

Reinforced aluminium foams

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Abstract

The aluminium foams prepared by PM-techniques are very promising materials for lightweight stiff body structures and crash absorbing elements. However their surface skin usually contains small holes or even cracks which can initiate premature fracture of the foam, especially when they appear on the tensile loaded surface. Strengthening of surface skin with various reinforcements can solve this problem very effectively. According to a novel foaming technique, the reinforcements are placed in the foaming mould together with foamable precursor and in a course of foam expansion 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 anisotropically according to the applied load.

1 Introduction

The aluminium foam parts prepared by powder metallurgical technique are always covered by dense aluminium skin that enhances the mechanical properties similarly as cover sheet in the case of sandwich structures [1]. In distinction to standard sandwiches foam structures possess higher stiffness-to-weight ratio, can be shaped and also manufactured at lower costs. However, the natural skin of foams has variable thickness and contains small holes or even cracks. These inevitable defects arise during solidification and cooling of the foam due to decreasing temperature accompanied with pressure changes inside the initially closed pores. The defects in the skin can lead to the sudden fracture of the foam, especially when they are located on the tensile loaded surface of foamed part.

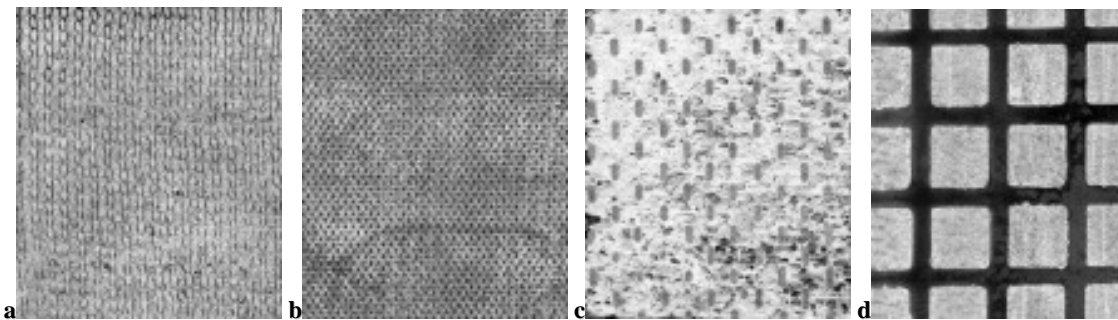


Fig. 1: Aluminium foam panel reinforced in the surface with stainless steel a -net, b - expanded metal sheet, c - woven steel wire, d – perforated sheet.

The fracture resistance and damage tolerance of foamed parts can be significantly improved with metallic wires, nets or meshes implemented into foam surface (Fig. 1) similarly as it is in a case of reinforced concrete. This possibility was investigated in this work with an aim to

examine the effect of reinforcements on the bending properties of aluminium foam panels made by PM-route [2].

2 Experimental results and discussion

The one side of aluminium foam panel (600x500x15 mm) made of AlSi12 casting alloy was reinforced with expanded stainless steel sheet (Fig.2). 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. During foaming the interfacial $\text{Al}_{12}\text{Fe}_3\text{Si}$ phase is formed as a result of mutual chemical reaction between liquid foam and reinforcement (Fig. 2). This type of metallurgical 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 this case -in distinction to typical metal matrix composites- the interfacial layer does not represent “the weakest link”; its properties are usually much better than the properties of highly porous foam matrix.

The bending properties of reinforced foams were tested in four-point-bending of beam specimens (400x50x15 mm). During bending the reinforcements were located either in tensile- or compression-loaded foam surface. The beams made of plain foam were also tested for comparison (Fig. 3). The expanded metal sheet increases the bending stiffness of the foam almost twice, though the weight increases due to reinforcement only about 30%. As expected the stiffness does not depend on the position of the reinforcements. However, when the bending strength is considered, the position of reinforcements is crucial. If the reinforcement is placed in compression-loaded surface of the foam beam, the bending strength is almost the same as it was obtained for plain foam. When it is located on tensile-loaded side, the bending strength increases significantly; the specimens even do not break up to the final deflection of the beam.

