CORRELATION BETWEEN THE DAMPING FACTOR PER UNIT MASS AND THE FREE LENGTH FOR COMPOSITE SANDWICH BARS. EXPERIMENTAL INVESTIGATIONS

[1]**Associate professor Phd. Eng., Cristian-Oliviu BURADA,** University of Craiova, Faculty of Mechanics, Department of Applied Mechanics and Civil Constructions, Calea Bucuresti Street, no. 107, Craiova, Code 200512, Romania, cristian.burada@yahoo.com
[2]**Assistant Phd. Eng., Cosmin-Mihai MIRIȚOIU,** Postdoctoral researcher at University of Craiova, Faculty of Mechanics, Department of Vehicles, Transports and Industrial Engineering, Calea Bucuresti Street, no. 107, Craiova, Code 200512, Romania, miritoiucosmin@yahoo.com
[3] **Associate professor Phd. Math., Marius-Marinel STĂNESCU,** University of Craiova, Department of Applied Mathematics, 13 AI Cuza, Code 200396, Craiova, Romania, mamas1967@gmail.com
[4] **Professor, Phd. Eng., Dumitru BOLCU,** University of Craiova, Faculty of Mechanics, Department of Applied Mechanics and Civil Constructions, Calea Bucuresti Street, no. 107, Craiova, Code 200512, Romania, dbolcu@yahoo.com

Abstract. *In this paper we have build some composite sandwich bars in this way: the core is made with polypropylene honeycomb (its thickness is 10, 15 and 20 mm) reinforced with 1 layer of carbon fiber (on the sample upper and lower sides). For these samples we have determined, by experimental means, the damping factor per unit mass and per unit length. Then, by using the regression analysis, we have established correlations between the damping factor per unit mass and the bars free length. In order to obtain these correlations, we have considered the next free lengths of the bars: 200, 230, 260, 290, 320, 350.*

Keywords: composite bar, sandwich bar, carbon fiber, damping factor

1. INTRODUCTION. ANALYTICAL MATHEMATICAL PROCEDURE FOR DAMPING CALCULUS

In order to obtain the formula for the damping factor calculus, according to Manea (2006) [1], Manea (2007) [2], if an oscillating system is considered where it is applied the Lagrange procedure, the motion equation will have the form presented in (1).

$$\ddot{x}(t)+2\cdot\mu\cdot\dot{x}(t)+p^{2}\cdot x(t)=F\cdot m^{-1}\cdot e^{i\omega t} \qquad (1)$$

where μ is the damping factor, p is the eigenpulsation, F is the force, m is the mass. The solution of the equation given above can be determined as a sum between the homogenous solution and the particular solution (which corresponds to the forced motion). In order to solve the homogeneous equation (obtained by equaling (1) with zero instead of $F\cdot m^{-1}\cdot e^{i\omega t}$), there is searched for a solution like the one given by (2).

$$x_0= A\cdot e^{\psi t} \qquad (2)$$

By solving (1) and taking into account (2), we obtain the solution (3).

$$x_o(t)= A\cdot e^{(v\cdot i-\mu)\cdot t} \qquad (3)$$

The vibratory motion of the homogenous solution disappears in time through the damping mechanisms. One of the damping evaluations is to determine the logarithmic decrement. For its calculus, the formula (4) may be used (according to Burada (2014) [3] or Manea (2006) [1]).

$$\delta = \ln \frac{x_{01}}{x_{02}} \Rightarrow \quad \mu = T^{-1} \cdot \ln \frac{\beta_i}{\beta_{i+1}} \tag{4}$$

In (3) we have marked with v the natural damped pulsation. In (4) we have marked with β_i, β_{i+1} the maximums separated by periods.

The particular equation to the harmonic excitation has the form (5).

$$x_p(t) = A_p \cdot e^{i\omega t + i\varphi} \tag{5}$$

In (5) we have marked with φ the phase shift and A_p is determined with (6).

$$A_p = F_0 \cdot k^{-1} \cdot \left[\left(1 - \omega^2 / p^2\right)^2 + 4 \cdot \left(\zeta \cdot \omega\right)^2 / p^2 \right]^{-0,5} \tag{6}$$

The general solution of (1) is given by (3) summed with (5).

