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Study of Vibration Damping in Composite Bars with a Dammar-Based Hybrid Matrix and Natural Fabric Reinforcements

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Abstract

Using a parameter that characterizes the damping capacity of the bar material, a mathematical model was developed to control the transverse vibration motion of a slender bar under boundary conditions defined by various support configurations. The model was validated for composite bars reinforced with natural fabrics made of flax, cotton, silk, or hemp fibers, and a hybrid resin matrix containing a 60% volumetric fraction of natural Dammar resin.

Keywords: composite bar; transvers vibrations; mathematical model

1. Introduction

The literature indicates that PFCs (plant fiber composites) exhibit loss factor values ranging from 0.7% to 14%, whereas SFCs (synthetic fiber composites) show values between 0.24% and 2.5% [1]. Therefore, the damping capacity of PFCs is generally significantly higher than that of SFCs. The damping range is also broader. This behavior is related to the wide variety of fibers and their complex structure.

The literature reports differing viewpoints and sometimes contradictory results [2]. This is attributed to the large diversity of bio composites studied, involving various types of plant fibers arranged in different reinforcement architectures and embedded in a wide range of polymer matrices. Therefore, although the damping behavior of PFCs has been documented [3,4], it is not yet fully understood.

Numerous studies have highlighted the potential of flax fibers in terms of specific mechanical properties, low density, and especially their damping characteristics [5–9]. For example, [10] and [11] showed that the damping properties of flax-reinforced composites are significantly higher than those of glass- or carbon-fiber-reinforced composites.

The feasibility of hybrid configurations combining natural fibers and carbon fibers to enhance the damping properties of carbon composites was investigated in [12,13]. In this context, [14] examined the effect of layer stacking sequence on the damping behavior of flax–carbon hybrid composites. A significant increase in damping performance was observed when flax layers were placed on the outer surface of the carbon laminate.

Study [6] reported that the damping of flax-fiber-reinforced composites was 51% higher than that of glass-fiber-reinforced composites. Another study [15] investigated the damping behavior of flax-fiber-reinforced polypropylene (PP) composites using vibration measurements. The composites were manufactured by vacuum bag molding with different fiber volume fractions (31%, 40%, and 50%) and orientations (45°, 60°, and 90°). The results showed that fiber orientation has a greater influence on vibration damping than fiber content.

Vibration studies on hemp fiber-polypropylene composites were conducted in [16] for fiber loadings ranging from 0 to 60%, in 10% increments. The effect of a coupling agent on vibration

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behavior was also examined. The highest damping ratio was obtained at a hemp content of 30%. The influence of hemp content on the dynamic behavior of glass- and hemp-fiber-reinforced composites was analyzed in [17]. An increase in hemp fiber content led to an increase in the loss factor.

In [18], the dynamic structural and mechanical properties of natural fiber-reinforced polymer composites were investigated both experimentally and numerically. Three types of laminated composites-jute-epoxy and hemp-epoxy-with one, three, and five layers were analyzed.

Among natural fibers, silk is one of the most durable and exhibits excellent mechanical properties, such as stiffness, strength, and ductility [19]. Topics such as the diversity of spider silk, its composition and architecture, the differences between silkworm and spider silk, and the biosynthesis of natural silk were addressed in [20].

Another study [21] investigated the development of biocompatible composites using basalt fibers and ductile silk fibers, together with a polylactic acid (PLA) matrix. Five distinct stacking sequences with alternating layers were fabricated and enhanced by the addition of graphene nano platelets (GNP) at 3, 6, and 9% relative to the PLA matrix. The results showed that the incorporation of 6% GNP improved damping by a factor of 1.54.

2. Materials and Methods

2.1. Theoretical Considerations

Beams represent structural elements frequently encountered in engineering applications, typically analyzed via the Euler-Bernoulli model. This framework relies on the kinematic hypothesis that a plane section, initially normal to the centroidal axis, remains plane and perpendicular to said axis throughout the deformation. The model is further governed by the following assumptions:

- the displacement field is analogous to that of simple bending;
- the transverse deflection is considered a function of the longitudinal coordinate alone;
- the material behavior is defined by a one-dimensional constitutive relation;
- the beams are subjected exclusively to transverse external loading;
- the boundary conditions remain constant, with no auxiliary supports emerging during deformation.

The Euler-Bernoulli theory hypotheses are valid exclusively for beams where the cross-sectional dimensions are small relative to the total length.

