Damping Study for Dammar Composite Bars Reinforced with Natural Fibers, With and Without Sandarac Core

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In this paper, we have studied the vibrations damping capacity for some composite materials that have as matrix a combination of Dammar and epoxy resin. We have used flax, cotton and silk fabrics as reinforcement materials. For comparison, half of the studied materials were made with Sandarac core. We have suggested a mathematical model for studying the vibrations of composite bars with three layers and rectangular section, based on a bar section non-linear strain. Singularizing the obtained model, there are achieved the Timoshenko equations for bars with rectangular section. For the considered bars, we have experimentally determined the damping and loss factors.

Keywords: vibrations, damping, natural fibers, Dammar, Sandarac

The energy degradation mechanisms presence is now accepted in all used models for mechanical vibrations simulation in elastic systems. There are distinguished two types of damping: external damping (owed to environmental or other physical systems interaction) and internal damping (owed to processes within the system, as thermal energy growth to the detriment of mechanical energy, owed to internal friction). Energy degradation mechanisms are often implied by experimental results. The energy degradation mechanisms influence is taken into account by introducing some auxiliary terms in movement equations.

In [1], there are brought in two types of energy degradation mechanisms. There were studied Euler-Bernoulli and Timoshenko bars with thermo-elastic damping and with one from shear stresses irregularities. In [2], there was studied a damping additional source for so-called genetic materials or for shape memory materials. In Euler-Bernoulli model, there are taken into account only the transversal sections translation motions, and rotational inertia effects are neglected. This fact can be accepted only for thin bars. Instead, these effects are being considered in Raleigh models. The most complete model is the Timoshenko model, where shear strains [3-6] are also taken into account. In [7], it is made a comparative analysis referring to energy degradation measurement methods to plates with regular layers with visco-elastic damping. In [8], there were examined damped bending vibrations for fiber-glass composite plates that have one or more gaps. In [9-10], there were explored the damping properties of steel, rubber and epoxy resin armed with fiber-glass laminated structures. Discrete loss factors for component materials were used to determine hybrid structures loss factors. Other studies regarding composite bars damped vibrations are made in [11-13].

In recent years, the interest of using natural fibers in making composite materials has increased. Natural fibers represent reinforcing materials suitable for composites due to combination between agreeable mechanical properties and environment protection advantages (renewability and biodegrability). Using natural fibers as reinforcement produces more advantages, as: relatively low cost, nature opulence, low weight, less damages to manufacturing equipments, refined surface finishing of the castings (compared with fiber glass composites), relative eligible mechanical properties. Several articles [14-21] introduce natural fibers properties.

The poor consistency of natural fibers with more polymeric matrices can lead to fibers irregular leakage inside the matrix. To eliminate this disadvantage, it was tried using some thermoset-biological matrices (resins based on plant oil, soya resins or other seed oils) prepared in a way that would make them bio-degradable [14, 22, 23]. There were used seed resins as Sandarac, Copal and Dammar. From fossil resins, amber is known, and from animal resins, Shellac is known. A chemical composition study of these resins is made in [24]. In [25-26], it is studied the mechanical behaviour of some composite materials whose matrix is of Dammar resin. As reinforcement materials, there were used flax, hemp, cotton and silk fabrics. There were determined the main mechanical characteristics also for the used resin, and for composite materials obtained by its reinforcement with the specified fabrics.

In this paper, it is examined the vibrations damping capability of some composite materials whose matrix is of Dammar and epoxy resin combination. As reinforcement materials, there were employed flax, cotton and silk fabrics. For comparison, half of the studied materials were made of Sandarac core.

Theoretical considerations

Mathematical model

We consider a sandwich bar of width b , made of three layers, with geometrical and mass symmetry (fig. 1).

