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ALUMINIUM FOAM FOR AUTOMOBILES:-A REVIEW OF MANUFACTURING TECHNIQUES, APPLICATION AND MATERIAL PROPERTIES

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Abstract

Mainly because of the strong demand of the transport industry for lower operating costs, higher payloads, improved environmental compatibility as well as increased passenger safety and comfort aluminium foams have become more and more important during the last few years. They had been identified as a new class of material of great interest due to their unique combination of properties derived from their cellular structure and metallic behaviour. Utilization of Aluminium foam core will increase the capability of component to absorb crash energy in multiple impact directions. The reduction of noise and vibration of initially hollow component is expected as well.

INTRODUCTION

In the last years the interest in metallic foam has increased considerably. The main reasons for this development are new concepts for light weight cars and other light Constructions. Aluminium, offer a great potential for applications in the automotive industry. Foams are light weight, energy absorbing and in combustible and have good Sound absorbing properties. Other applications are also possible in engineering, building, household goods and the chemical industry. The research in automotive industry always focuses on new concepts that save the fuel consumption and CO_2emissions, improve the passive safety and suppress the noise and vibration of future vehicles. These targets cannot be simultaneously achieved with recently used concepts; the improvements in safety and comfort lead always to a weight increase. Weight savings in load bearing components are usually accomplished by utilization of welded or hydro formed metallic profiles or castings having weight-saving cavities. However, the useof such hollow components is accompanied with high level of disturbing noise and vibration. Although hollow parts are often utilized as absorbers of crash energy, this property is usually effective only in one impact direction. The wall-thickness of these parts (often limited by the technology used) is mostly constant and is determined by most loaded section of the component, which leads to an additional weight in cross sections where it is not necessary.

It is a known fact that globally customer appreciation and demand for less noisy and more comfortable products are increasing every year constantly. In the automotive industry for example noise and heat conduction control are becoming important design criteria mainly driven by competitive nature of the market and increasing customer awareness. In addition, the increasing demands of decreasing exterior noise emissions, engine and tire noise are further required by the European Union (EU). Therefore, nowadays it is inevitable to optimize the interior and exterior noise and exterior heat level of exhaust system and engines of vehicles. It is well known that exterior noise emission of vehicles is a substantial factor contributing to the environmental acceptance of traffic. Therefore, legislators all over the world have created regulations limiting the exterior noise levels. Exterior noise measurements are carried out by using special test vehicles, which make it possible to study the contribution of each sound source such as engine, gearbox and tires. Noise, vibration and harshness (NVH) analysis and thermal barrier measurements for both power-trains and exhaust systems are routinely performed to the vehicles by the most of the automotive companies and their suppliers. There are also research centres conducting R&D for aiming at identifying and classifying many qualities of unwanted sounds of power-trains and decreasing the exhaust and power-train system's heat conduction to the considerable lower levels.

Aluminium and aluminium foam parts could be manufactured in a single piece with a wide range of bulk and surface properties that provide excellent physical, thermal and acoustic characteristics. Sound absorption and thermal barrier coating properties of aluminium foams were studied over the 15 years. In the last decade, aluminium foams were investigated as the potential materials to be used in sound silencers and thermal barriers. Most of the applications however are based on the open cell aluminium foams (interconnected cells) or semi-opened aluminium foams, owing to their better sound and thermal emissions as compared with closed cell foams. On the other hand, the processing cost of closed-cell Al foams are lower than that of open cell foam and with the use of foaming from powder compact process, it also possible to manufacture parts in the final form, in any shape and dimensions with a dense Al skin on it. The dense skin allows the applications of finishing process such as grinding, polishing and painting. Recently, Al foams with SiCp (silicon carbide particulate), showing metal matrix composite structure, have been produced using the foaming from powder compact process. To improve the performance of sound silencers and thermal barrier coatings many absorbing materials, generally foamy and fibrous, are developed. However, the performance of SiCp/Al foams as sound silencers and thermal barrier coatings has not been investigated yet.

