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MEASURING METHOD TO DETERMINE THE VIBRATION DAMPING BEHAVIOUR OF METALLIC FOAMS

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Abstract: *The damping capability of metallic foams is worse than for the solid metal materials will be the result if we make the calculation. This would be the opposite of those statements that underline the significant vibration damping capability of metallic foams. The vibration damping behaviour of solid metal materials can be described with a viscous damping model. It is questionable whether we can use or not the same damping model for metallic foams. In this paper the authors describe a measuring method to determine the vibration damping behaviour of the metallic foams and try to determine which damping model is good to describe the behaviour of metallic foams (Coulomb damping or viscous damping).*
Keywords: *metallic foams, vibration damping, damping model*

INTRODUCTION

The technological development brought close to avail metallic foams for designers in industrial use. Many Hungarian institutions are manufacturing and working with metallic foams such as the University of Miskolc And The Bay Zoltán Nonprofit Ltd. in Miskolc, or in Budapest, the Budapest University of Technology and Economics.

The name metallic foam indicates such a solid metallic material, which has more than 90% porosity (some manufacturer produces 'metal foams' less than 90% porosity). The density of this kind of materials is less by one order of magnitude. Metallic foam has several properties that make its use desirable in engineering. These properties are energy-absorbing, heat conduction, damping, sound-absorbing and filtering abilities. Metallic foams have two types; the open-cell and closed-cell ones. Most of the cases the material of the metallic foam is aluminium-alloy but metallic foam also can be created from other materials (steel, copper, silver and titan). [1], [2]

Many researches were carried out to determine physical, chemical and mechanical properties of metallic foams. Properties of metallic foams depend on the size of the cells, the thickness of the walls (bridges) between the cells and the shape of the cells if the material is the same. With the use of the modified ratio between the solid metal density and the foam metal density, we can approximately determine foam material properties. The computational equation is equation (1).

$$\frac{P}{P^0} = k \cdot \left(\frac{\rho}{\rho^0}\right)^n \qquad (1)$$

where, P: a kind of property, ρ: density, 0: index for metals, without index 0 is for metal foams, n, k: can be chosen according to Table 1, parameters from measurements.

Table 1. *k and n factors to determine parameters of metal foams*

Property	k	n
R (Ωm)	1	-1.6÷-1.85
λ (W/mK)	1	1.6÷1.85
E (GPa)	0.1÷4	1.8÷2.2
σ (MPa)	0÷1.0	1.5÷2

Literature is short-spoken in the point of view of the damping behaviour of metallic foams. About the damping behaviour of solid metals many literature publish data such as logarithmical decrement or Lehr's damping ratio. [3], [4].

That would be obvious to use equation (1) to determine the damping capability of metallic foams. The damping capability of metallic foams is worse than for the solid metal materials will be the result if we make the calculation. This would be the opposite of thosestatements that underlinethe significant vibration damping capability of metallic foams. We can determine that equation (1) cannot use for determine vibration damping capability of metallic foams.

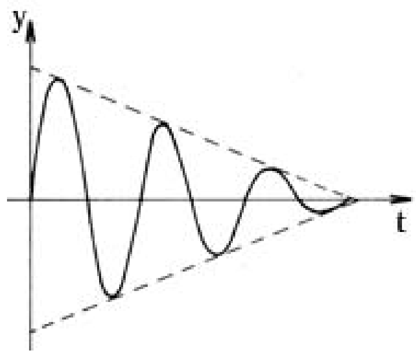

Figure 1. *The nature and the envelope of Coulomb damping*

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The vibration damping behaviour of solid metal materials can be described with a viscous damping model (Figure 2). It is questionable whether we can use or not the same damping model for metallic foams.

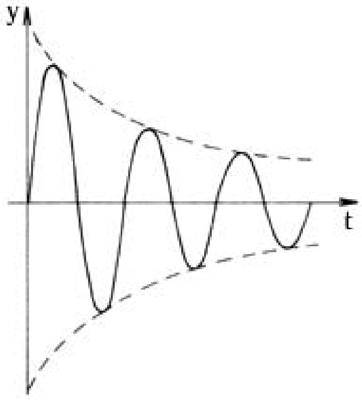

***Figure 2**. The nature and the envelope of viscous damping*

Next chapters will be described a measurement, which can help to determine the vibration damping behaviour of metallic foams and the value of logarithmical decrement.This paper introduces the next step of the research introduced in [1].

THE SHAPE OF THE SAMPLE AND THE LAYOUT OF THE MEASUREMENT

We made beams with rectangular cross-section from the metallic foam material. The beam was made from a greater metallic foam plate with a milling machine.

***Figure 3**. The metallic foam beam*

The dimensions of the metallic foam beam: 35.5mm x 27mm x 300mm, weight 92 g (Figure 3).We fastened a weight to one of the ends of the beam with a screw fastening (it is signed with $m_0$in Figure 6), in this way set up the sample (Figure 4).

