A REVIEW ON THE MANUFACTURING PROCESSES OF ALUMINUM METAL FOAMS AND ITS APPLICATIONS

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Abstract
Aluminum foam can be manufactured applying a variety of methods including direct foaming of aluminum alloy melts and advanced metal powder processing. Complex-shaped foam components and 3D-shaped sandwich panels consisting of foam cores and aluminum face sheets can be produced. A short review of the most promising techniques is given. The application potential of these materials is discussed for various fields, namely light-weight construction, crash energy absorption and thermal or sound insulation. Various case studies are presented a lifting arm for a lorry, a crash box for a car, an impact energy absorber for a tram, a motor bracket for a car and a transverse beam for a machine. Such studies allow us to assess in which application fields aluminum forms perform well and in which direction future development should be directed.
Keywords: Aluminum foam, absorption, metallic,

1. Introduction

Solid metallic foams especially the ones based on light-weight metals are known to have many interesting combinations of different properties such as high stiffness in conjunction with very low specific weight or high compression strengths combined with good energy absorption characteristics. For this reason, the interest in these materials is still increasing The development of metal foams is described in review articles and conference proceedings [1–5]. The present paper will be restricted to closed-cell aluminum alloy foams which have a good potential for market introduction. We shall first review different manufacturing routes, address the importance of fundamental research and then discuss applications.

2. Metal Foam

The history of metal foams is quite interesting and dates back to the 1940s [11] . A large number of patents were issued in a first surge from the late 1950s to the 1970s and many variants of foaming processes were proposed. Hardly anything was ever published beside the patents by the companies involved in the research. Therefore many details were forgotten and it is difficult to assess today whether all the ideas proposed then actually worked. A second surge of scientific activities starting in the late 1980s led to the re-establishment of some of the old techniques and the discovery of new ones. At first companies like Alcan, Hydro Aluminum and Shinko Wire carried out inhouse research but as the attitude towards publication seems to had changed since the 1970s some publications emerged even from the company laboratories. Fraunhofer-Institute in Bremen entered the field in 1990 after they had re-discovered an old powder-based metal foaming process. From the beginning this in-stitute carried out and published work related to the processing of foams. However, still the work was not fundamental and processing issues were mostly solved more in a trial-and-error manner than by exploring systematically the background of technology which is typical for industry-driven research. In the mid-1990s an American research programme and shortly after a German state-funded research network started considerable fundamental research on metal foams. up with an already existing industrial production technology. Nowadays the number of ba-sic research publications is increasing every year. The task is to understand how metal foams are stabilized and how stability can be improved. The aim is to make production more reliable and to improve the properties of foamed metals. It was realized that the presence of non-metallic particles in the size range from tens of nanometers to tens of micrometers in the liquid metal is crucial for foam stability. However, the stabilization mechanism is still under dispute. In analogy to aqueous foam physics the term high-temperature colloid chemistry has been coined for this research field. [12].

A second important field is the investigation of structure-property relationships. Intuitively it seems obvious that uniform metal foam with smooth cell walls yields the best mechanical properties. However, an actual proof is still lacking. As there is a wealth of macroscopic and morphological parameters describing a metal foam density, cell size distribution, cell size orientation, cell wall curvature, cracks in cell walls and the microstructure also plays an important role grain size distribution, impurity level, ageing conditions an easy and comprehensible representation of the experimental evidence is difficult to find.

Third, modeling of metal foam structures is important for being able to interpret the experimental data and to help design engineers to apply the material. Here modeling on various levels has been attempted, starting from micro modeling of foam structures themselves usually by representing the actual foam by a simplified geometry and ranging to modeling work of entire components in which the foam is represented by an effective medium. Beside these areas there are other more technological fields of interest such as joining, cutting, or coating of metal foams. Examples for fundamental research can be found in the conference proceedings of al Metal Foam conferences [2–4, 13] .

3. Types of processes

There are two main strategies for making aluminum foams .Direct foaming methods start from a molten metal containing uniformly dispersed non-metallic particles into which gas is injected to create a foam. Alternatively, titanium hydride can be added to the melt, after which decomposition leads to the same effect. Indirect foaming methods start from solid precursors which consist of an aluminum matrix containing uniformly dispersed blowing agent particles, mostly titanium or zirconium hydride. Upon melting this precursor expands and forms a foam.