Many investigations of composite materials made with carbon fiber have been made. In Li (2001) [4] the evolving process of the composition and structure of PAN carbon fiber during preoxidation has been studied. There was used the scanning electronic microscope, X-ray diffraction analysis, PYR-GCMS and IR. The conclusion of the study is that, in the final stage of preoxidation, there exist only the fragment of –CN which disappears at last. Also, the index of cyclation rises with the process of preoxidation and the structural shape stabilizes. In Baurova (2014) [5] some structural studied are presented that take into account fractured carbon-fiber composite surfaces before and after its use for one year. Based on the results, principal types of damage were classified. The carbon-fiber composite was prepared from high-modulus carbon fiber and an epoxide binder.

2. EXPERIMENTAL MONTAGE AND DETERMINATIONS

We have built some original composite bars made in this way: the core is made with polypropylene honeycomb (its thickness is 10, 15 and 20 mm) reinforced with 1 layer of carbon fiber (on the sample upper and lower sides). For these samples we have determined, by experimental means, the damping factor per unit mass and per unit length. A general view with the used samples is presented in fig. 1. We have marked the samples in this way: sample 1 with thickness 10 mm, sample 2 with thickness 15 mm and sample 3 with thickness 20 mm. The experimental montage is characterized in this way: the bars are embedded at one end and free at the other. At the free end, as close as possible from the edge, an accelerometer was placed to record the bars free vibrations.

The damping factor calculus for the sample 2 (free lengths of 200, 230, 260 and 290 mm) is presented in fig. 2 (the damping factor was determined after 5 cycles of vibration). All of the experimental results have been written in table 1. In table 1, the damping factor is in *Ns/m·kg*, the free length, thickness and width in *mm*, the mass in *kg*, the eigenfrequency is in s^{-1}.

The damping factor per unit mass and the eigenfrequency variation are presented in fig. 3 and 4.

Fig. 1. Composite sandwich bars with polypropylene honeycomb core reinforced with carbon-fiber