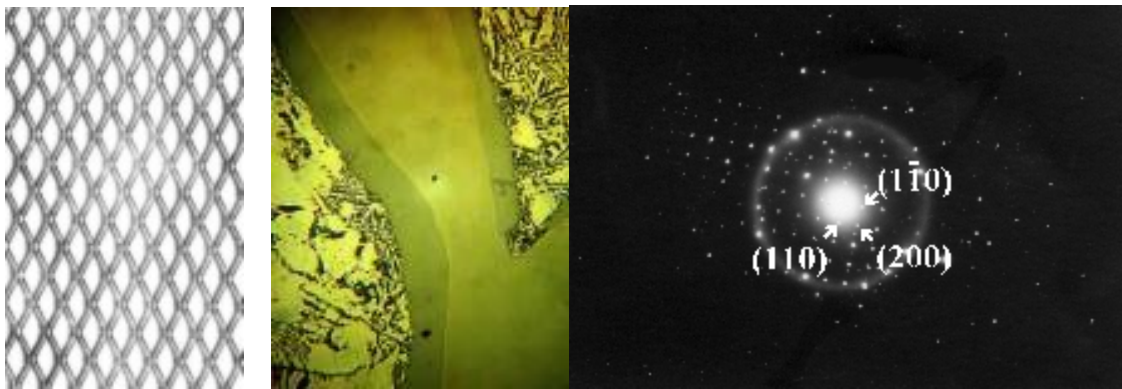


Fig.2: Expanded stainless steel sheet used as reinforcement of AlSi12 aluminium foam panel (right – $\text{Al}_{12}\text{Fe}_3\text{Si}$ phase formed during foaming due to interfacial reaction between liquid foam and stainless steel)

Fig. 4 illustrates the changes of bending properties for various use of aluminium in beams of the same weight. As can be seen the beam made of plain foam possesses considerably higher stiffness than bulk Al-sheet. However, no benefits were observed for bending strength and the resistance to fracture was even worse. Therefore, for practical use of aluminium foams in structural applications, it will be necessary to reinforce at least the tensile loaded surface of

the foam. Similar effect can be obtained if the coversheet is applied, however the use of the reinforcements is more efficient because of their lower weight, which enables to increase the thickness of the foam. The reinforcements have also additional stabilising effect - they prevent liquid foam from collapsing thus allowing higher final porosity of the foam.

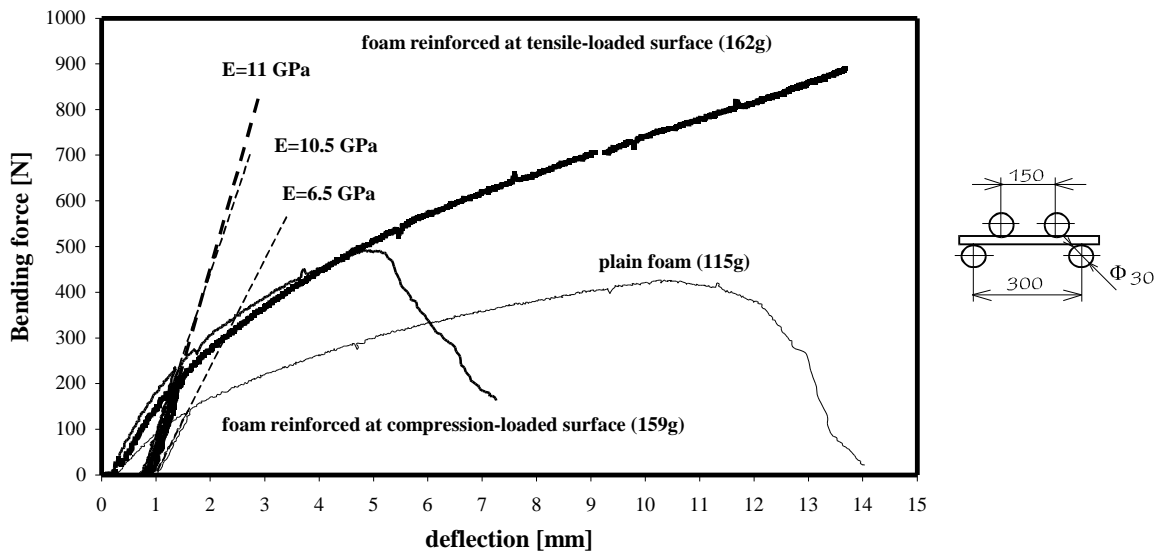


Fig. 3: Comparison of plain and reinforced aluminium foam beams at four point bending (sample size 400x50x15 mm, weight of the specimens is given in brackets)