Due to internal friction and aerodynamic interaction, the transverse vibrations of the beams are damped. The inclusion of energy dissipation mechanisms is now a standard requirement in all models used for the simulation of mechanical vibrations in structural systems. Numerous studies have investigated various aspects and mechanisms of this phenomenon, as well as its influence on the vibratory behavior of different composite materials [22–28].

In the presence of damping, the governing equation of motion is expressed as follows [29]:

$$\ddot{w}(x;t)+2c_0\,\dot{w}(x;t)-2c_1\frac{\partial^2\dot{w}(x;t)}{\partial x^2}+2c_2\frac{\partial^4\dot{w}(x;t)}{\partial x^4}+b^4\frac{\partial^4 w(x;t)}{\partial x^4}=0, \qquad (1)$$

where

- $w(x,t)$ is the displacement of the elastic centre of the bar section;

and

$$b=\sqrt[4]{\frac{\langle EI\rangle}{\langle \rho A\rangle}} \qquad (2)$$

with

- $\langle \rho A\rangle=\iint_{(S)}\rho(y)dS$ is the mass per unit length of the bar;
- $\langle EI\rangle=\iint_{(S)}E(y)dS$ is the stiffness of the bar;

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- $\rho(y)$ is the density of the material of the bar;
- $E(y)$ is the Young's modulus of the material of the bar.

The term $2c_0 \dot{w}$ introduces external or viscous damping. Under this model, the amplitudes of all vibration modes (modal amplitudes) are attenuated at a uniform rate, which contradicts experimental observations. A natural interpretation of term $-2c_1 \frac{\partial^2 \dot{w}}{\partial x^2}$ is that the damping force is proportional to the bending velocity of the beam. The presence of term $2c_2 \frac{\partial^4 \dot{w}}{\partial x^4}$ implies that the damping rates of the natural modes of vibration are proportional to the square of the frequency, characterizing the Kelvin-Voigt model of internal damping.

Experimental data indicate that, for damped vibrations, the predominant mechanism involves a damping force proportional to the bending velocity. Under these conditions, the equation of motion for the transverse vibrations of a slender beam can be expressed as:

$$\ddot{w}(x;t) - 2\lambda b^2 \cdot \frac{\partial^2 \dot{w}(x;t)}{\partial x^2} + b^4 \frac{\partial^4 w(x;t)}{\partial x^4} = 0, \quad (3)$$

where λ represents a parameter characterizing the damping capacity of the beam material.

The solution to Equation (3) is expressed as:

$$w(x;t) = e^{p^2 t}(C_1 \cosh\frac{px}{a} + C_2 \sinh\frac{px}{a} + C_3 \cosh\frac{px}{\bar{a}} + C_4 \sinh\frac{px}{\bar{a}}), \quad (4)$$

where $a = \frac{b\sqrt{1+\lambda}}{\sqrt{2}} - i\frac{b\sqrt{1-\lambda}}{\sqrt{2}}$ and $\bar{a} = \frac{b\sqrt{1+\lambda}}{\sqrt{2}} + i\frac{b\sqrt{1-\lambda}}{\sqrt{2}}$.

Leads to:

$$w'(x;t) = e^{p^2 t}(\frac{p}{a} C_1 \sinh\frac{px}{a} + \frac{p}{a} C_2 \cosh\frac{px}{a} + \frac{p}{\bar{a}} C_3 \sinh\frac{px}{\bar{a}} + \frac{p}{\bar{a}} C_4 \cosh\frac{px}{\bar{a}}), \quad (5)$$

$$w''(x;t) = e^{p^2 t}(\frac{p^2}{a^2} C_1 \cosh\frac{px}{a} + \frac{p^2}{a^2} C_2 \sinh\frac{px}{a} + \frac{p^2}{\bar{a}^2} C_3 \cosh\frac{px}{\bar{a}} + \frac{p^2}{\bar{a}^2} C_4 \sinh\frac{px}{\bar{a}}), \quad (6)$$

$$w'''(x;t) = e^{p^2 t}(\frac{p^3}{a^3} C_1 \sinh\frac{px}{a} + \frac{p^3}{a^3} C_2 \cosh\frac{px}{a} + \frac{p^3}{\bar{a}^3} C_3 \sinh\frac{px}{\bar{a}} + \frac{p^3}{\bar{a}^3} C_4 \cosh\frac{px}{\bar{a}}). \quad (7)$$

The determination of the constants C_1, C_2, C_3 and C_4 is performed based on the boundary conditions defined by the specific support configuration of the beam.

Case 1. Simply supported beam (Supported-supported beam).