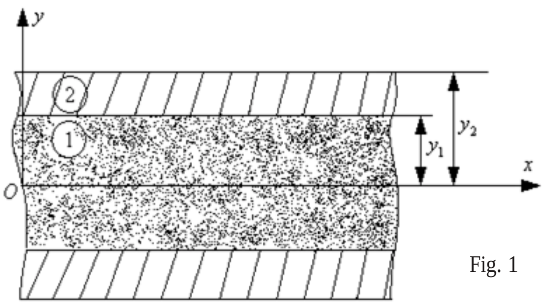

Fig. 1

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The motion equations for bar sectional vibrations in xOy plane are:

$$\iint_{(S)} \ddot{u}_y\, \rho\, dS - p_y - \frac{\partial T}{\partial x} = 0, \qquad (1)$$

$$\iint_{(S)} y\, \ddot{u}_x\, \rho\, dS + T + \frac{\partial M}{\partial x} = 0, \qquad (2)$$

where:

- u_x and u_y are bar strains towards Ox and Oy axes;
- ρ is the bar material density;
- p_y is the external load that acts on the bar;
- T is the shear stress from bar section;
- M is the bending moment.

Due to symmetry, we consider only the bar strains for $y>0$. The two layers from this area are marked with *1* for $y \in [y_0, y_1]$ and with *2* for $y \in [y_1, y_2]$ ($y_0 = 0$ is the two materials joint surface abscissa, and y_2 is the bar free surface abscissa).

We will consider that the displacements towards O_x and O_y axes for the two layers are:

$$u_x^{(k)}(x, y, t) = -\alpha_k(x,t)\cdot y + \beta_k(x,t)\cdot y^3,$$
$$u_y^{(k)}(x, y, t) = w(x,t),\ k \in \{1, 2\}. \qquad (3)$$

The non-zero components of strains tensor are:

$$\varepsilon_{xx}^{(k)} = -\frac{\partial \alpha_k}{\partial x} y + \frac{\partial \beta_k}{\partial x} y^3,$$
$$\gamma_{xy}^{(k)} = \frac{\partial w}{\partial x} - \alpha_k + 3\beta_k y^2,\ \ k \in \{1, 2\}. \qquad (4)$$

The stresses from bar sections will be:

$$\sigma_{xx}^{(k)} = E_k\left(-\frac{\partial \alpha_k}{\partial x} y + \frac{\partial \beta_k}{\partial x} y^3\right),$$
$$\sigma_{xy}^{(k)} = G_k\left(\frac{\partial w}{\partial x} - \alpha_k + 3\beta_k y^2\right),\ \ k \in \{1, 2\}, \qquad (5)$$

where:

E_k - is the elasticity modulus for layer;

G_k - is the sectional elasticity modulus for layer.

Displacements continuity conditions on joint surface between layers are:

$$-\alpha_1 y_1 + \beta_1 y_1^3 = -\alpha_2 y_1 + \beta_2 y_1^3. \qquad (6)$$

Stresses continuity condition on joint surface between layers is:

$$G_1\left(\frac{\partial w}{\partial x} - \alpha_1 + 3\beta_1 y_1^2\right) = G_2\left(\frac{\partial w}{\partial x} - \alpha_2 + 3\beta_2 y_1^2\right). \qquad (7)$$

On the bar external surface, the shear stresses are null, and therefore:

$$\frac{\partial w}{\partial x} - \alpha_2 + 3\beta_2 y_2^2 = 0. \qquad (8)$$

The relations (6), (7) and (8) symbolize an undetermined consistent linear system, with the solution:

$$\alpha_1 = \frac{1}{2G_1}\left\{\alpha\left[3G_1\left(1-\frac{y_1^2}{3y_2^2}\right) - G_2\left(1-\frac{y_1^2}{y_2^2}\right)\right] + \frac{\partial w}{\partial x}\left(G_2 - G_1\left(1-\frac{y_1^2}{y_2^2}\right)\right)\right\}, \qquad (9)$$

$$\alpha_2 = \alpha, \qquad (10)$$

$$\beta_1 = \frac{1}{2G_1 y_1^2}\left[G_1\left(1-\frac{y_1^2}{3y_2^2}\right) - G_2\left(1-\frac{y_1^2}{y_2^2}\right)\right]\left(\alpha - \frac{\partial w}{\partial x}\right), \qquad (11)$$

$$\beta_2 = \frac{1}{3y_2^2}\left(\alpha - \frac{\partial w}{\partial x}\right). \qquad (12)$$

