

DETERMINATION OF ELASTIC AND DAMPING PROPERTIES FOR CLOSED-CELL ALUMINIUM FOAMS USING IMPULSE EXCITATION TECHNIQUE

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Summary: *The damping behavior of metallic foams is excellent. This attribute can be useful in applications in lightweight structures to overcome noise and vibration problems. This paper presents an experimental investigation for determination of elastic and damping properties for ductile aluminum foam (AlMg1Si0.6) produced by the powder metallurgy method. The Resonant Frequency and Damping Analyzer (RFDA), which is a non-destructive testing device to determine the resonant frequency of materials, were used to perform the experiment. Tests were carried out on rectangular bar samples with skin, having density in range 0.5 to 0.6 g/cm³. If the sample shape, dimensions and mass are known the Young's Modulus and Shear Modulus are calculated from the fundamental flexural resonant frequency (out of plane flexure) and torsional resonant frequency according to ASTM E 1876. Internal friction coefficient (Q^{-1}) can be also calculated according with f_r - Frequency [Hz] and k - Loss rate [1/s].*

Keywords: *Metal foams, Damping properties, Elastic properties*

1 Introduction

In many industrial applications, new materials are required for lightweight structures. Metal foams are highly porous materials with cellular structure. Due to this, they possess an excellent combination of mechanical properties (strength and stiffness) and low weight; absorb high impact energies regardless of the impact direction and vibration damping [1].

The mechanical damping properties of aluminum foams, AlSi12 alloy foams, measured by Banhart et al. [2] using rectangular beam samples revealed that the damping is strongest in foams with the lowest densities. Sevostianov et al. [3, 4] determined the elastic properties for AlMgSi0.6 aluminum foams, for measurement of the Young's modulus the specimens of cylindrical shape (diameter of 17 mm and length of 300 mm) were vibrated longitudinally using impact hammer method.

Kováčik et al. [5] measured the elastic properties on cylindrical rods samples with diameter of 17 mm and length of 300 mm prepared from aluminum alloy powder Al 99.7 that was mixed together with a foaming agent (TiH₂), the density of the foamed samples was in the range of 300 - 800 kg/m³. Körner et al. [6, 7] investigated the damping behavior of integral foam molding of light materials, the internal friction increases with decreasing relative density and the dependence on the relative density is best fitted by a linear

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dependence on the relative density. Roebben et al. [8] measured the resonant frequency, elastic modulus and internal friction at room and high temperature using an impulse excitation apparatus. The present paper is focused on experimental determination of elastic and damping properties of ductile aluminum foam using impulse excitation technique (IET).

2 Experimental program

Aluminum foams samples were prepared by the powder metallurgy technique, foamable precursor of the diameter of 8 mm was hot extruded from the compacted mixture of AlMgSi0.6 powder and powdered foaming agent (0.4 wt. % TiH₂), [2]. Cellular structure of used aluminum foam is presented in Fig. 1.

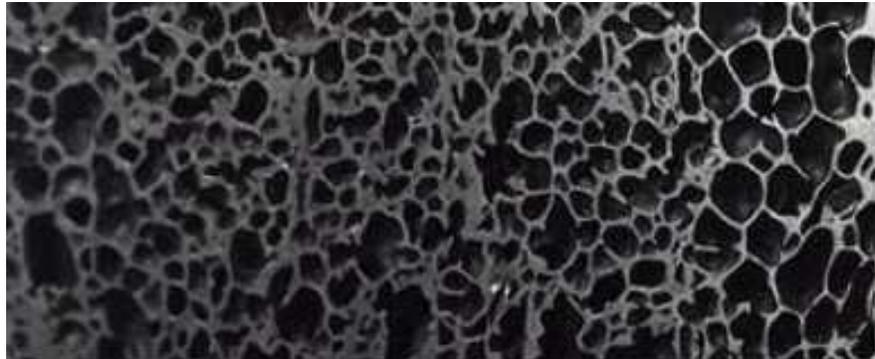


Figure 1: Typical microstructure of AlMgSi0.6 foam

The density of the foam specimen was determined by dividing weight on sample volume, weight was determined using a digital balance (Sartorius GD 503 Class Balance) and sample dimensions was measured using a digital caliper. The measured density was found to be between 0.5 and 0.6 g/cm³. Tests were carried out on rectangular bar samples (85×35×10 mm) vibrated in flexural and torsional mode.