***Figure 4**. The sample*

We fastened the free end of the assembled sample with a fixed support (Figure 5).

We placed load to the sample with another weight, with a help of a fishing line(signed with m in Figure 6).After cutting the fishing line which held the (m) weight we measured the displacement of the free end of the beam.The displacement was measured with a laser displacement meter(signed with L in Figure 6). The sketch of the measurement can be seen in Figure 6, and real measuring in Figure 7.

***Figure 5**. Fasten of the sample*

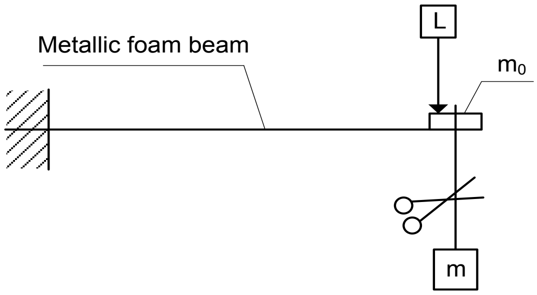

***Figure 6** .Sketch of the measurement*

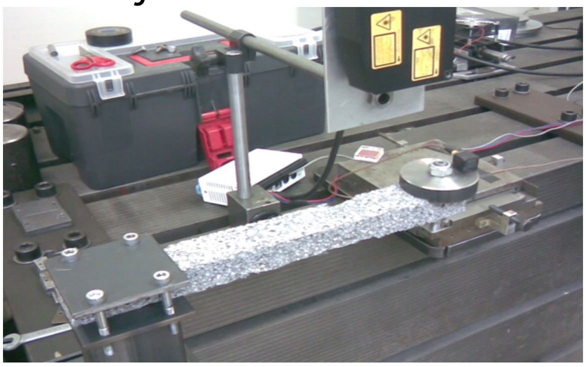

***Figure 7**. Real environment of the measurement*

We lead the fishing line of the weight trough the bore in the fasten screw of the $m_0$weight. We chose this type of line leading to prevent the sample to make vibration outside the vertical plain. Measurements were made with 1kg, 2kg, 3kg loads. Beside the measurements with loads, we made knocking measurements too. We compared the two types of measurement.

MEASURED DATA

The displacement of the free end of the metallic foam beam we saw on the computer monitor.A picture from the computer monitor can be seen in Figure 8.

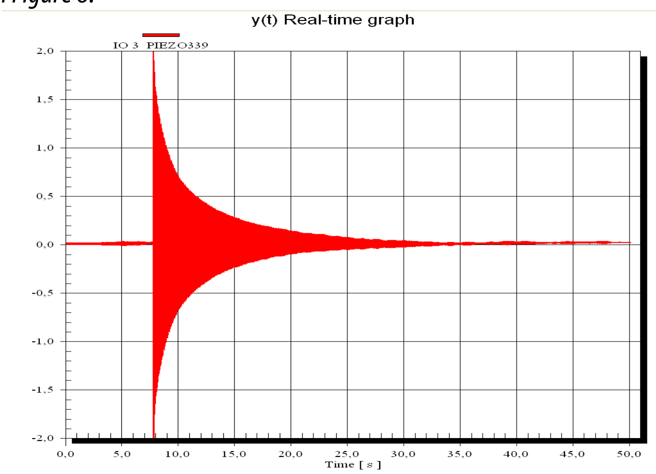

***Figure 8**. Displacement of the end of the beam depending on time*

The measurement software is able to export the measured data into Excel format. Further processing was made in Microsoft ™ Excel ™. Excel file contains the measured data (displacements) in one column. We need to modify the measured displacement data to get result from that.

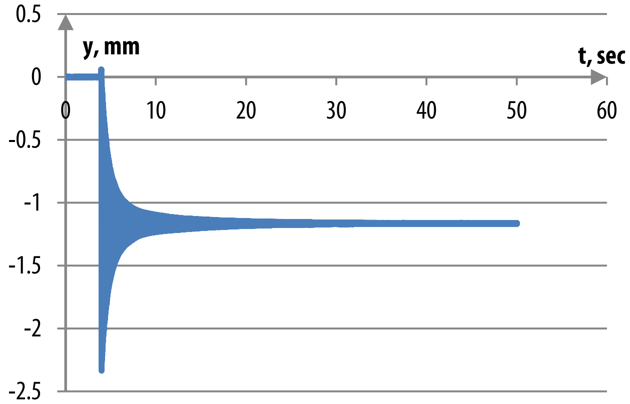

***Figure 9**. Displacement of the rod end after the line was cut (1kg load)*

Modifications were the following:

- *remove data before the line was cut,*
- *remove data after the vibration ends,*
- *place the curve symmetrical to the abscissa.*

After modification, we received such a curve, where we could determine the logarithmical decrement. After the analysis, we experienced that the value of the logarithmical decrement was not permanent during the vibration. According to the results we concluded that the damping behaviour of the metallic foams is not the classical viscous damping type.The curve does not fit to the Coulomb type damping, where the damping coefficient is increasing with the vibration time. This symptom leaded us to carry on to analysing the measured data. We made other modifications on the measured data. We filtered the peak values of the vibration wave and used just the positive values.