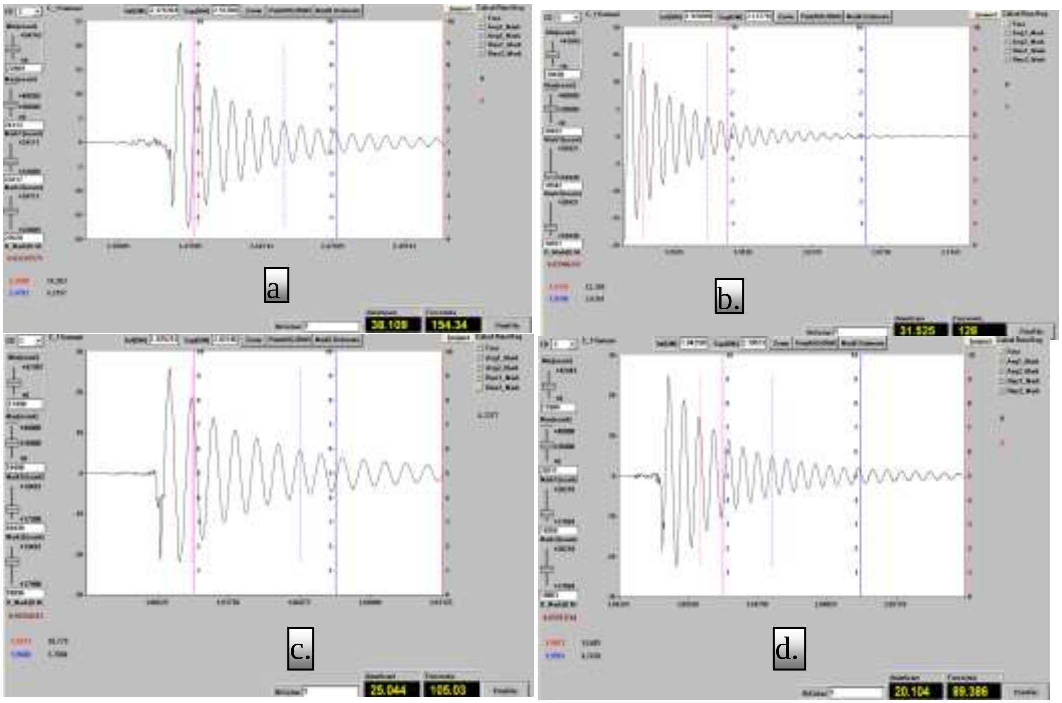

Fig. 2. Damping factor calculus for the sample 2; a. free length of 200 mm; b. free length of 230 mm; c. free length of 260 mm; d. free length of 290 mm

Table 1. Experimental results for the carbon fiber

Width	Thickness	Free length	Eigenfrequency	Damping factor per unit mass	Sample number	Mass
30	10	200	112,15	26,466	1	0,028
30	10	230	89,054	21,76	1	0,028
30	10	260	73,171	18,603	1	0,028
30	10	290	54,115	15,905	1	0,028
30	10	320	46,243	14,549	1	0,028
30	10	350	33,543	12,081	1	0,028
30	15	200	154,34	38,109	2	0,032
30	15	230	128	31,525	2	0,032
30	15	260	105,03	25,044	2	0,032
30	15	290	89,386	20,104	2	0,032
30	15	320	75,353	17,529	2	0,032
30	15	350	53,393	15,008	2	0,032
30	20	200	164,38	46,811	3	0,036
30	20	230	137,54	40,963	3	0,036
30	20	260	119,4	32,444	3	0,036
30	20	290	100,63	25,406	3	0,036
30	20	320	87,432	21,127	3	0,036
30	20	350	71,217	16,075	3	0,036

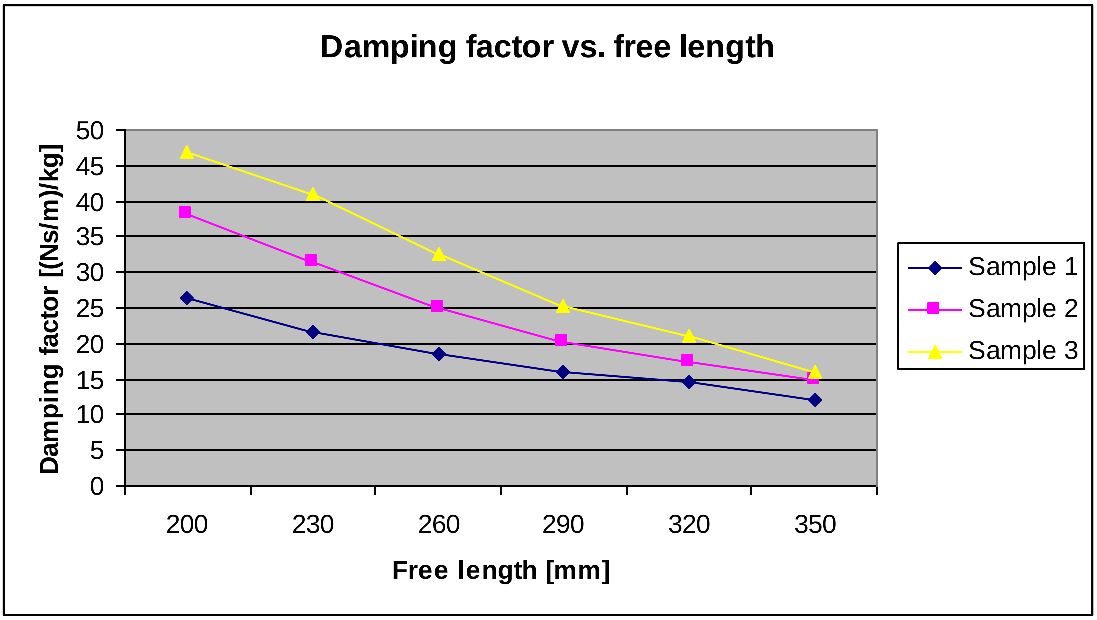

Fig. 3. Damping factor versus the bars free length

In the next part of the paper, we have used the regression analysis to determine a correlation between the damping factor per unit mass and the bars free length. We have followed the same procedures from Miriţoiu (2012) [6] (we have searched for an exponential function to approximate the damping factor per unit mass calculus depending on the bars free lengths). The calculus formulas are given in table 2.