The shear force is:

$$T = 2b\sum_{k=1}^{2}\int_{y_{k-1}}^{y_k}\sigma_{xy}^{(k)}dy = 2b\sum_{k=1}^{2}G_k\left[\left(\frac{\partial w}{\partial x}-\alpha_k\right)(y_k - y_{k-1}) + \beta_k\left(y_k^3 - y_{k-1}^3\right)\right]. \qquad (13)$$

The bending moment is:

$$M = -2b\sum_{k=1}^{2}\int_{y_{k-1}}^{y_k} y\,\sigma_{xx}^{(k)}dy = 2b\sum_{k=1}^{2}E_k\left[\frac{\partial \alpha_k}{\partial x}\left(\frac{y_k^3 - y_{k-1}^3}{3}\right) - \frac{\partial \beta_k}{\partial x}\left(\frac{y_k^5 - y_{k-1}^5}{5}\right)\right] \qquad (14)$$

With $\alpha_1, \alpha_2, \beta_1, \beta_2$ produced by the relations (9-12), we obtain:

$$Q = \langle GA\rangle\left(\frac{\partial w}{\partial x} - \alpha\right) \qquad (15)$$

where

$$\langle GA\rangle = 2b\left[G_1\left(y_1 - \frac{y_1^3}{3y_2^2}\right) + G_2\left(\frac{2y_2}{3} - y_1 + \frac{y_1^3}{3y_2^2}\right)\right] \qquad (16)$$

respectively

$$M = \langle EI_1\rangle\frac{\partial \alpha}{\partial x} + \langle EI_2\rangle\frac{\partial^2 w}{\partial x^2} \qquad (17)$$

where

$$\langle EI_1\rangle = 2b\left[\frac{2}{5}E_1 y_1^3\left(1-\frac{y_1^2}{3y_2^2}\right) - \frac{E_1 y_1^3 G_2}{15G_1}\left(1-\frac{y_1^2}{y_2^2}\right) + \frac{E_2}{15y_2^2}\left(4y_2^5 - 5y_1^3y_2^2 + y_1^5\right)\right] \qquad (18)$$

respectively

$$\langle EI_2\rangle = 2b\left[E_1 y_1^3\left(\frac{G_2}{15G_1}\left(1-\frac{y_1^2}{y_2^2}\right) - \frac{1}{15} + \frac{2y_1^2}{15y_2^2}\right) + E_2\frac{y_2^5 - y_1^5}{15y_2^2}\right] \qquad (19)$$

With (15) and (17), the motion equations (1) and (2) become:

$$\langle \rho A\rangle\ddot{w} - p_y - \langle GA\rangle\left(\frac{\partial^2 w}{\partial x^2} - \frac{\partial \alpha}{\partial x}\right) = 0 \qquad (20)$$

respectively

$$-\langle \rho I_1\rangle\ddot{\alpha} - \langle \rho I_2\rangle\frac{\partial \ddot{w}}{\partial x} + \langle GA\rangle\left(\frac{\partial w}{\partial x} - \alpha\right) + \langle EI_1\rangle\frac{\partial^2 \alpha}{\partial x^2} + \langle EI_2\rangle\frac{\partial^3 w}{\partial x^3} = 0 \qquad (21)$$

in which

$$\langle \rho A\rangle = 2b\left[\rho_1 y_1 + \rho_2(y_2 - y_1)\right]$$
$$\langle \rho I_1\rangle = 2b\left[\frac{2}{5}\rho_1 y_1^3\left(1-\frac{y_1^2}{3y_2^2}\right) - \frac{\rho_1 y_1^3 G_2}{15G_1}\left(1-\frac{y_1^2}{y_2^2}\right) + \frac{\rho_2}{15y_2^2}\left(4y_2^5 - 5y_1^3y_2^2 + y_1^5\right)\right] \qquad (22)$$

$$\langle \rho I_2 \rangle = 2b\left[\rho_1 y_1^3\left[\frac{G_2}{15G_1}\left(1-\frac{y_1^2}{y_2^2}\right)-\frac{1}{15}+\frac{2y_1^2}{15y_2^2}\right]+\rho_2\frac{y_2^5-y_1^5}{15y_2^2}\right] \tag{23}$$