The boundary conditions for this case are given by

$$w(0;t) = 0, \quad w''(0;t) = 0, \quad (8)$$

$$w(l;t) = 0, \quad w''(l;t) = 0. \quad (9)$$

To obtain non-trivial solutions, it is required that

$$\sinh\frac{pl}{a} = 0 \text{ or } \sinh\frac{pl}{\bar{a}} = 0. \quad (10)$$

Case 2. Cantilever beam (Clamped-free beam).

The boundary conditions for this case are given by

$$w''(0;t) = 0, \quad w'''(0;t) = 0, \quad (11)$$

$$w(l;t)=0, \quad w'(l;t)=0. \tag{12}$$

For non-zero solutions to exist, we must have

$$1+\frac{\bar{a}^4}{a^4}-2\frac{\bar{a}^2}{a^2}\cosh\frac{pl}{a}\cosh\frac{pl}{\bar{a}}+\left(\frac{\bar{a}}{a}+\frac{\bar{a}^3}{a^3}\right)\sinh\frac{pl}{a}\sinh\frac{pl}{\bar{a}}=0. \tag{13}$$

Case 3. Fully clamped beam (Clamped-clamped).
The boundary conditions for this case are given

$$w(0;t)=0, \quad w'(0;t)=0, \tag{14}$$

$$w(l;t)=0, \quad w'(l;t)=0. \tag{15}$$

To obtain non-trivial solutions, it is required that

$$2-2\cosh\frac{pl}{a}\cosh\frac{pl}{\bar{a}}+\frac{a^2+\bar{a}^2}{a\bar{a}}\sinh\frac{pl}{a}\sinh\frac{pl}{\bar{a}}=0. \tag{16}$$

Case 4. Propped cantilever beam (Clamped-supported beam).
The boundary conditions for this case are given

$$w(0;t)=0, \quad w'(0;t)=0, \tag{17}$$

$$w(l;t)=0, \quad w''(l;t)=0. \tag{18}$$

For non-zero solutions to exist, we must have

$$\bar{a}\cosh\frac{pl}{a}\sinh\frac{pl}{\bar{a}}-a\sinh\frac{pl}{a}\cosh\frac{pl}{\bar{a}}=0. \tag{19}$$

Equations (8), (13), (16) and (19) each admit a solution $p_k, k\in N^*$ for every vibration mode. If, $u_k=\mathrm{Re}\left(\frac{l\sqrt{2}}{b}p_k\right)$ and $y_k=\mathrm{Im}\left(\frac{l\sqrt{2}}{b}p_k\right)$ represent the real and imaginary parts of the function $\frac{l\sqrt{2}}{b}p_k$, respectively, then the damping factor, the natural frequency and the damping ratio for the k vibration mode are given by:

$$\mu_k=\frac{b^2}{2l^2}(y_k^2-u_k^2), \tag{20}$$

$$\omega_k=\frac{b^2u_ky_k}{l^2}, \tag{21}$$

$$\xi_k=\frac{y_k^2-u_k^2}{y_k^2+u_k^2}. \tag{22}$$

Table 1 presents the values for components u_1 and y_1, as well as the damping ratio ξ_1, of the first vibration mode, for each of the four types of boundary conditions across various values of parameter λ.

Table 1. Values of u_1, y_1, ξ_1 for the first vibration mode, across various values of parameter λ.

Beam configuration	λ	u_1	y_1	Damping ratio (ξ_1)
Supported-supported	0	$\frac{\pi}{\sqrt{2}}$	$\frac{\pi}{\sqrt{2}}$	0

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	0.05	$\frac{\pi\sqrt{0.95}}{\sqrt{2}}$	$\frac{\pi\sqrt{1.05}}{\sqrt{2}}$	0.05
	0.1	$\frac{\pi\sqrt{0.9}}{\sqrt{2}}$	$\frac{\pi\sqrt{1.1}}{\sqrt{2}}$	0.1
	0.15	$\frac{\pi\sqrt{0.85}}{\sqrt{2}}$	$\frac{\pi\sqrt{1.15}}{\sqrt{2}}$	0.15
	0.2	$\frac{\pi\sqrt{0.8}}{\sqrt{2}}$	$\frac{\pi\sqrt{1.2}}{\sqrt{2}}$	0.2
Clamped-free	0	1.875104069	1.875104069	0
	0.05	1.851412407	1.901766366	0.02682787047
	0.1	1.831148407	1.930841007	0.05296274351
	0.15	1.814653599	1.961688103	0.07775352462
	0.2	1.802146038	1.993609875	0.1006270828
Clamped-lamped	0	4.730040745	4.730040745	0
	0.05	4.627364110	4.851229318	0.04720962142
	0.1	4.550523752	4.974774434	0.08890235886
	0.15	4.495661633	5.084847965	0.1225334384
	0.2	4.452873085	5.171729010	0.1485501468
Clamped-supported	0	3.926602312	3.926602312	0
	0.05	3.852701250	3.999331134	0.03733524309
	0.1	3.777524677	4.070984831	0.07467671467
	0.15	3.700961529	4.141655833	0.1120307523
	0.2	3.622891116	4.211433285	0.1494039085

2.2. Specimen Preparation

Composite beams were fabricated using a Dammar-based hybrid resin, reinforced with fabrics made of flax, cotton, silk, or hemp fibers.

