Noise attenuation using aluminium foams

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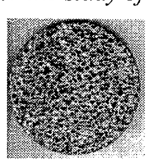
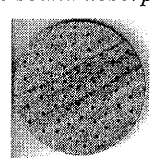
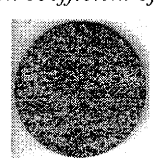
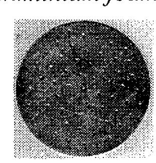
Abstract

The contribution of the aluminium foam to the attenuation of noise has been carefully evaluated from the following viewpoints: the sound absorption, shift of the resonance frequencies and inner (structural) damping. The foamed samples prepared from various casting and wrought aluminium alloys by PM route were used in this case study.

1 Sound absorption in foams

Sound absorbing performance of aluminium foam depends predominantly on the permeability of the structure. As the porosity of aluminium foams is usually closed, it is necessary to open it. Effect of various methods, such as cutting of surface skin, sand blasting, compressing, drilling of various holes was examined (see Fig. 1). If the porous structure is opened enough the sound absorption coefficient reaches its maximum within a wider frequency range when compared with simple perforated Al - sheet of the same weight. This range can be shifted by creating an air gap behind the plate using the principle of the Helmholtz resonator [1]. The sound absorption can be enhanced for wider frequency range by an appropriate design of the absorber, e.g. by combination of several foam plates with an air gap between them.

Table I *Samples used for the study of the sound absorption coefficient of aluminium foam.*

				
Sample	**Alulight**	**Alulight 1**	**Alulight 2**	**Al sheet**
Thickness [mm]	5	8.9	6.3	1.5
Density[kg.m^{-3}]	550	450	540	2 700
Weight [g]	21	31	26	31
Surface	cut	present	sandblasted	present
Opening	pores	drilled holes	drilled holes	drilled holes

2 Shift of resonant frequencies in foams

Disturbing vibrations may occur when the eigen (resonant) frequencies of structural component are within its working frequency range. The eigen frequencies generally depend on the modulus of elasticity and the density of the material of which the component is made and of course on its geometry. Therefore the eigen frequencies of aluminium foam can be altered by changing the density (see Fig. 2). In this way the eigen frequencies of a component

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containing aluminium foam can be shift out of the working frequency range, thus suppressing the detrimental vibrations without changing the shape and dimensions of the component.

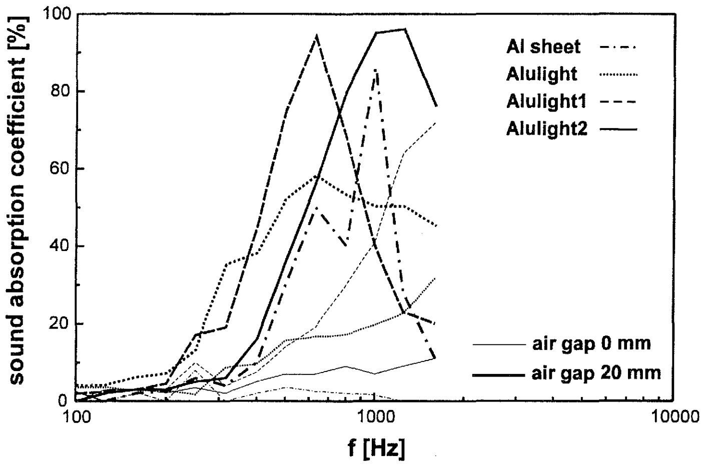

Fig. 1: Sound absorption coefficient of various samples (see Table I.) with and without air gap behind them: Al sheet (61 holes ϕ 1.5 mm); Alulight (without surface skin); Alulight1 (61 holes ϕ 1.5 mm); Alulight2 (sand blasted)

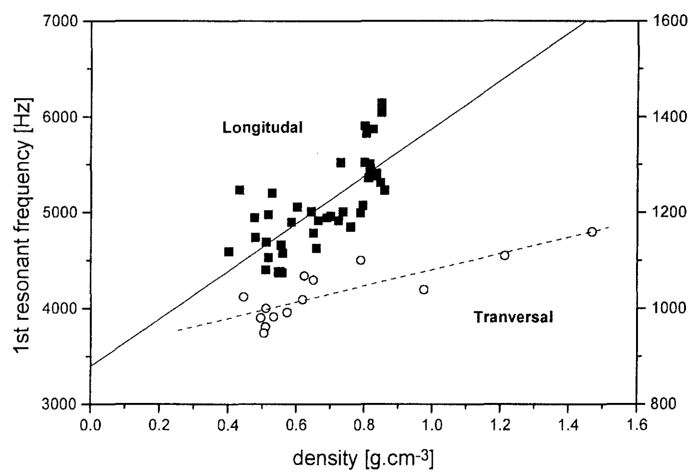

Fig. 2: Dependence of the resonant frequency on the apparent density of aluminium foams: longitudinal vibrations of AlSi12 foam ϕ25 x 300 mm (left axis) transversal vibrations of Al 99.7 foam 140 x 140 x 8.5 mm (right axis).

3 Structural damping in foams

Structural damping characterises the ability of material to convert the mechanical vibrational energy into the heat [2]. When compared with aluminium and its alloys (η about 10^{-4}), aluminium foam exhibits at least one order higher values of the loss factor η. The dissipation of the energy in aluminium foam results from the friction between the neighbouring surfaces of the cracks appearing in the structure and partially due to the vibration of the thin pore walls. Higher loss factor values are therefore achieved with foams made of casting aluminium alloys exhibiting very fine porosity with thin pore walls containing a lot of cracks (see Fig. 3). These values can be further significantly improved by an addition of the non soluble particles, (e.g. graphite, SiC) into the powder mixture. Additional interfaces are introduced into the structure in this way, thus improving the dissipation of energy (see Fig. 4). Nevertheless, the loss factor of aluminium foam is still too low if compared with typical damping materials having η in a range of 0.01-0.1.