Singularizing the relations (20) and (21), there are obtained the motion equations for transversal vibrations for rectangular sectioned homogeneous bars. It follows:

$$\rho bh\ddot{w}-p_y-\frac{2}{3}bhG\left(\frac{\partial^2 w}{\partial x^2}-\frac{\partial \alpha}{\partial x}\right)=0, \tag{24}$$

respectively

$$-\rho\frac{bh^3}{12}\left(\frac{4}{5}\ddot{\alpha}+\frac{1}{5}\frac{\partial \ddot{w}}{\partial x}\right)+\frac{2}{3}bhG\left(\frac{\partial w}{\partial x}-\alpha\right)+ \\ +\frac{Ebh^3}{12}\left(\frac{4}{5}\frac{\partial^2\alpha}{\partial x^2}+\frac{1}{5}\frac{\partial^3 w}{\partial x^3}\right)=0, \tag{25}$$

in which is the bar thickness.

It can be noted that if the function is changed

$$\varphi=\frac{4}{5}\alpha+\frac{1}{5}\frac{\partial w}{\partial x}, \tag{26}$$

equations (24) and (25) are exactly the Timoshenko motion equations for transversal vibrations in the case of rectangular sectioned homogeneous bars. Function change (26) is made so that the bending moment is proportional to function φ derivative depending on variable x, the same as in Timoshenko theory.

Free vibrations

The free vibrations study is made considering the external loading null. In these conditions, it is used the variables division method, the unknown functions α(x, t), w(x, t), being of:

$$\alpha(x,t)=Y(x)T(t), \quad w(x,t)=W(x)T(t) \tag{27}$$

Replacing (27) in (20) and (21), the equations are achieved:

$$\ddot{T}+\omega^2 T=0 \tag{28}$$

$$\langle GA\rangle(W''-Y')+\omega^2\langle\rho A\rangle W=0 \tag{29}$$

$$\langle GA\rangle(W'-Y)+\langle EI_1\rangle Y''+\langle EI_2\rangle W'''+ \\ +\omega^2\langle\rho I_1\rangle Y+\omega^2\langle\rho I_2\rangle W'=0 \tag{30}$$

in which ω is the eigenpulsation.

From the relation (28), there results

$$T(t)=\sin(\omega t+\varphi) \tag{31}$$

and from the relations (29) and (30), it is attained

$$Y(x)=\frac{1}{\langle GA\rangle-\omega^2\langle\rho I_1\rangle}\left[\begin{array}{l}(\langle EI_1\rangle+\langle EI_2\rangle)W'''(x)+\\ +\left(\langle GA\rangle+\omega^2\langle\rho I_2\rangle+\dfrac{\omega^2\langle EI_1\rangle\langle\rho A\rangle}{\langle GA\rangle}\right)W'(x)\end{array}\right] \tag{32}$$

$$Y'(x)=W''(x)+\frac{\omega^2\langle\rho A\rangle}{\langle GA\rangle}W(x) \tag{33}$$

$$(\langle EI_1\rangle+\langle EI_2\rangle)W''''+\omega^2\left(\langle\rho I_1\rangle+\langle\rho I_2\rangle+\frac{\langle EI_1\rangle\langle\rho A\rangle}{\langle GA\rangle}\right)W''+ \\ +\frac{\omega^2\langle\rho A\rangle}{\langle GA\rangle}\left(\omega^2\langle\rho I_1\rangle-\langle GA\rangle\right)W=0 \tag{34}$$

The differential equation (34) solution is:

$$W(x)=C_1\sin(\lambda_1 x)+C_2\cos(\lambda_1 x)+ \\ +C_3\sin(\lambda_2 x)+C_4\cos(\lambda_2 x) \tag{35}$$

if all auto-equation roots attached to differential equation (34) are complex or:

$$W(x)=C_1 sh(\lambda_1 x)+C_2 ch(\lambda_1 x)+ \\ +C_3\sin(\lambda_2 x)+C_4\cos(\lambda_2 x) \tag{36}$$

if two of auto-equation roots are real-valued. The contrast between the two situations is studied in [27]. The constants from relations (35) or (36) and the eigenpulsation are determined from the bar boundary conditions.

