilize the wall [9, 10, 11, 12, 13, 14, 15]. Similarly, Koerner et al. [14] discussed the aluminium foam stabilization by the presence of an oxide network. They have also suggested that the effect of the second phase on the stability of foam is due to its wetting characteristics with aluminium liquid. A good wetting (for example, Al/Al_2O_3 contact angle 63º at 1100ºC) leads to a decrease in the pressure in particle-free regions of the cell wall which in turn reduces the tendency of liquid drainage and thus cell wall thinning. The ceramic particles are segregated at the cell boundaries, and as the cell grows particles are pushed away. Finally the particles mainly decorate the cell walls leading to its strengthening.

Metal foams combine properties of cellular materials with those of metals. For this reason, metal foams are advantageous for lightweight constructions due to their high strength-toweight ratio, in combination with structural and functional properties like crash energy absorption, sound and heat management. Many metals and their alloys can be foamed. Among the metal foams, the Al-alloy ones are commercially the most exploited due to their low density, high ductility, high thermal conductivity, and metal competitive cost. [4].

3. Manufacturing process

Sheet Casting

Once melted, the MMC is poured into a foaming box. The foam is formed when gas bubbles exit the immersed rotating impellers (a component of the gas injection system). The foam collects on the surface of the molten material where it can be continuously drawn off to form a sheet. The foam structure is predominantly closed cell. The cell size is controlled by the gas flow rate, impeller design and impeller rotational speed. The rate and means by which the gas is introduced can be varied to produce foams with densities varying from 3% to 20% of the density of solid aluminum. Because many of the mechanical and physical properties of SAF vary with density and cell size, SAF can be tailored to suit the targeted application. [17].

Low Pressure Casting

Low Pressure Casting is similar to the aluminum die-casting process, which is commonly used to make aluminum wheels. Cymat’s process involves injecting SAF into a mould. The pressure of injection is controlled so that it is sufficient to fill the mold precisely, while not being so high as to collapse the unique cell structure of SAF. This technology is currently in the developmental phase. Cymat has built experimental equipment for process development, manufacturing of simple products, and further exploration of the technology. Features of this process are that it produces 3 dimensional shapes that have foam on the inside and an aluminum ‘skin’ on the outside surface.

Tabel 1. **Metal foam applications [16]**

Application	Comments	Examples
Light weight structures	Excellent stiffness to weight ratio when loaded in bending	Shipping container, building material, filling in hollow materials against buckling and builders staging
Sandwich cores	Metal foam has low density with good shear and fracture strength	Panel like floor and drop ceiling, aircraft pallet, heavy duty pallet, panel replacing honeycomb, elevator cab and door
Strain isolation (compression)	Metal foams can take up strain mismatch by crushing at controlled pressure	Joining elements
Mechanical damping	The damping capacity of metal foams is larger, by up to a factor of 10, than that of solid metals	Basis of rotating machine or loudspeaker
Biomedical industry	Biocompatibility (titanium or cobalt–chromium alloys)	Prostheses or dental implants
Acoustic absorption	Open cell foams have sound absorbing capacity	Sound barrier for highways, overhead bridge and tunnel, achine casing with improved sound and vibration damping
Acoustic control	Guidance and redirection of the sound waves	Closed cell foams suitable as impedance adaptors for ultrasound sources
Kinetic energy absorbers (compressive)	Exceptional ability to absorb energy at almost constant pressure	Crash attenuator, crash barrier, safety wall of tornado shelter, crash helmet, impact energy absorption parts for cars, lifting and conveying systems
Blast resistance	Excellent energy absorption capability	Amour and gas tank
Storage and transfer of liquids	Cell structure, open structure	Automatic humidity control, self lubricating bearings, porous rolls holding and distributing water or adhesives to surfaces, reducing undesired movements of the liquid in partially filled tanks (anti-sloshing)
Fluid flow control	Many available degrees of “openness” of cellular metals	Flow straighteners in wind tunnels or flow distributors in valves
Artificial wood (with high temperature capability	Metal foams has some wood-like characteristics: light, stiff and ability to be joined with wood screw	Rail car bulkhead, fire door and wall
Filtration and separation	Fine filtration capacity, good particle retention, clean ability, mechanical properties, corrosion resistance and low cost	Filters for cleaning recycled polymer melts, for removing yeast from beer, for contaminated oil, filtration of diesel fumes or water removal in air lines
Heat excengers/refrigeratos	Open-cell foams have large accessible surface area and high cell wall conduction giving exceptional heat transfer ability	Heat sink for processor
Thermal isolation	Thermal conductivities are much lower than those of solid metals, but still much larger than polymer foam	Cooking pot and vessels
Heat shields	Oxidation of cell faces of closed-cell aluminium foams appears to impart exceptional resistance to direct flame	Fireproof wall
Electrical shielding	Good electrical conduction, mechanical strength and low density make metal foams	Housings for electronic devices providing electromagnetic and

	attractive for shielding	thermal shielding
Electrodes and catalyst carriers	High surface/volume ratio allows compact electrodes with high reaction surface area	Long life battery
Electrode material	Increasing the electrode surface while maintaining the turbulence promotion	Electrochemical reactors, improvement of electro-catalytic processes (electro-oxidation)
Spargers	Creation of sufficiently small gas bubbles and corrosion, heat or shock resistance	Carbonation of beverages
Buoyancy	Low density and good corrosion resistance suggest possible flotation application	Ship and boat
Water purification	Redox reaction between ions and matrix metal of the cellular structure (for instance, electroless reduction of Cr(VI) ions by cast aluminium foams)	Water purifier
Sporting equipment	Good energy absorption capacity of SAF	Shinbone protectors for football players
Decoration and arts	Visual appearance or a large volume with a correspondingly low weight	Fancy furniture, clocks, lamps