I. Production methods for aluminium foams

A. *Foaming of liquid metal:*

a. *Foaming Melts by Gas Injection (Alcan/Norsk Hydro process):-*

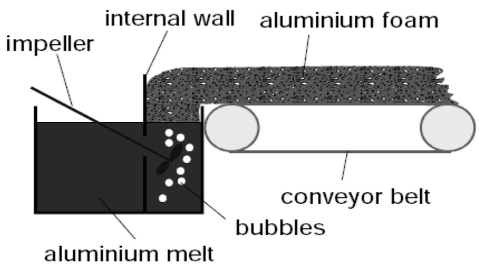

Figure1 - Foaming Melts by Gas Injection

The first method is it to foam directly by injecting gases into the liquid metal. The Alcan/Norsk hydro process is shown in figure1. It includes an addition of SiC or Al2O3 (10 to 15%) to the melt to increase its viscosity. After this a gas (air, nitrogen or argon) is injected into the melt using a rotating impeller. Then the floating foam is continuously pulled off from the surface of the melt. Foam slabs of considerable size (e.g. 0.1 x 1 x 10 m) can be produced by this way. The product of this technology is a porous sheet material with porosities ranging from 80% to 97%.

b. *Foaming Melts with Blowing Agents (Alporas process) -*

This technology includes addition of1.5% calcium to the aluminium melt for adjusting the viscosity. Calcium is introduced to the molten aluminium at 680°C and stirred for 6 minutes in an ambient atmosphere. The thickened aluminium melt is poured into a casting mould and stirred with an addition of powdered TiH2 (foaming agent) by using a rotating impeller. If a sufficient amount of the hydride is added (usually 1.6%) the foaming agent decomposes under the influence of heat and releases hydrogen gas. Thereby, the foam is expanding and fills up the mould within 15 minutes. It is cooled down by fans in the mould and solidifies asa block with porosity between 89% and 93%. A cast Alporas block is 450 x 2050 x 650mm and weighs 160 kg. The blocks are cut into sheets of the required thickness.

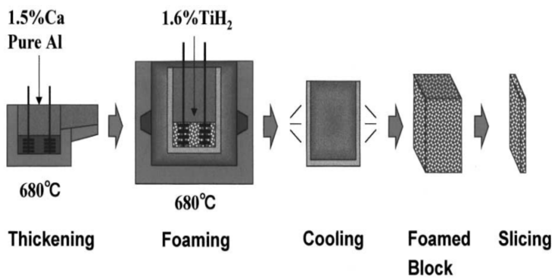

Figure2Foaming Melts with Blowing Agents

c. *Foams made from metal powders (PM foams)-*

Among these technologies the processes are of great importance for the production of aluminium foams, that are basing on the use of a foaming agent. Instead of foaming agents inert gases can be directly entrapped in the precursor.

Expansion with a gas released by a foaming agent (IFAM, MEPURA) Technologies basing on the use of foaming agents start with the mixing of the metal powders (pure metal, alloy or powder blend) with a foaming agent (for aluminium and its alloys usually 0.4 – 0.6 wt.-% TiH2). The most common alloys for foaming are wrought alloys of the series 1xxx (pure aluminium), 2xxx (Al-Cu) and 6xxx (Al-Mg-Si) or cast alloys, e.g. AlSi7 and AlSi12. The last have excellent foam ability due to their low melting point and their good foaming properties. The mixture is compacted to a dense, semi-finished product. In the IFAM-process (Fraunhofer-Institute in Bremen, Germany) the material is compacted by uniaxial compression, CIP, powder rolling or extrusion depending on the required shape. The MEPURA process (Alulight by Mepura, Ranshofen, Austria) uses a continuous extrusion technology for the compaction of the mixture. The next step is a heat treatment up to the melting point of the matrix metal and above the decomposition temperature of the blowing agent. At this temperature the foaming agent decomposes and releases hydrogen gas. This gas leads to an expansion of the material resulting in a highly porous structure with closed cells. By cooling under the melting point the foaming process is stopped. The porosities range from 60% to 85%.

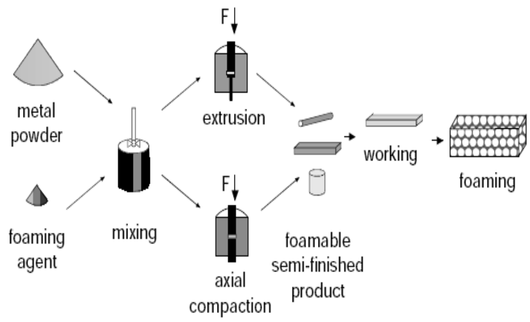

Figure3.Foaming from powder compact process

II. AUTOMOTIVE APPLICATIONS OF ALUMINIUM FOAM

Aluminium foam can be use in many automotive applications. 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 foam is high, these parts also increase safety in crash situations. In addition, aluminium foams are going to be used for sound attenuators in automobiles as foot panels, doors, back of the power-train (dash panel) sections (Figure5). In a vehicle, interior noise was caused by several parts of the car body, such as engines, exhaust system, suspension, tyres, etc. and interior thermal problems caused by power-train, exhaust system, body panel, etc., are the main problems that the automobile manufacturers, designers and OEM manufacturers faced for several years. The major noise and heat sources, in their order of significance, in the vehicle are:

-Engines - crankcase, oil sump, cylinder head

-Tappet covers, engine mounts besides combustion

-Exhaust system, Intake system

-Transmission

-Fan and cooling system

-Tyres

-All the body panels including that of bonnet

-The good relation between weight and stiffness supports the use of foams for large area light-weighting automobile body sheets and structural parts, that are used in areas of the cars with increase requirements on stability. Examples are trunk lids, engine hoods and sliding roofs. All these parts should suffer no elastic deformations caused by the air stream. Vibrations must be avoided. Aluminium foams with their good insulation properties can be a good solution for these components. Another example is the stiffening of convertibles and the bodies of commercial vehicles.

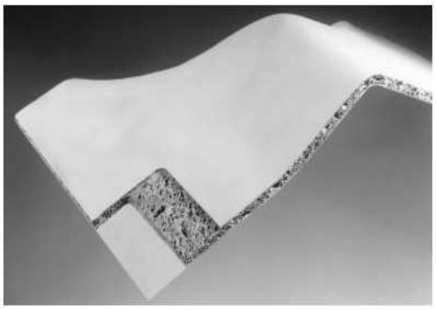

Figure 4: Aluminium foam sandwich

To the third group belong applications that use the good sound absorbing and thermal insulating properties of aluminium foams.

The sound absorbing properties make foams useful for a sound insulating covering of the engine compartment of cars. The objective in this case is it to prevent transfer of noise into the passenger compartment and into the environment.

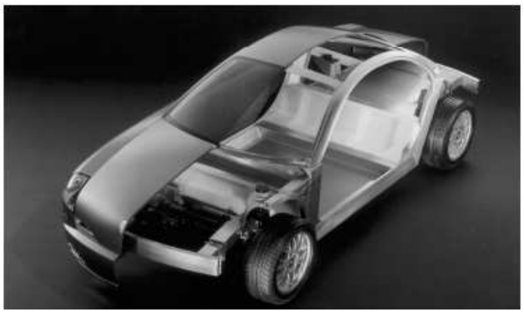

Figure 5. Aluminium Foam Body

Welded structures or hydro formed profiles are manufactured from metallic sheets or tubes with constant thickness; there is no possibility to vary the thickness in a component according to the loading requirements. The thickness is determined by the most loaded section which leads to an additional weight in the sections where it is not necessary. Moreover maximum but also minimum thickness is often limited by available pressing forces or by the technology (e.g. hydro forming can be used only for Limited thickness range)

Figure 6: Aluminium spare frame made of hydrofoamed and Welded profiles

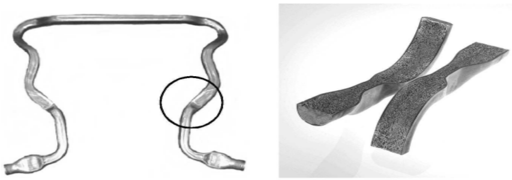

Figure 7:-Motor carrier made by hydro forming filled in weakest sections with aluminium foam

Complex foamed body parts are promising for lightweight stiff body structures of future vehicles because they can be manufactured at relatively lower costs. The complex aluminium foam panels prepared by PM-techniques (see Fig. 7) are always covered by dense aluminium skin that enhances the mechanical properties similarly as cover sheet in the case of sandwich structures. However the natural skin of foams has variable thickness and sometimes contains small holes or even cracks. These inevitable defects can initiate premature fracture of the foam, especially when they appear on the tensile loaded surface of foamed part. This problem can be solved very effectively by reinforcing of tensile loaded surface skin with metallic or ceramic wires woven into grids with various mesh size. According to a novel foaming technique developed recently, the reinforcements are placed in the foaming mould together with formable precursor, foam expansion moves them to the mould surface where they are infiltrated with molten cell-wall material. The main advantage of this method is the simplicity, lower manufacturing costs and the possibility to reinforce the foamed part selectively and anisotropic according to the applied load.