Damped vibrations case

In reality, due to internal frictions and air interaction, all vibrations are damped. The damping can be taken into account by initiating the complex elasticity modulus:

$$E^*=E(1+i\eta) \tag{37}$$

in which η is the loss factor. The function T(t) will have, in this case, the form:

$$T(t)=e^{-\mu t}\sin(2\pi\nu\cdot t+\varphi) \tag{38}$$

in which μ is called the damping factor, and ν is the vibration frequency. The association between the damping factor μ and the loss factor η is [28]

$$\eta=\frac{\mu}{\pi\nu} \tag{39}$$

If the loss factor defines the bar material damping capacity, the damping factor defines the overall sample damping capacity, being induced by the bar dimensions, as well as the eigenpulsation. The most common procedure used to determine the loss factor is *The Half-Power Bandwidth Method* presented in [29-31]. A general damping case is shown in [6], entering some terms in the motion equation, as $c_0\dot{w}$ or $c_1\frac{\partial^2\dot{w}}{\partial x^2}$ or $c_2\frac{\partial^4\dot{w}}{\partial x^4}$.

Experimental part

We have made samples of Dammar natural resin. The composite materials based only on this resin have a very long binding time. To eliminate this defect, we have used a small quantity of synthetic resin. More precisely, we have employed 60 % Dammar and 40% epoxy resin. The obtained samples sets have had densities between . The main mechanical characteristics resulted for Dammar-epoxy resin combination are presented in [25]:

- breaking strength between 25-29.5 MPa;
- breaking elongation between 1.1-1.4%;
- transversal contraction coefficient between 0.5-0.6;
- elasticity modulus between 2210-2560 MPa.

We have accomplished a first set of samples from this combined resin that was reinforced with:

-blending fabric with 40% cotton and 60% flax (typification DI), with specific mass of . We have used 12 layers, the obtained composite having resin mass proportion of 0.52;

-blending fabric with 60% silk and 40% cotton (typification DM), with specific mass of 240g/m^2. We have used 20 layers, the obtained composite having resin mass proportion of 0.51;

-cotton fabric (typification DB), with specific mass of 126g/m^2. We have used 24 layers, the obtained composite having resin mass proportion of 0.5.

The second set of samples was made with Sandarac core, the external layers being composed of materials used at the first set of samples. For Sandarac core samples, the complete number of Dammar layers reinforced with textile fabrics was half of the number of layers used at the first set of samples (6 layers for cotton and flax blending fabric (typification SDI), 10 layers for silk and cotton blending fabric (typification SDM) and 12 layers for cotton fabric (typification SDB)). The number of layers was chosen so that all sets of samples had 5 mm thickness.

The properties of composite materials reinforced with natural fibers can be very distinctive due to these fibers properties variations. Even in scientific literature, there are estimation dissimilarities. These reasons show that, in the case of some new composite materials, it is necesary to experimentally determine the mechanical properties.

We have experimentally determined the damping factor for these sets of samples. The studied samples had the length of 220 mm and the width of 25 mm, they were embedded to an end, and the vibration measurement was made to the other free end. The free length for each studied bar was 110, 130, 150, 170 and 190 mm.

The employed measurement equipment was:

-accelerometer with sensibility of 0.04 pC/ms^{-2};

-data acquisition system SPIDER 8;

-signal conditioner NEXUS 2692-A-0I4 connected to the system SPIDER 8.

Data acquisition set was made through the software CATMAN EASY, and the frequency measurement domain was set from 0 - 2.400 Hz from SPIDER 8.

In figure 2, there is presented the vibration experimental recording for the sample from the first set of assays reinforced with flax and 170 mm free length.

In figure 3, it is shown the damping factor determination for the recording from figure 2. The damping factor determination per bar mass unit was done by relation:

$$\mu = \frac{1}{t_2 - t_1} \ln \frac{w_1}{w_2}, \qquad (40)$$

t_1 and t_2 are the times to which two maxima of experimentally recorded chart are obtained;

w_1 is the greatest value at time moment t_1, and w_2 is the greatest value at time moment t_2.

In figure 4, it is displayed the vibration experimental recording for sample with Sandarac core, reinforced with flax and 170 mm free length.