The mechanical properties of the utilized fibers are presented in Table 2.

Table 2. Principal mechanical properties of the reinforcement fibers (see [30]).

Fiber	Density (g/cm³)	Elongation (%)	Tensile strength (MPa)	Elastic Modulus (MPa)
Cotton	1.5-1.6	7.0-8.0	287-800	5.5-12.6
Flax	1.5	2.7-3.2	345-1100	27-39
Hemp	1.4-1.5	2-4	310-750	30-60
Silk	1.3-1.4	18-33	160-260	4-6

The hybrid resin was synthesized by combining natural Dammar resin with a synthetic counterpart. The volumetric fraction of Dammar was 60%, with the remainder being Resoltech 1050 epoxy resin, utilized in conjunction with its corresponding Resoltech 1055 hardener. Specimens were fabricated with a width of 20 mm and a length of 240 mm. The casting process was conducted at a controlled temperature of 21–23°C. The principal properties of the investigated composite materials are summarized in Table 3.

Table 3. Mechanical properties of the investigated composite materials.

Reinforcement type	Flax	Cotton	Silk	Hemp
Areal density	$240\ g/m^2$	$130\ g/m^2$	$160\ g/m^2$	$350\ g/m^2$
Number of layers	16	26	30	8
Resin mass ratio	0.52	0.52	0.51	0.54
Composite density	$1.16\ g/cm^3$	$1.13\ g/cm^3$	$1.11\ g/cm^3$	$1.12\ g/cm^3$

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Specimen thickness	7.9	8.0	7.8	8.1

The four specimens used for the vibration analysis are shown in Figure 1.

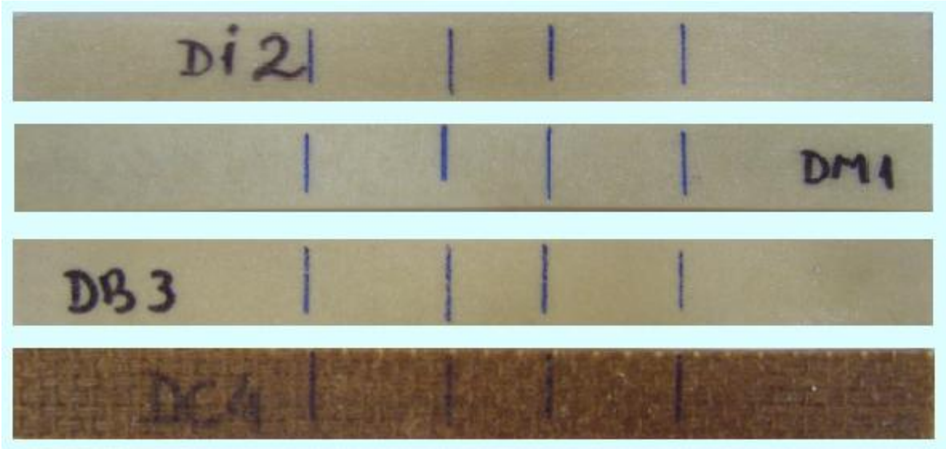

Figure 1. Specimens utilized for vibration analysis.

2.3. Testing Equipment

Vibration analysis was executed using SPIDER 8 acquisition system coupled with NEXUS 2692-A-0I4 signal conditioner and a 0.04 pC/ms^{-2} sensitivity accelerometer. Measurement protocols utilized a frequency bandwidth of 0 to 2.400 Hz. Potential experimental artifacts were eliminated by implementing a Butterworth "High-Pass" filter at 3 Hz.

3. Results

The beams were clamped at one end, with the cantilever lengths set to 120 mm, 140 mm, 160 mm, 180 mm, and 200 mm, respectively. For each specimen, the free vibrations-induced by an initial deformation resulting from a point load applied at the free end-were recorded. Two measurements were performed for each specific length. Figure 2 illustrates an experimental recording for the hemp-reinforced specimen with an effective free length of 200 mm.