Precursor technology

Precursor technology involves adding a foaming agent to molten MMC, followed by rapidly cooling the melt to form a solid precursor with a defined shape. Under specific re-heating conditions the precursor will expand to fill a cavity. Precursor technology will provide the ability to produce components with complex geometries and fill other complex and difficult to access parts. [17].

4. Preliminary experiments and results

The experimental equipment consists of an electric resistance furnace (maximum heating temperature 800ºC), which was adapted for insufflation gas (SO_2, N_2, inert gas, etc.) It is also equipped with a wide agitator and a trough acquisition of foam formed.

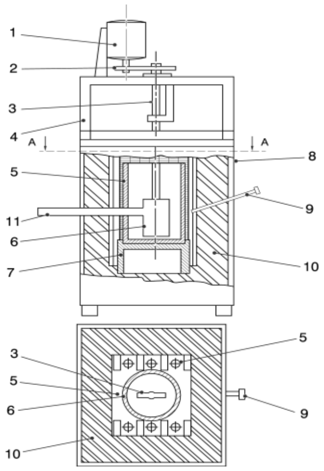

Figure 1: *Electric resistance furnace. 1 – engine, 2 – reductor, 3 – port rod paddle, 4 – metal frame, 5 – crucible, 6 – paddle, 7 - crucible support, 8 – silica bars, 9 – thermocouple, 10 – refractory shield, 11 – collecting gutter foam.*

Has been obtained metal foam by mixing the alloy melt AlMg15 with 10% SiC powder 120 μm size, at a temperature of 710 ºC with SO_2 injection at 1.2 atm pressure and also AlMg10 with 15% SiC powder 120 μm size at the same temperature with C_4H_{10} injection.

Figure 2: *Macroscopic image of AlMg15 metal foam*

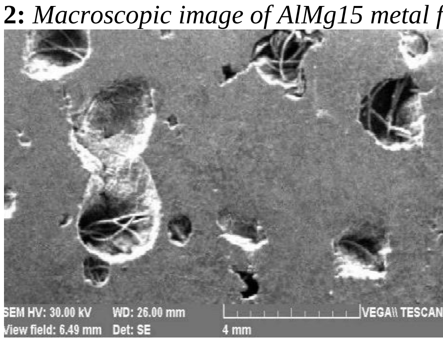

Figure 3: *Electron microscopy of AlMg15 metal foam*

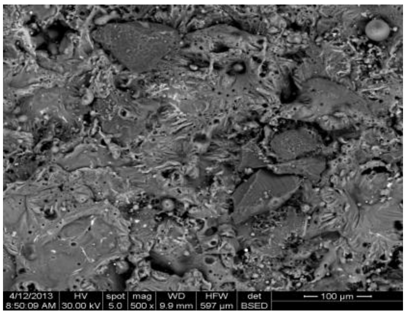

Figure 4: *SEM image highlighting the composite structure and arrangement of silicon carbide particles. Carbides in size to about 100µm. In matrix alloy may notice a random arrangement of microspheres with diameters of 3-25 µm.(AlMg10).*

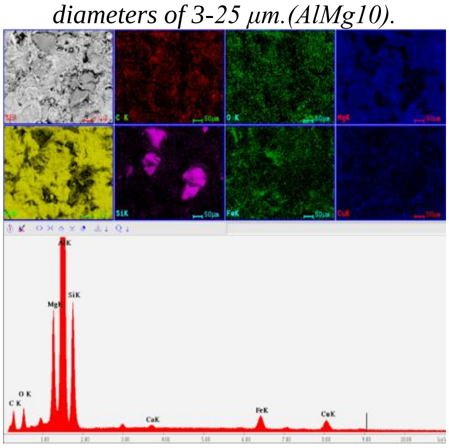

Figure 5: *Electron diffraction analyzer EDAX emphasizes the distribution maps for the main constituenmţi of composite. The colors chosen for call distribution to be able to differentiate the constituents on the basis of: Al.Si, Fe, Cu, Mg. (AlMg10).*

As can be seen from the analyses presented, attempts have not had favorable results in terms of getting metal foams, so we have to study more in the future how to obtain good results.

5. Conclusions

From this study concluded that we need a higher amount of SiC for obtaining foams, and SiC particles must have smaller dimensions, fact that will be studied further.

There are a lot of applications of metallic foams, but most of them are in the automotive, aircraft and building industries, in which the SAF manufacturers have the objective to achieve a market penetration that will bring stabilized aluminum foam to where magnesium is today.

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