In figure 5, it is displayed the damping factor determination for recording from figure 4.

There were chosen the studied experimental recordings because they are the samples from the two sets of assays with the same reinforcement, to which it has been discovered the greatest relative variation of the studied damping factor. Similarly, there were processed all experimental recordings. In table 1, there are shown the experimental results for samples from the first set of assays, and in table 2, there are displayed the experimental results for samples with Sandarac core. The values from these tables are the three experimental recordings averages. The elasticity modulus was determined through the method presented in [13]. The obtained value is an equivalent mean

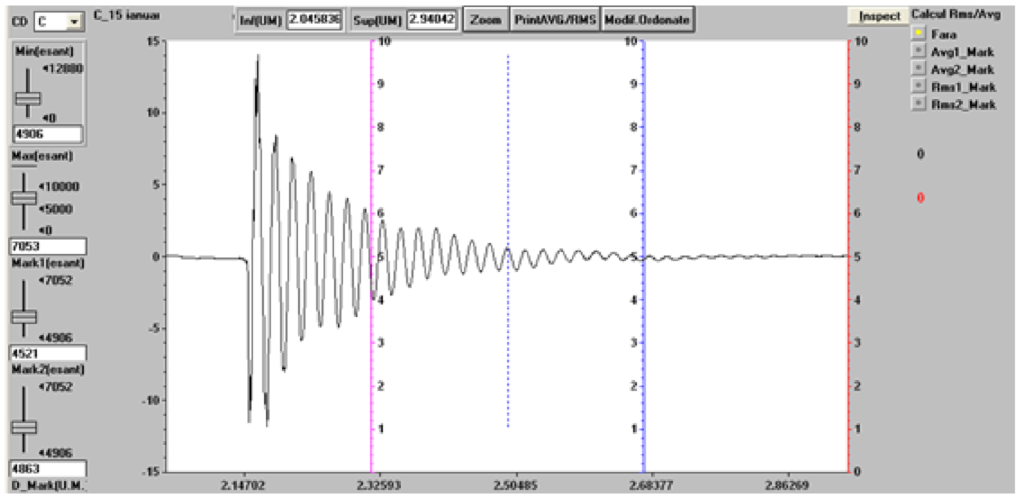

Fig. 2. Vibration experimental recording for sample from the first set of assays reinforced with flax and 170 mm free length

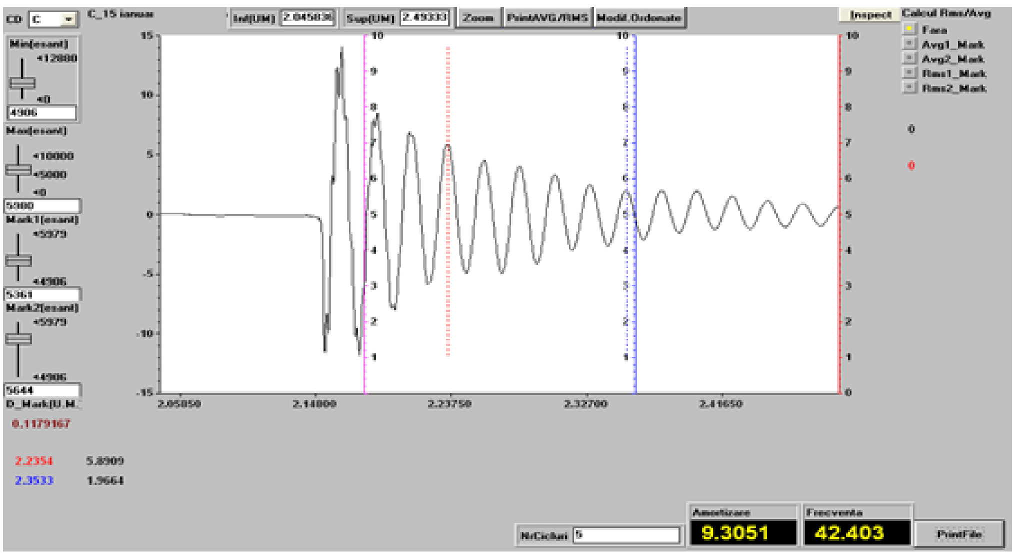

Fig. 3.Damping factor determination for sample from the first set of assay reinforced with flax and 170 mm free length