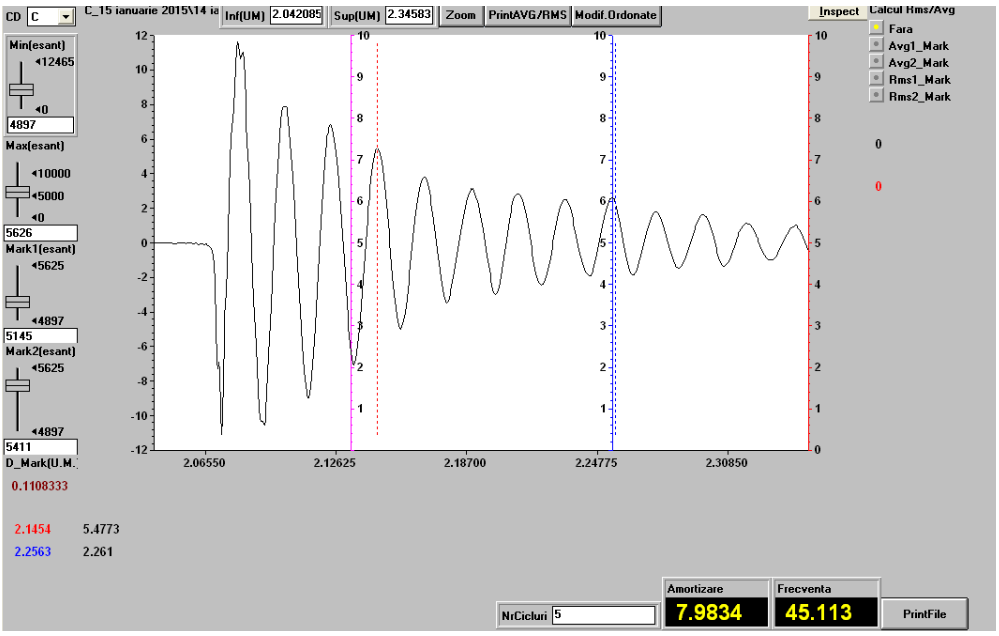

Figure 2. Experimental recording for the hemp-reinforced specimen with a free length of 200 mm.

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For each recording, the frequency, damping factor, damping ratio and loss factor were determined using the following relations (see [28]):

- frequency $\nu = \frac{n}{t_2 - t_1}$;
- damping factor $\mu = \frac{1}{t_2 - t_1} \ln \frac{w_1}{w_2}$;
- damping ratio $\xi = \frac{\mu}{2\pi\nu}$;
- loss factor $\eta = 2\xi$;

where

- t_1 and t_2 represent the time instances at which two local maxima of the experimentally recorded signal are obtained;
- w_1 represents the peak value at time t_1 and w_2 represents the peak value at time t_2;
- $n = 5$ denotes the number of oscillations occurring during the interval $[t_1, t_2]$.

Table 4 presents the mean values obtained from the two measurements for each experimental test.

Table 4. Mean values of frequency, damping factor, damping ratio, and loss factor.

Reinforcement type	Free length (mm)	Frequency (Hz)	Damping factor (s^{-1})	Damping ratio	Loss factor
Flax	120	117.8	30.3	0.0409	0.0818
	140	86.6	22.8	0.0419	0.0838
	160	66.8	17.6	0.0419	0.0838
	180	49.2	14.4	0.0465	0.0930
	200	39.1	11.4	0.0464	0.0928
Cotton	120	90.2	23.5	0.0415	0.0830
	140	64.1	18.1	0.0449	0.0898
	160	50.2	14.2	0.0450	0.0900
	180	39.6	11.0	0.0442	0.0884
	200	30.3	9.1	0.0478	0.0956
Silk	120	86.6	31.9	0.0586	0.1172
	140	62.5	24.4	0.0621	0.1242
	160	46.2	19.6	0.0675	0.1350
	180	36.1	16.2	0.0714	0.1428
	200	28.3	12.4	0.0697	0.1394
Hemp	120	135.4	20.4	0.0239	0.0478
	140	99.8	16.4	0.0261	0.0522
	160	74.5	12.7	0.0271	0.0542
	180	56.7	9.4	0.0264	0.0528
	200	45.2	7.9	0.0278	0.0556

Figure 3 illustrates the variation of the vibration frequency as a function of the beam length for the four composite specimens.