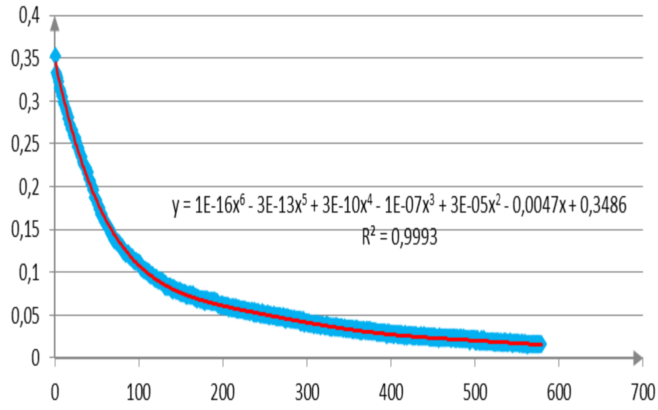

***Figure 10**. The diagram shows the positive amplitudes (abscissa: number of positive peaks, ordinate: the value of the peak in mm).*

In Figure 10 the curve generated by points of positive amplitudes of the vibration can be seen. The figure also shows the trend line of the curve and the determination coefficient (R^2). The equation of the trend line also can be seen in Figure 10, which is a sixth grade polynomial. The value of the determination coefficient is almost 1, that is to say it is a good approximation. This is not fit nor to Coulomb type damping nor to viscous damping. If we observe Figure 10, approximately at the 70th peak, the curve of the trend line suddenly turns aside. We divided the curve into two parts, and examined them separately. The first part of the curve can be seen in Figure 11. We placed a new trend line to the curve of Figure 11. In Figure 11 the equation of the trend line and the determination coefficient also can be seen. The approximation of the point is good, because the R^2 is 0.9915.

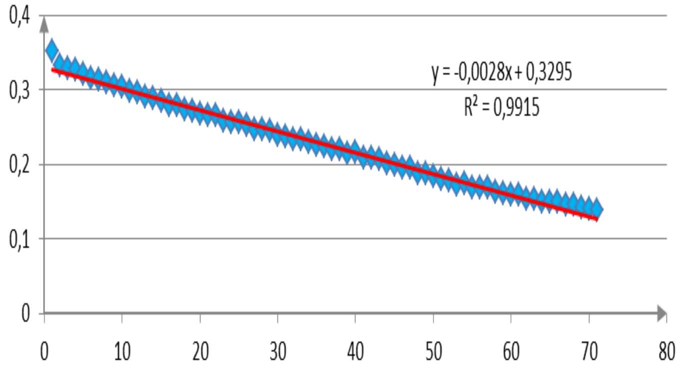

***Figure 11**. The first part of the curve, the new trend line (abscissa: number of positive peaks, ordinate: the value of the peak in mm)*

The curve of Figure 11 is almost line, which is continuously decreasing. This type of envelope is the type of the Coulomb damping envelope (Figure 1). If we examine the other part of the original curve (Figure 10), we get another new curve (Figure 12). We placed again a new trend line, which is fit to the points of Figure 12 (points after 70th peak). Figure 12 shows the equation of the 3rd curve and the determination coefficient, which is 0.9853. This approximation is also a good one.

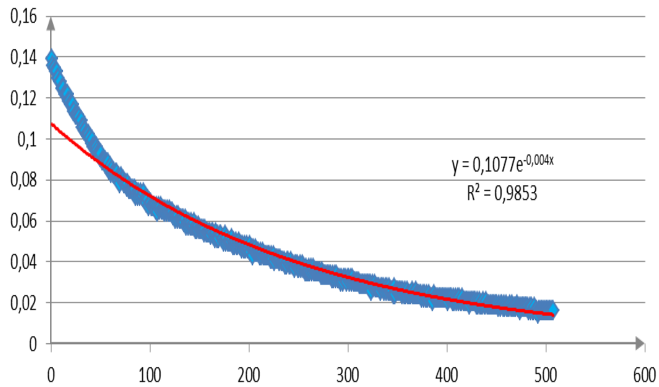

***Figure 12** .Curve after the 70th peak (abscissa: number of positive peaks, ordinate: the value of the peak in mm)*

EVALUATION OF RESULTS

Conclusion from the measured and calculated results is that the vibration damping behaviour of the examined metallic foam until approximately the first 70 peak is Coulomb type damping, after the first 70 peak is a viscous damping type. The behaviour of metallic foam was independent from the loads (1kg, 2kg, 3 kg).

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