FIBRE REINFORCED ALUMINIUM FOAMS - NEW ULTRALIGHT STRUCTURAL MATERIALS

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Aluminium foam is a highly porous cellular material were pores represent 65 - 90 % of the total volume. The foaming process principally does not affect the properties of the cell-wall material. However, it leads to a unique spatial distribution of metal, which results in significantly different properties of foamed component in comparison with a bulk part. Several of the engineering properties of aluminium foams are superior to those of polymeric foams; they are stiffer by an order of magnitude, they are stable at elevated temperatures, they possess superior fire resistance and do not evolve toxic fumes in a fire. It is obvious that the properties of aluminium foam significantly depend on its porosity, so that a desired profile of properties can be tailored by changing the foam density. Anisotropic or gradient pore structure allows the distribution of load bearing material in most convenient way according to loading conditions (simulating optimum bone-like structure), without need to increase the overall weight or volume of the component. Foam is crushable and thus it possesses high capability to absorb crash energy at adjustable stresses. Moreover, aluminium foams are also efficient in sound and vibration damping, can shield electromagnetic waves, are fully recyclable and environmentally friendly. Due to the development of new techniques [1], enabling reasonable manufacturing costs, this remarkable material becomes very attractive for transport industry, especially for lightweight stiff body structures of busses, trains, ships, etc.

Metallic foams arise by nucleation and subsequent growth of gas pores in a liquid or semi-liquid metal. The distribution of pores is therefore pretty random. The pores are initially closed although some cracks or openings can be found in the cell walls after solidification and cooling. These are the main features of this kind of cellular solids. Aluminium foams can be principally prepared by direct foaming of the melt or by powder metallurgical (PM) route, which is nowadays considered as most promising technique for the manufacturing of net shape foamed components [1, 2]. PM route comprise foaming of the precursor prepared by compacting of powdered metal or alloy, whereas the pore forming gas is developed during melting of this precursor from admixed foaming agent [2]. The powder must be thoroughly compacted in order to seal the particles of foaming agent. This avoids the premature release of the gas at heating. The formation of the pores starts during the melting of the metal matrix. If the precursor is inserted in a suitable mould before foaming, the foam follows its shape. Subsequent rapid solidification produces final shaped component with a continuous surface skin and a cellular internal structure. PM foams can be prepared with gradiently variable pore size and also with preferred orientation of pores. The possibility to use the simple-form precursor e.g. extruded rods or ribbons for foaming of components with various shapes and sizes lowers the high production costs, which represented the main disadvantage of PM process. There are almost no constraints considering complexity of the outer shape and geometry [3]. PM foams are always covered by dense skin, which significantly improves the mechanical properties (e.g. bending stiffness, etc.). 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. Reinforcing of tensile loaded surface skin with metallic or ceramic wires or fibres woven into grids with various mesh size can solve this problem very efficiently, similarly as it is in a case of steel reinforced concrete (Fig. 1).

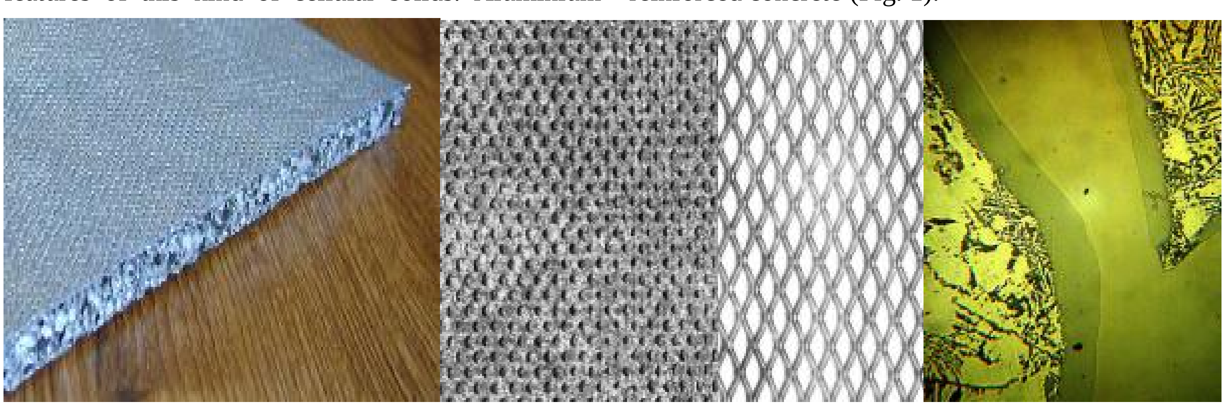


Fig. 1: *Aluminium foam panel reinforced in the surface with expanded stainless steel sheet*