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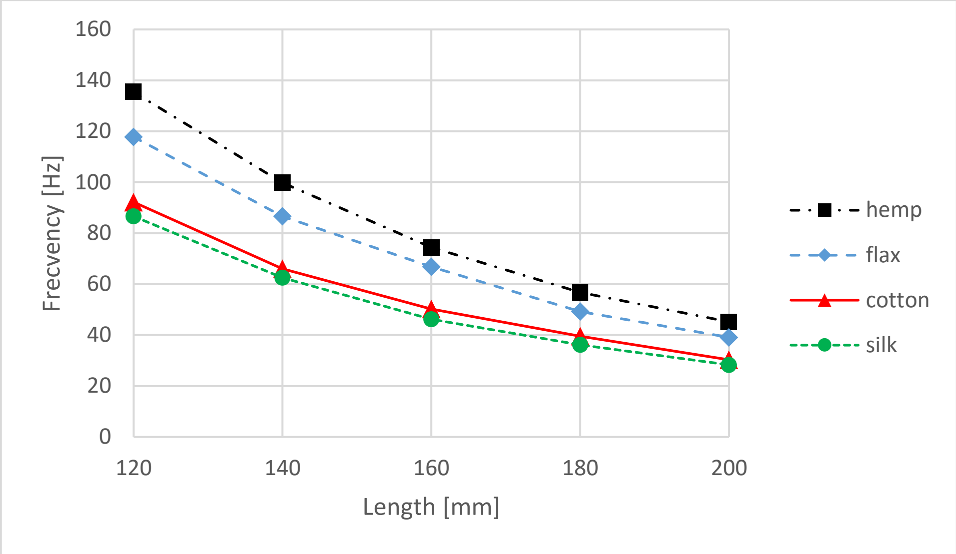

Figure 3. Vibration frequency versus beam length.

Figure 4 illustrates the variation of the vibration damping factor as a function of the beam length for the four composite specimens.

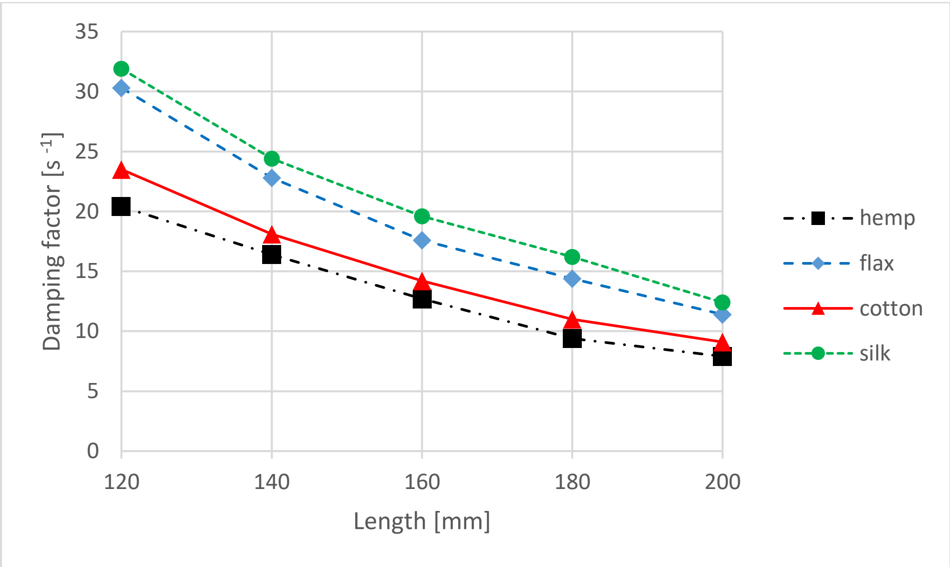

Figure 4. Damping factor versus beam length.

4. Discussion

The calculated average damping ratio and loss factor for the four composite materials are as follows:

- flax fabric reinforced composite: $\xi = 0.0435$, $\eta = 0.0870$;
- cotton fabric reinforced composite: $\xi = 0.0447$, $\eta = 0.0894$;
- silk fabric reinforced composite: $\xi = 0.0658$, $\eta = 0.1316$;
- hemp fabric reinforced composite: $\xi = 0.0263$, $\eta = 0.0526$.

The corresponding values of parameter λ, to be utilized in the transverse vibration equation, are as follows:

- flax fabric reinforced composite: $\lambda = 0.0817$;
- cotton fabric reinforced composite: $\lambda = 0.0827$;
- silk fabric reinforced composite: $\lambda = 0.1255$;
- hemp fabric reinforced composite: $\lambda = 0.0491$.

5. Conclusions

Vibration damping depends on the inertial and elastic properties of the materials, the beam dimensions, and the boundary conditions. Consequently, for a simply supported beam, the parameter λ used in the equation of motion coincides with the damping ratio. Conversely, for the other support configurations, the damping ratio increases with the parameter λ, although the relationship is no longer strictly linear.