Due to effects of clamping and plastic deformation of very thin cell walls at low stress levels, it is not easy to obtain the elastic properties of the aluminum foam from stress-strain curve. Instead, it is more appropriate to determine it from free vibrations of specimens. To determine the elastic and damping properties, an IET of IMCE, Belgium was used. The sample was freely excited by a light impact strike with a steel ball 6 mm in diameter glued to the end of a flexible 100 mm long polymer rod; two polymer wires support the sample, which is placed in the nodes of the vibration mode to avoid background damping; the specimen vibration is recorded by a microphone; the software detects the frequency for calculating the elastic modulus and the decay of the amplitude for calculating the loss factor, [9]. Young's modulus and shear modulus for rectangular bar samples can be calculated from the fundamental flexural resonant frequency (out of plane flexure) and torsional resonant frequency according to ASTM 1876-01 [10]. The internal friction coefficient (Q^{-1}) can be determined for each frequency as:

$$Q^{-1} = k/(\pi \cdot f_r) \quad (1)$$

where f_r [Hz] is the resonant frequency and k [1/s] is the exponential decay parameter of the vibration component of frequency f_r .

3 Results

Using the Resonant Frequency Damping Analyzer (RFDA), a non-destructive testing device to determine the resonant frequency of materials, the elastic (Young's modulus and shear modulus) and damping properties results for rectangular bar samples vibrated in flexural and torsional mode are presented in Table 1. The internal friction coefficient Q^{-1} versus relative density is depicted in Fig. 2.

Table 1: Elastic and damping properties for rectangular bar samples

Density [g/cm ³]	Vibration mode	Frequency [Hz]	k [1/s]	E [GPa]	G [GPa]	Q^{-1}
0.500	Flexural	4775	65.82	5.77	-	0.00439
	Torsion	5864	32.04	-	2.05	0.00174
0.535	Flexural	4490	51.46	6.01	-	0.00365
	Torsion	5982	29.92	-	2.28	0.00159
0.570	Flexural	4557	41.58	6.36	-	0.00291
	Torsion	5754	25.94	-	2.32	0.00143
0.600	Flexural	4618	39.74	7.39	-	0.00274
	Torsion	6085	25.76	-	2.42	0.00135

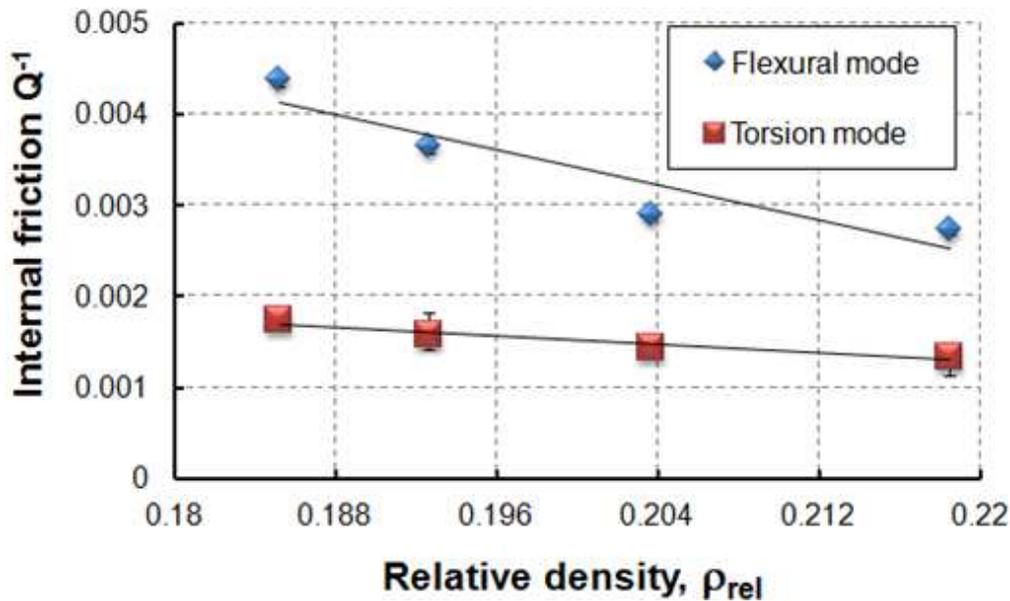


Figure 2: Internal friction coefficient versus relative density

4 Conclusions

The elastic and damping properties of closed-cell aluminum foams (AlMg1Si0.6) with various densities produced by the powder metallurgy method were investigated using IET. Experimental results show that the Young's modulus and shear modulus increases with increasing density for both types of vibration modes. The damping behavior of rectangular bar samples vibrated in flexural and torsional mode presented in Fig. 2, shows that the internal friction coefficient (Q^{-1}) increase with decreasing relative density.

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