The stresses, which usually cause the yielding or even fracture of surface skin, can be overtaken by reinforcements. The possibility to reinforce the foamed part selectively and anisotropicly according to the expected load allows to achieve significant improvement of the stiffness, strength (Fig. 2), plasticity, energy absorption capacity and damage tolerance (Fig. 3) of foamed part with only slight weight increase (ca. 20-30%). The reinforcements prevent liquid foam from collapsing on cooling and thus they have also an additional stabilizing effect. Moreover the reinforcements increase the thickness of surface skin, simplify joining of foamed parts (welding is possible) and enable limited shaping after foaming process. According to a recently developed foaming technique, the reinforcements are placed in the foaming mould together with foamable precursor and the foam expansion moves them to the mould surface where they are infiltrated with molten cell-wall material. One of the attractions of this process is that the composites are prepared in one technological operation (during foaming) what significantly reduces manufacturing costs. The liquid foam adheres to the reinforcements forming a diffusion bond (Fig. 1). This type of bonding provides a certain formability of the foam and results in a significant improvement of the mechanical properties and the thermal stability in comparison with glued or brazed sandwiches. In distinction to MMC – the interfacial layer in this case does not represent "the weakest link" – its properties are usually much better than the properties of highly porous foam matrix.

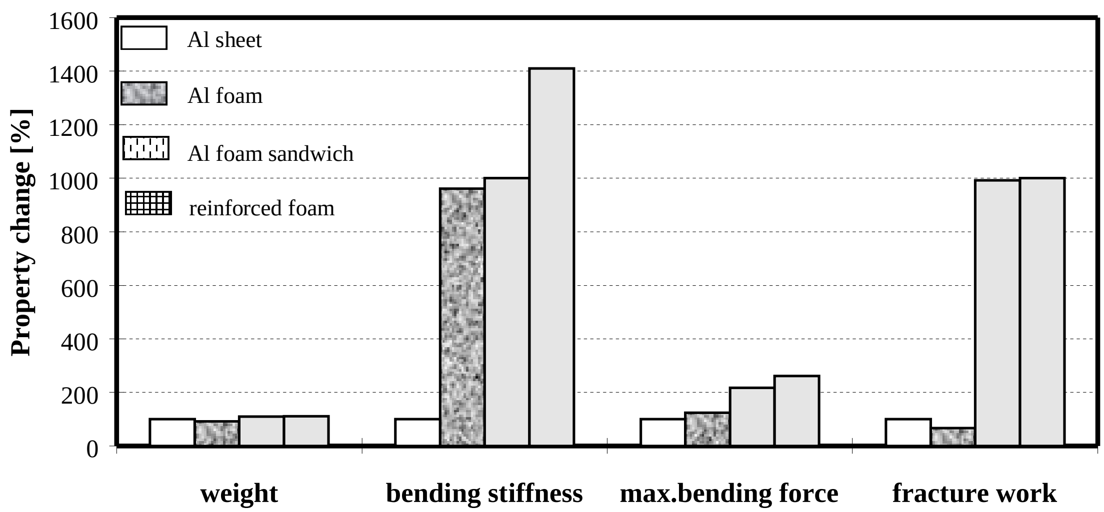
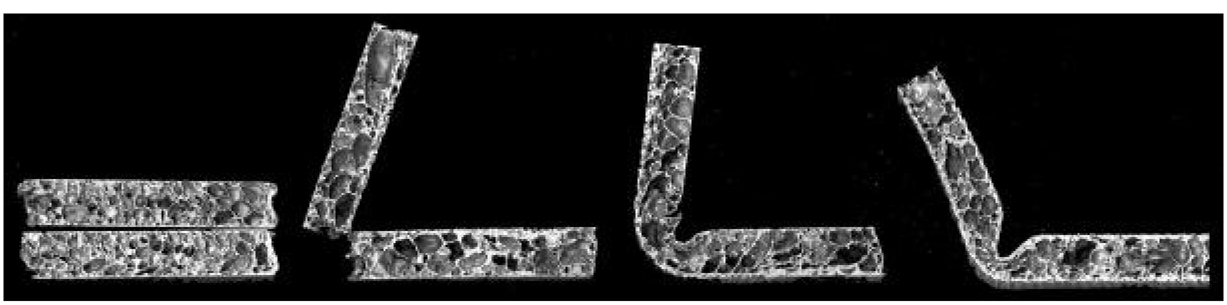


Fig. 2: *Properties of reinforced aluminium foam (thickness 15 mm, porosity 85%) in comparison with: Al-sheet (thickness 3 mm), Al-foam (thickness 15 mm, porosity 80%) and Al-foam sandwich (foam thickness 11 mm, porosity 80%, Al-coversheet thickness 1 mm at one side)*



no reinforcement | reinforced compression loaded surface | reinforced tensile loaded surface | reinforced both-surfaces

Fig. 3: *Deformation of foamed samples (15x15x120mm, foam density 0.4 gcm^{-3}") after impact test*

Of course, for successful application of this novel material also some potential problems have to be solved in a future. The presence of residual internal stresses, more difficult recycling and lower resistance to electrolytic corrosion are some of them.

References

[1] Simančík, F.; Rajner, W.; Laag, R.: Alulight - Aluminum foam for lightweight construction. In: SAE Technical Paper Series 2000-01-0337. Warrendale: SAE, Inc., 2000, p. 31-38.

[2] Allen, B.C.: US Patent 3087 807, 1963.

[3] Schoerghuber, F., Simancik, F., Hartl, E.: US Patent 5 865 237, 1999.