Since the dimensions and constituent proportions of the investigated specimens are similar, the discrepancies observed in the experimental results are attributed to the variations in the mechanical properties of the reinforcement fabrics. It is observed that the beams reinforced with cotton or silk fabrics exhibit damping properties superior to those reinforced with flax or hemp fabrics.

The most significant vibration damping properties were observed in the silk-reinforced beam, which exhibits the lowest elastic modulus and the highest elongation at break. Conversely, the hemp-reinforced beam-characterized by the highest elastic modulus and the lowest elongation at break-yielded the lowest damping performance.

It can be concluded that reinforcement materials with higher deformability are preferable for developing composite materials with enhanced vibratory performance.

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Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Kalusuraman, G.; Kumaran, S.T.; et al. Vibration studies on fiber reinforced composites – a review. *J. Nat. Fibers* **2022**, *20*, doi:10.1080/15440478.2022.2157361.
2. Saba, N.; Jawaid, M.; A., O.Y.; Paridah, M.T. A review on dynamic mechanical properties of natural fibre reinforced polymer composites. *Constr. Build. Mater.* **2016**, *106*, 149-159, doi:10.1016/j.conbuildmat.2015.12.075.
3. Duc, F.; Bourban, P.E.; Plummer, C.J.G.G.; Manson, J.A.E.E. Damping of thermoset and thermoplastic flax fibre composites. *Compos. –A: Appl. Sci. Manuf.* **2014**, *64*, 115-123, doi:10.1016/j.compositesa.2014.04.016.
4. Duc, F.; Bourban, P.E.; Manson, J.A.E. The role of twist and crimp on the vibration behaviour of flax fibre composites. *Compos. Sci. Technol.* **2014**, *102*, doi:10.1016/j.compscitech.2014.07.004.
5. Yan, L.; Chouw, N.; Jayaraman, K. Flax fibre and its composites - a review. *Compos. B Eng.* **2014**, *56*, 296–317, doi:10.1016/j.compositesb.2013.08.014.
6. Prabhakaran, S.; Krishnaraj, V.; Senthil Kumar, M.; Zitoune, R. Sound and vibration damping properties of flax fiber reinforced composites. *Procedia Eng.* **2014**, *97*, 573–581, doi:10.1016/j.proeng.2014.12.285.
7. Monti, A.; El Mahi, A.; Jendli, Z.; Guillamat, L. Experimental and finite elements analysis of the vibration behaviour of a bio-based composite sandwich beam. *Compos. B Eng.* **2017**, *110*, 466–475, doi:10.1016/j.compositesb.2016.11.045.
8. Cheour, K.; Assarar, M.; Scida, D.; Ayad, R.; Gong, X.L. Effect of water ageing on mechanical and damping properties flax-fibre reinforced composite materials. *Compos. Struct.* **2016**, *152*, 259–266, doi:10.1016/j.compstruct.2016.05.045.