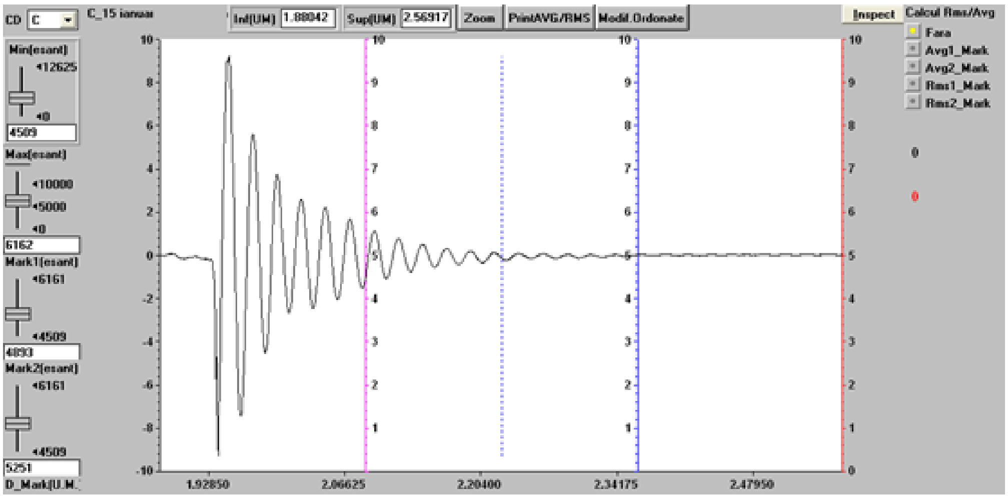

Fig. 4. Vibration experimental recording for sample with Sandarac core, reinforced with flax and 170 mm free length

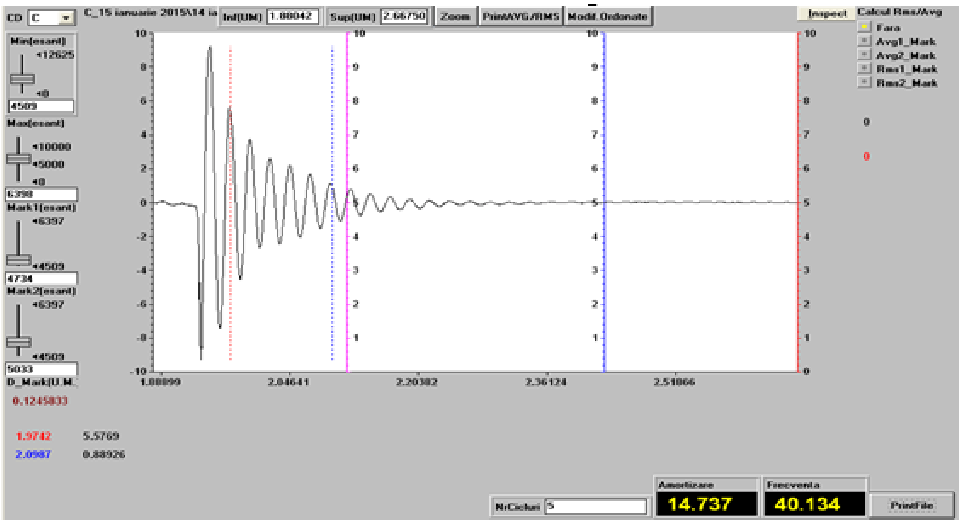

Fig. 5. Damping factor determination for sample with Sandarac core, reinforced with flax and 170 mm free length