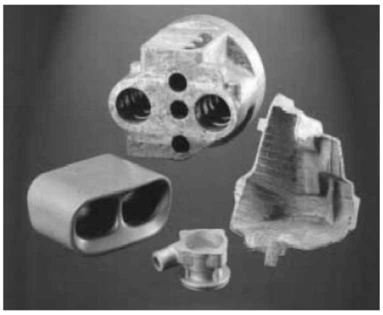

Figure 8: Complex foamed aluminium parts

Due to its lightweight aluminium foams can become important for the aerospace industry. For example, aluminium foam sheets or sandwich panels could replace the expensive honeycomb structures. This would have several advantages, for example reduced costs. Another important advantage is the isotropy of the properties of such panels and the absence of any kind of adhesive bonding. The latter could help to maintain the integrity of the structure in cases of fire. However, an important issue, which is addressed in current investigations, is the fatigue behavior of aluminium foams and panels.

Figure 9: Aluminium castings accomplished with *Permanent aluminium foam core*

IV Material Properties

In comparison to bulk aluminium material aluminium foams have some special properties. These properties however depend very much on their cell structure. Open cell structures possess a good liquid and gas permeability, a large inner surface and due to this a good heat conductivity. In contrast to this, closed cell structures possess heat insulating properties because neither liquids nor gas can pass through them. Both kinds of foam have a high stiffness, a high capability of shock absorbing and vibration damping and what is most important in combination to the previously mentioned properties low densities. The application of aluminium foam has advantages when parts are redesigned to optimize the multi functionality. According to different studies up to 70 kg of foam can be used in an average car. It could provide structural reinforcement and energy absorption in door panels, front hoods, bumpers, roof panels, crash boxes and body frame elements. Or it can be used as a combination of firewall, acoustic dampener, energy absorber and semi-structural component between the passenger department and trunk. The two main competitors of aluminium foam concerning energy absorption are honeycomb structures and polymer foams. But in contrast to honeycomb structures aluminium foams have isotropic properties and they are much stronger and stiffer than polymer foams. They also can operate at much higher temperatures and have constant properties over time, humidity ranges and crash speeds.

a. Mechanical property:

Aluminium foam has a cellular structure that's why the conventional testing methods cannot be used for testing aluminium foam. The compression & tensile stress-strain diagram are shown in figure.

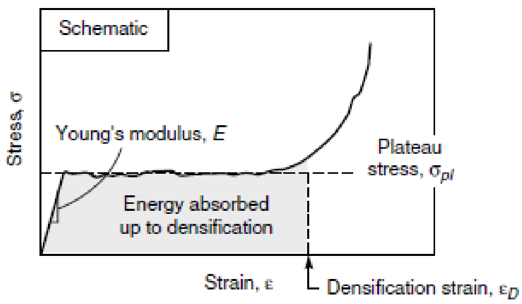

Figure 10: compression stress-strain Curve for aluminium foam

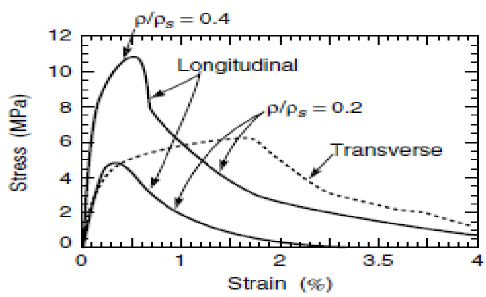

Figure 11: compression stress-strain curve for aluminium foam

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 (E/ρ) of aluminium foams is much lower than that of dense aluminium as shown in figure 12. [1]

The modulus of foams increases with increasing density. This effect appears in both cases – PM- and LM-foams. Therefore the modulus can be adapted to a special application by controlling the density of the foam.

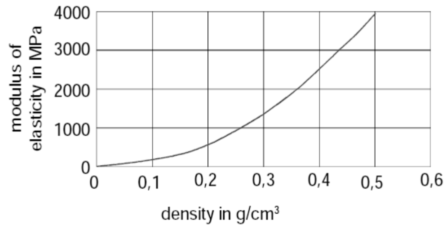

Figure 12: Relationship between densities & modulus of elasticity

b. Electrical property:

Figure 13. Shows measurements of the conductivity of open (ERG-Duocel) and closed (Mepura-Alulight) cell aluminum foams as a function of relative density, normalized by the conductivity of the fully dense alloy. The conductivity varies in a non-linear way with relative density