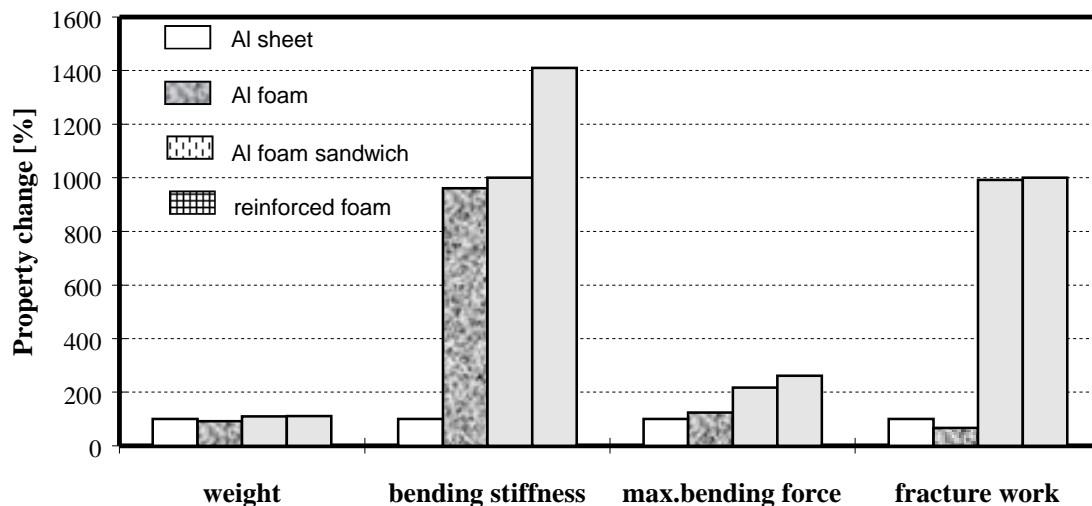


Fig. 4: Properties of reinforced aluminium foam (thickness 15 mm, porosity 85 %) in comparison with: Al-sheet (thickness 3 mm), Al-foam (thickness 15 mm, porosity 80%) and Al-foam sandwich (foam thickness 11 mm, porosity 80 %, Al-coversheet 1 mm at one side)

The benefit of reinforcements was confirmed also in bending of foamed panels (565x285x15 mm). In this case the panels were loaded at the whole surface by pressure difference between two chambers separated with the specimen. The reinforced foam panels withstand the pressure difference of 70 kPa while plain foams suddenly breaks at pressure of approx. 40 – 45 kPa (Fig. 5). With increasing load the permanent deformation occurs due to the yielding or fracture of weakest cell walls. The reinforcements allowed the cyclic loading of the panel with

amplitude of 50 kPa. After first loading the stiffness and permanent deformation of panel remained nearly unchanged during the whole experiment (up to 1500 cycles).

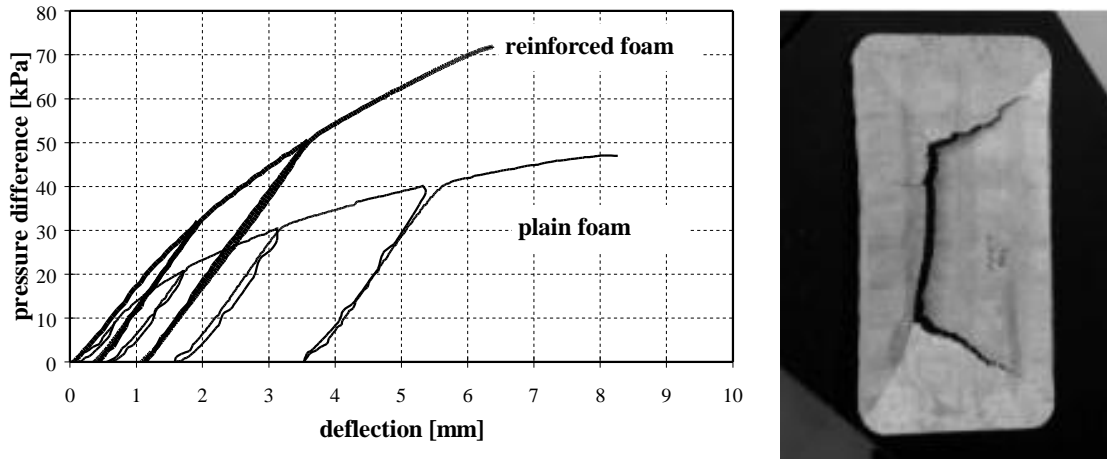


Fig. 5: Bending of foamed panels under surface loading (right- broken plain foam panel).

3 Conclusions

The metallic reinforcements implemented into the foam surface significantly improve the strength, plasticity, energy absorption capacity, fracture toughness and damage tolerance of foamed part with only a little weight increase (ca. 20-30%). The reinforcements can be effectively used also for the improving of bending stiffness when the thickness of the foam is limited. They ought to be placed and oriented in the vicinity of foam surface according to the way of expected loading (preferably tensile loaded side of the foam). The manufacturing method makes possible to reinforce the foamed part only selectively in weakest points, which enables to obtain maximum property-to-weight ratio. Moreover the reinforcements increase the thickness of surface skin, simplify joining of foamed parts (welding is possible) and enable limited shaping after foaming process.

Easy manufacturing allowing reasonable production costs can make the reinforced foams very attractive for transport industry, especially for lightweight stiff body structures of future cars, busses, trains, ships, aeroplanes, etc.

Of course the use of reinforcements is accompanied also with some difficulties, which should be solved in a future. More complicated recycling, the residual internal stresses in the structure and lower resistance to electrolytic corrosion are some of them.

References

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