3.1 gas injection process

Foaming aluminum or aluminum alloys by gas injection is already in the state of commercial exploitation. Silicon carbide, aluminum oxide or other ceramic particles have to be admixed to make the alloy foam able. The volume fraction of the reinforcing particles typically ranges from 10 to 20%, and the mean particle size from 5 to 20 µm. Gas injections (usually air) is done through specially designed injectors, some of which have been described to rotate or vibrate. The resultant foam accumulates on top of the liquid from where it can be pulled off, for example, with a conveyor belt, and is then allowed to cool and solidify. The foamed material is either used in the state it comes out of the casting machine, having a closed outer surface, or is cut into the required shape after foaming. Advantages of this foaming process include the large volume of foam which can be produced and the low densities which can be achieved. Cymat, Canada, produces its foam called ‘Stabilized Aluminum Foam (SAF)’ in this way.

3.2 precursors foaming

Foam able precursor materials can be produced in various ways: by mixing aluminum powder and titanium hydride and compacting this mix, example, by hot pressing, extrusion or powder rolling to a dense precursor[7] . If alloy foams are required, powdered metals have to be added to the mix accordingly (‘Foam-in-Al’ or ‘Alu-light’ process), by pre-compacting powder mixtures to billets, heating these billets to the semisolid state and thixocasting them to shaped precursor parts , by adding blowing agent to an aluminum alloy melt after which the melt is solidified. This can be done in a die-casting machine or in an ordinary crucible in which case, however, the blowing agent powders have to be pre-treated to prevent them from premature decomposition[10] (‘Form grip’ process). by processing a liquid aluminum spray and allowing for deposition in the presence of a blowing agent.

4 .Applications

4.1 General applications

Metal foams have properties which make them suitable for automotive industry which has been extremely interested in them since they were first developed. Potential applications also exist in ship building, aerospace industry and civil engineering[1] . The principal functionalities can be distinguished as follows:

compression strength of the material. Foams can therefore act as impact energy absorbers which limit accelerations in crash situations. This mode exploits the horizontal regime of irreversible deformation in the load-deformation diagram. As metal foams can have much higher collapse strengths than polymer-based foams up to 20 MPa they can find applications in areas not accessible to foams up to date.

4.2 Light-weight construction with aluminum foam sandwich (AFS) panels

The AFS technology developed in 1994 by Fraunhofer-IFAM in Bremen and Karmann GmbH, a German car builder, is one example for the use of foams in conjunction with dense material : sandwich panels consisting of a foamed metal core and two metal face sheets can be obtained by roll-cladding conventional aluminum sheets to a sheet of foam able pre-cursor material manufactured from powders. The resulting composite can be shaped in an optional step, example, by deep drawing. The final heat treatment, in which only the foam-able core expands and the face sheets remain dense, then leads to sandwich structures. The ability to make 3D-shaped panels and the high stiffness-to-weight ratio are a clear advantage over competing technologies such as honeycomb structures. In combination with new constructional principles AFS could replace conventional stamped steel parts in a car and lead to significant weight reductions. At the same time AFS could also reduce the number of parts in the car frame, facilitate assembly and therefore reduce costs while improving performance because such sandwich panels act as vibration dampers beside being light. AFS sandwich parts can be joined with aluminum

Light-weight construction: Aluminum foams can be used to optimize the weight-specific bending stiffness of engineering components. The bending stiffness of flat foam panels is approximately inversely related to foam density. Light-weight construction exploits the quasi-elastic and reversible part of the load-deformation curve.

Energy absorption: Owing to their high porosity, aluminum foams can absorb a large quantity of mechanical energy when they are deformed, while stresses are limited to the

sections by various welding techniques which facilitates their integration into the car body.

4.3 Aluminium foams as cores for castings

Yet another application makes use of the beneficial properties of Al foam inside a dense aluminum shell both during manufacture and in use after. One starts from a shaped part of aluminum Metcomb or Alulight foam (indirect or direct foaming). The parts have dense outer skins and can therefore be used as cores in low-pressure die-casting during which composites consisting of a cast outer surface and a light-weight inner core are formed[8]. Such composites have advantageous service properties such as higher stiffness and improved damping compared to the empty hollow parts while their weights are only marginally higher. LKR (Austria) and the German car maker BMW have jointly designed an engine mounting bracket based on such composites. The produced parts show no noticeable infiltration of the Met comb core itself by the melt during casting. It can be loaded with the high weight of a car engine and absorbs mechanical vibrations by internal dissipation into thermal energy. Stiffness is enhanced and, as fracture toughness of such composites is high, these parts also increase safety in crash situations.

5. Conclusions

A number of new metal foaming technologies have been developed in the past decade which now offers a wide range of different forms of this exciting material. Compared to early developments in the 1950s to 1970s the quality of metal foam has been improved and the possibilities for making composites widened.

With some first applications already on the road it seems quite realistic that aluminum foams will find an even wider use very soon in cars, ships, aircrafts or even spacecraft

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