Table 1
EXPERIMENTAL RESULTS FOR THE FIRST SET OF ASSAYS

Reinforcement (Typification)	Composite density kg/m^3	Free length (mm)	Frequency (Hz)	Damping factor µ $((Ns/m)/kg)$	Loss factor	Elasticity modulus (MPa)
Cotton (DB)	1095	110	122.1	36.3	0.0947	3679
		130	90.5	28.6	0.1006	3607
		150	66.6	21.4	0.1023	3786
		170	50.4	16.2	0.1023	3577
		190	40.1	12.8	0.1016	3533
Flax+Cotton (DI)	1065	110	102.6	21.6	0.0670	2527
		130	73.4	16.1	0.0711	2523
		150	55.8	13.5	0.0770	2585
		170	42.4	9.6	0.0721	2463
		190	34.9	8.3	0.0757	2603
Silk+Cotton (DM)	1160	110	96	32.4	0.1075	2399
		130	66.8	24.2	0.1153	2265
		150	50.7	19.7	0.1237	2268
		170	39.2	15.1	0.1226	2282
		190	31.7	12.4	0.1245	2328

Table 2
EXPERIEMNTAL RESULTS FOR THE SECOND SET OF ASSAYS

Reinforcement (Simbolizare)	Composite density kg/m^3	Free length (mm)	Frequency (Hz)	Damping factor µ $((Ns/m)/kg)$	Loss factor	Elasticity modulus (MPa)
Cotton (SDB)	1115	110	116.5	29.5	0.0806	3410
		130	82.7	21.4	0.0824	3353
		150	63.9	16.9	0.0842	3548
		170	48.6	13.6	0.0891	3386
		190	40.5	10.7	0.0841	3559
Flax+Cotton (SDI)	1160	110	93.4	29.9	0.0999	2270
		130	66.6	21.9	0.1047	2252
		150	50.5	17.7	0.1116	2295
		170	40.3	14.3	0.1130	2411
		190	31.8	11.5	0.1151	2343
Silk+Cotton (SDM)	1105	110	85.4	26.8	0.0995	2016
		130	61.8	19.8	0.1020	2056
		150	46.8	15.8	0.1075	2086
		170	36.6	12	0.1044	2103
		190	28.7	9.6	0.1065	2026

elasticity modulus, as if the material is homogeneous in bar section.

Conclusions

From experimental results analysis, the next conclusions can be extracted:

Dammar composite materials reinforced with natural fibers have proper vibrations damping properties.

Damping factor per mass unit decreases along with bar length, explained by the fact that the initially induced strain energy, by loaded at the free end, dissipates in a bigger material quantity. The greates values of damping factor per mass unit were obtained for Dammar bars reinforced with silk, respectively cotton, that have comparable values, and the least ones for bars reinforced with flax.

The loss factor has the greatest values for Dammar composite bars, reinforced with silk, and the least ones for bars reinforced with flax. Loss factor mean value for Dammar bar reinforced with cotton is 0.1006, for the one reinforced with flax is 0.0726, and for the one reinforced with silk is 0.1187. Although the damping factor values per mass unit for bars reinforced with silk, respectively cotton, has close values, loss factor values for the same materials are different. This conclusion is explained by elastical characteristics values dissimilarities.

Elasticity modulus greatest values were obtained for bars reinforced with cotton, and the least ones for bars reinforced with flax, respectively silk. The bigger elasticity modulus for bars reinforced with cotton resulted in a smaller initial strain, and therefore, in a smaller strain energy that is subsequently dissipated through vibrations. Inserting the Sandarac core lead to decreasing the leasticity modulus to all samples, regardless the used reinforcement. For bars reinforced with cotton, the mean elasticity modulus (the average between the five data from the table) decreased from 3636 MPa to 3451 MPa, for bars reinforced with flax it decreased from 2540 MPa to 2314 MPa, and for bars reinforced with silk it lowered from 2308 MPa to 2057 MPa. This behaviour can be explained by the fact that Sandarac core is not reinforced, and therefore, it has a smaller elasticity modulus than the materials reinforced with fibers.

The loss factor mean value for the bar with Sandarac core reinforced with cotton is 0.0841, for the one reinforced with flax is 0.1088, and for the one reinforced with silk is 0.1040. Inserting Sandarac core led to increasing the damping factor per mass unit and the loss factor for bars reinforced with flax. Conversely, for bars reinforced with cotton and silk, both damping factor per mass unit and loss factor decreased. This situation can be explained by the fact that Sandarac damping properties are inferior to those for Dammar reinforced with cotton or silk, but they are superior to those for Dammar reinforced with flax.

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