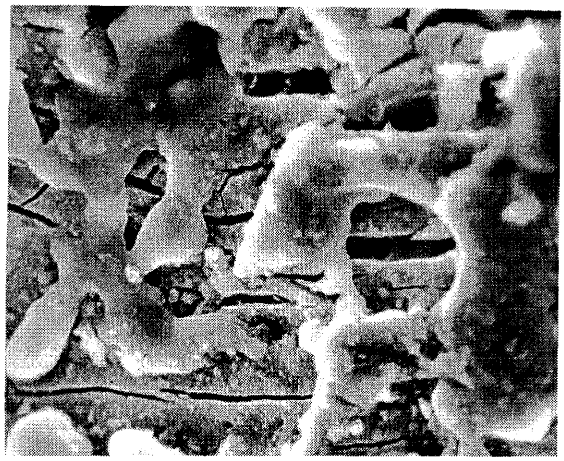

Fig. 3: Cracks in the cell-walls of AlSi12-foam (zoom 500x).

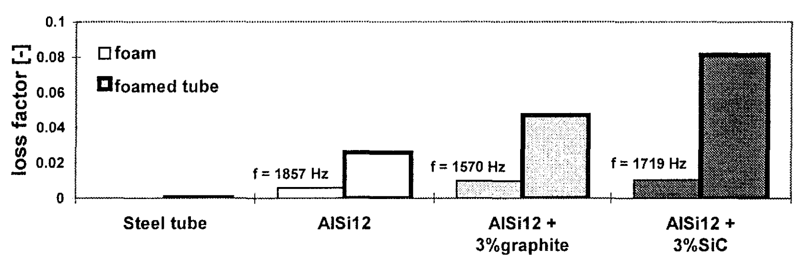

Fig. 4: Effect of addition of non soluble particles on the damping properties of aluminium foams and steel tubes filled with them (ϕ 30 x 300 mm, foam density 600 kg.m^{-3}).

Recently, a lot of effort has been done to investigate the possibility of aluminium foam to enhance the performance of hollow steel or aluminium profiles in various structural components. Beside stiffening and increasing energy absorbing capabilities also the reduction of noise and vibrations is expected (see Fig. 5). Because of the relatively low loss factor, aluminium foam cannot provide good damping characteristics if the vibrations are transmitted directly from the vibrating profile into the foam core. However this is only the case of a very good (usually metallurgical) bonding between the foam and shell. Without such a bonding surprisingly good damping has been observed (see Figs. 5 and 6). The main reason for this is a friction arising between shell and foam surface which results in a heat dissipation of the vibrational energy.

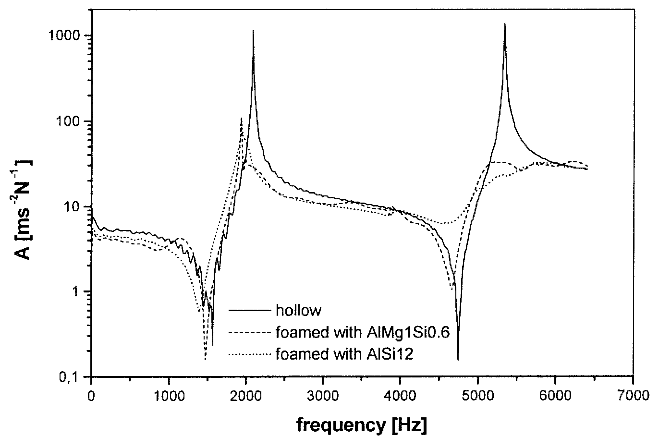

Fig. 5: Frequency spectra of reciprocal mass for hollow profile and profile foamed with various types of aluminium foams (steel tube ϕ 22 x 245 mm filled with ϕ 18 x 245 mm foams of the density 700 kg.m^{-3}).

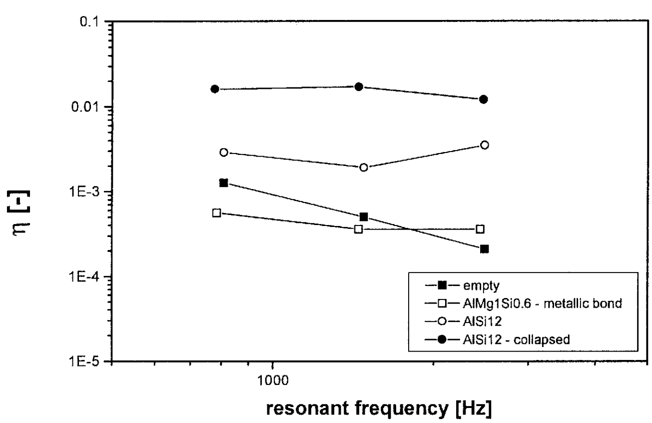

Fig. 6: Effect of the foaming on the damping characteristics of steel hollow profile.

This behaviour can be utilised also for the *non-destructive* testing of foamed profiles to be used in industrial applications, where the bending stiffness plays an important role. High loss factor indicates always absence of bonding or even insufficient filling of the cavity (see loss factor of the profile filled with a collapsed foam in Fig. 6).

References

[1] R. C. Chanaud, J. Sound Vib. 178, 337 (1994)
[2] T. Pritz, J. Sound Vib. 178, 315 (1994)