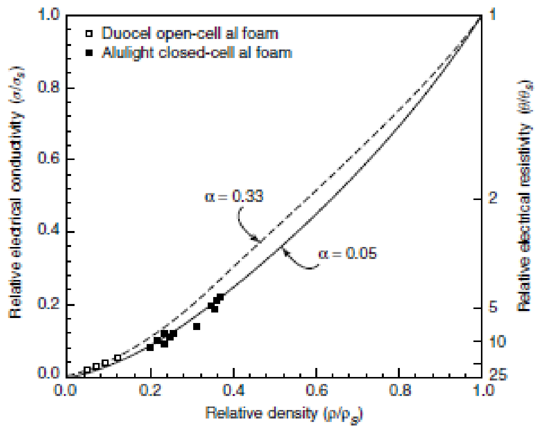

Figure 13: The electrical conductivity and resistivity of open cell and closed cell aluminium foam of different relative density.

c. Sound absorption property:

It is the fraction of the incident energy of the sound wave which is absorbed by the material. The upper figure shows the value of ˛ for a good absorber, glass Wool: at frequencies above 1000 Hz the absorption coefficient is essentially1, meaning that the sound is almost completely absorbed. The central figures hows absorption in a sample of Alporas foam in the as-received (virgin) state Metal foams have limited sound-absorbing ability, not as good as glass wool, but still enough to be useful in a multi-functional application.

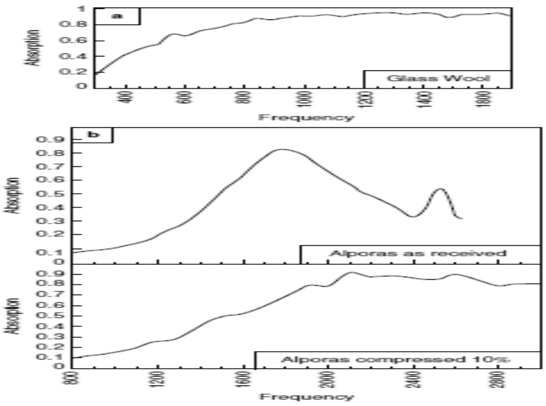

Figure 14.*Sound absorption, measured in a plane-wave*

Impedance tube, for glass fiber, Alporas foam in the as-

Received condition and Alporas foam after10% compression to rupture the cell faces

Conclusion:-

The main aim of the paper was to present a new concept for design and manufacture of light-weight load-bearing structures. This concept is based on utilization of aluminium foam made by PM-process for stiffening of hollow welded or hydro formed profiles or aluminium castings.

Aluminium foam is an ultra light material which possesses high stiffness at very low density, it absorbs high amount of impact energy, is highly efficient in sound absorption, electromagnetic shielding and vibration damping, is fully recyclable, fire resistant, non inflammable and does not evolve toxic fumes in afire. These outstanding properties allow using this material in light-weight structural components in modern vehicle design especially for body structures, frames, suspension parts and crash absorbing elements. The utilization of the foam will allow the distribution of load-bearing material in most convenient way according to loading conditions, without need to increase the overall weight or volume of the part. Application of aluminium foam will also increase the capability of the component to absorb crash energy and the reduction of noise and vibration.

REFERENCES

1. “Metal Foams: A Design Guide” by M.F. Ashby, A.G. Evans, N.A. Fleck, L.J. Gibson, J.W. Hutchinson and H.N.G. Wadley

2. "Processing and application of aluminium foams" by Nidhi Sinha, V. C. Srivastava, K. L. Sahoo

3. "Mechanical Properties of Metallic Foams" by Chin-Jye Yu and John Banhart.

4. "New concept for design of Lightweight automotive Components" By Jaroslav JERZ, Rain hard LAAG, Frantiäek SIMAN

5. "Aluminium foam prepared" by Dr. –Ing. Catrin Kammer, Goslar, Germany………..1

6. "The application of aluminum foam For the heat and noise reduction In automobiles" by Ilgaz AKSELİ

7. "Aluminium Alloy Foams: Production and Properties and Recycling Possibilities" by Bernd Friedrich, Katherina Jessen, Georg Rombach

8. "Alulight - Aluminum Foam for Lightweight Construction" By Frantisek Simancik, Walter Rajner Rain hard Laag

9. "Manufacture, characterization and application of cellular metals and metal foams" by John Banhart

10. "Steel foam for structures: A review of applications, manufacturing and material properties" by B.H. Smith, S. Szyniszewski , J.F. Hajjar , B.W. Schafer , S .R. Arwade.