9. Le Guen, M.J.; Newmana, R.H.; Fernyhough, A.; Staiger, M.P. Tailoring the vibration damping behaviour of flax fibre-reinforced epoxy composite laminates via polyol additions. *Compos.–A: Appl. Sci. Manuf.* **2014**, *67*, 37–43, doi:10.1016/j.compositesa.2014.08.018.
10. Wielage, B.; Lampke, T.; Utschick, H.; Soergel, F. Processing of natural-fibre reinforced polymers and the resulting dynamic-mechanical properties. *J. Mater. Process Technol.* **2003**, *139*, 140–146, doi:10.1016/S0924-0136(03)00195-X.
11. Duc, F.; Bourban, P.E.; Manson, J.A.E. Dynamic mechanical properties of epoxy/flax fibre composites. *J. Reinf. Plast. Compos.* **2014**, *33*, 1625–1633, doi:10.1177/0731684414539779.
12. Ashorth, S.; Rongong, J.; Wilson, P.; Meredith, J. Mechanical and damping properties of resin transfer moulded jute-carbon hybrid composites. *Compos. B Eng.* **2016**, *105*, 60–66, doi:10.1016/j.compositesb.2016.08.019.
13. Li, Y.; Cai, S.; Huang, X. Multi-scaled enhancement of damping property for carbon fiber reinforced composites. *Compos. Sci. Technol.* **2017**, *143*, 89–97, doi:10.1016/j.compscitech.2017.03.008.
14. Assarar, M.; Zouari, W.; Sabhi, H.; Ayad, R.; Berthelot, J.M. Evaluation of the damping of hybrid carbon-flax reinforced composites. *Compos. Struct.* **2015**, *132*, 148–154, doi:10.1016/j.compstruct.2015.05.016.
15. Rahman, M.Z.; Jayaraman, K.; Mace, B.R. Influence of damping on the bending and twisting modes of flax fibre-reinforced polypropylene composite. *Fibers Polym.* **2018**, *192*, 375–382, doi:10.1007/s12221-018-7588-7.
16. Etaati, A.; Mehdizadeh, S.A.; Wang, H.; Pather, S. Vibration damping characteristics of short hemp fibre thermoplastic composites. *J. Reinf. Plast. Compos.* **2013**, *33*, 330–341, doi:10.1177/0731684413512228.
17. Indra Reddy, M.; Srinivasa Reddy, V. Dynamic mechanical analysis of hemp fiber reinforced polymer matrix composites. *IJERT* **2014**, *3*, 410-415, doi:10.17577/IJERTV3IS090342.
18. Singh, S.P.; Dutt, A.; Hirwani, C.K. Mechanical, modal and harmonic behavior analysis of jute and hemp fiber reinforced polymer composite. *J. Nat. Fibers* **2022**, *20*, 2140328, doi:10.1080/15440478.2022.2140328.
19. Ranakoti, L.; Gupta, M.K.; P.K., R. *Silk and silk-based composites: opportunities and challenges*; Springer Nature Singapore Pte Ltd.: 2019; Volume Chapter: 7.
20. Kiseleva, A.P.; Krivoshapkin, P.V.; Krivoshapkina, E.F. Recent advances in development of functional spider silk-based hybrid materials. *Front. Chem.* **2020**, *8*, 554, doi:10.3389/fchem.2020.00554.
21. Hamim, R.; Hasan, T.; Shahriar, F.; Chowdhury, S.R.; Rahman, A.; Nasim, M.; Habib, M.A. Basalt-silk fiber reinforced PLA composites: Effect of graphene fillers and stacking sequence. *Compos. Part C-Open* **2025**, *16*, 100564, doi:10.1016/j.jcomc.2025.100564.
22. Kumar, N.; Singh, S.P. Vibration and damping characteristics of plat-bands with active constrained layer treatments under parametric variations. *Materials & Design* **2009**, *30*, 4162-4174, doi:10.1016/j.matdes.2009.04.044.
23. Stănescu, M.M.; Bolcu, D.; Pastramă, S.D.; Ciucă, I.; Manea, I.; Baciu, F. Determination of damping factor at the vibrations of composite bars reinforced with carbon and kevlar texture. *Mater. Plast.* **2010**, *47*, 492-496.
24. Sarlin, E.; Liu, Y.; Vippola, M.; Zogg, M.; Ermanni, P.; Vuornien, J.; Lepisto, T. Vibration damping properties of steel/rubber/composite hybrid structures. *Compos. Struct.* **2012**, *94*, 3327-3335, doi:10.1016/j.compstruct.2012.04.035.
25. Bowyer, E.P.; Krylov, V.V. Experimental investigation of damping flexural vibrations in glass fibre composite plates containing one- and two-dimensional acoustic black holes. *Compos. Struct.* **2014**, *107*, 406-415, doi:10.1016/j.compstruct.2013.08.011.
26. Yang, J.; Xiong, J.; Ma, L.; Zhang, G.; Wang, X.; Wu, L. Study on vibration damping of composite sandwich cylindrical shell with pyramidal truss-like cores. *Compos. Struct.* **2014**, *117*, 362-372, doi:10.1016/j.compstruct.2014.06.042.
27. Vanwalleghem, J.; De Baere, I.; Loccufier, M.; Van Paepegem, W. External damping losses in measuring the vibration damping properties in lightly damped specimens using transient time-domain methods. *J. Sound Vib.* **2014**, *333*, 1596-1611, doi:10.1016/j.jsv.2013.10.015.
28. Burada, C.O.; Miritoiu, C.M.; Stanescu, M.M.; Bolcu, D. The vibration behaviour of composite sandwich bars reinforced with glass fiber. *Rev. Rom. Mater.* **2015**, *45*, 244-254.

29. Hermann, L. Vibration of the Euler-Bernoulli beam with allowance for dampings. In Proceedings of the World Congress on Engineering 2008 (WCE 2008), London, UK, 2–4 July 2008, 2008.
30. Ciuca, I.; Bolcu, A.; M.M., S. A study on some mechanical properties of bio-composite materials with a Dammar-based matrix. *EEMJ* **2017**, *16*, 2851-2856.