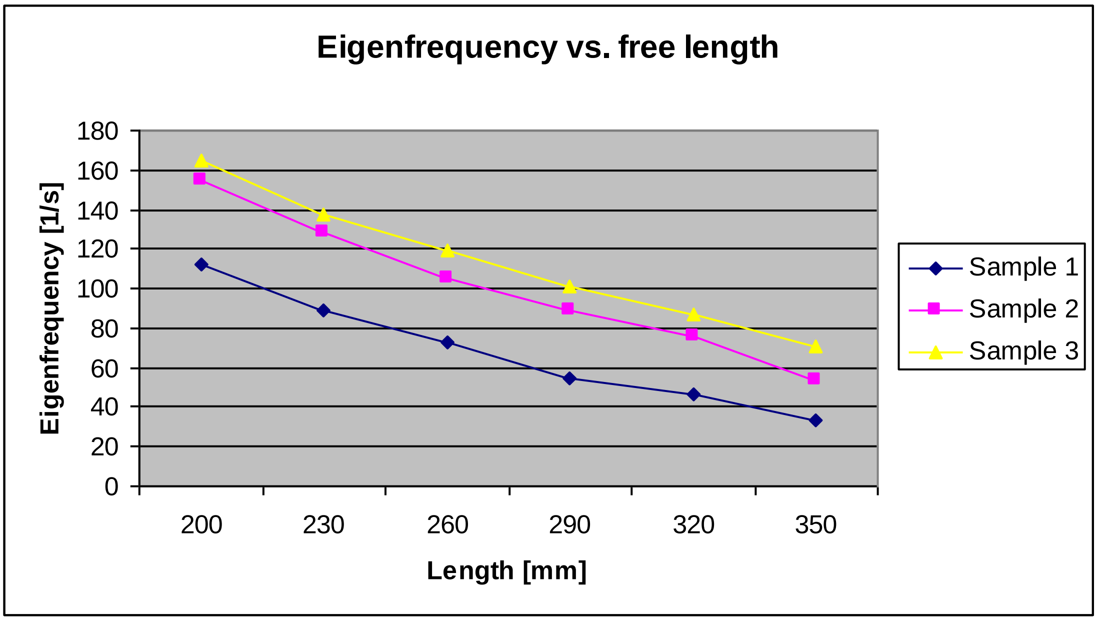

Fig. 4. Eigenfrequency versus the bars free lengths.

Table 2. Calculus relations for the damping factor per unit mass

Sample No.	Calculus relation for the damping factor per unit mass
1	$\mu= 29,8959263640 \cdot e^{-0.1510136403 \cdot L}$
2	$\mu= 45,2191093655 \cdot e^{-0.1897092451 \cdot L}$
3	$\mu= 60,8066369727 \cdot e^{-0,21643227723 \cdot L}$

For the determined calculus relations, the correlation factors R^2 are: sample 1 – 0,991; sample 2 – 0,992; sample 3 – 0,993.

3. CONCLUSIONS

In this paper we have built some new composite bars with the polypropylene honeycomb core (with the thickness of 10, 15 and 20 mm) reinforced with one layer of carbon-fiber. The width of these samples is 30 mm. The have embedded the bars at one and and left them free at the other end. As close as possible from the free edge, we have mounted an accelerometer to record the bars vibratory response. We have used the SPIDER 8 data acquisition system and the signal conditioner NEXUS in order to record the bars vibrations.

The added value of this paper is:

- building some new original composite bars made of classical materials but combined in an original way;
- determining the damping factor per unit mass for these bars;

-determining the eigenfrequency that corresponds to the first eigenmode;

- determining the correlation between the damping factor per unit mass and the bars free length (direct calculus relations written in table 2);
- determining the dependence between the eigenfrequency and the bars free length.

4. ACKNOWLEDGEMENT

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