Dynamic behaviour of composites reinforced with needles from fir trees

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Abstract. In this paper we build some composite materials reinforced with needles from fir trees. In order to build the samples, we have firstly created some strips in this way: we put the pines, continuously, on a sheet of paper where we apply a thin layer of resin (we have used epoxy and polyester ones). We have made 10 strips and we have glued them together by using the same synthetic resins (epoxy and polyester). In the end we have obtained some composites reinforced with strips from fir trees needles and paper sheet, and the matrix is made from epoxy and polyester resins. From the obtained plate, we have cut some samples in order to study their free vibrations. We have placed an accelerometer at about 10 mm from the free edge and we have clamped the samples on several free lengths. The accelerometer is connected to a signal conditioner NEXUS which is also connected to a data acquisition system SPIDER 8. The data acquisition system is connected to a notebook through USB port. From the samples free vibrations, we have determined: the eigenfrequency, the damping factor per unit mass, damping factor per unit length, dynamic stiffness, dynamic Young modulus and loss factor.

1 Introduction

1.1 General aspects regarding the theories for studying the composite structures

The composite materials theories found in the engineering literature can be studied by several methodologies that take into account or not the results of angles strain and the spinning inertia. In this way, there have been developed two already known theories mentioned in the literature as The First – order Shear Deformation Theory – FSDT and The High – order Shear Deformation Theory – HSDT. The first theory is mentioned in [1] and [2] and assumes that if there is a straight line on the median plane before strain, it remains in the same shape without retaining the perpendicularity during the strain. The second theory, HSDT [3], considers the stresses and strains perpendicular on the median surface to be neglected. The normal stresses and strains that are perpendicular on the median surface

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are not neglected in the [4,5] studies; there were taken into account all the stresses and strains that appeared after acting with forces and moments upon the composite samples.

Another theory called The Layer - Wise Models (LWM) is presented in [6,7,8,9,10,11]. In [6,7] the sandwich structures are studied by considering every layer as a distinct structure. In [8], each layer of the sandwich structure is considered as a Reissner – Mindlin plate and these layers are studied separately. The papers from [9,10] study each layer individually, using linear strains in the thickness direction. In [11], each layer of the composite structure is calculated individually using a high-order strain field for bending ripple emission in the structure of the studied plates.

1.2 General aspects regarding similar studies

In this paper we aim to study the dynamic behaviour for composite structures reinforced with pines from fir trees and two types of matrices: epoxy and polyester. From the fir, as a tree, point of view, the engineering literature provide very little information about the usage of its needles in manufacturing the composite materials. Most of the studies are concentrated regarding the usage of timber [12,13,14,15].

2 Dynamic mechanical behaviour

2.1 The composite samples manufacturing

In the fist phase of composite manufacturing, we have created some sheets made in this way: on a sheet of paper we have applied the matrix and under the matrix we have placed side by side the needles from tree firs (Fig. 1).

Fig. 1. A sheet from epoxy resin and tree firs

We have created ten sheets like the one presented in fig. 1. The, we glued the sheets by applying resin on them (epoxy for the first set, then polyester for the second set – Fig. 2). The resin was applied manually (Fig. 2). We have used the RESOLTECH 1050 resin with the RESOLTECH 1058s hardener. The ratio resin:hardener was applied according to the manufacturer recommendation [16]. The final obtained plate is presented in Fig. 3. The final plate has A4 sheet dimensions. From this plate we cut samples with a width of 25 mm, 8 mm thickness and the length 200 mm (Fig. 4).

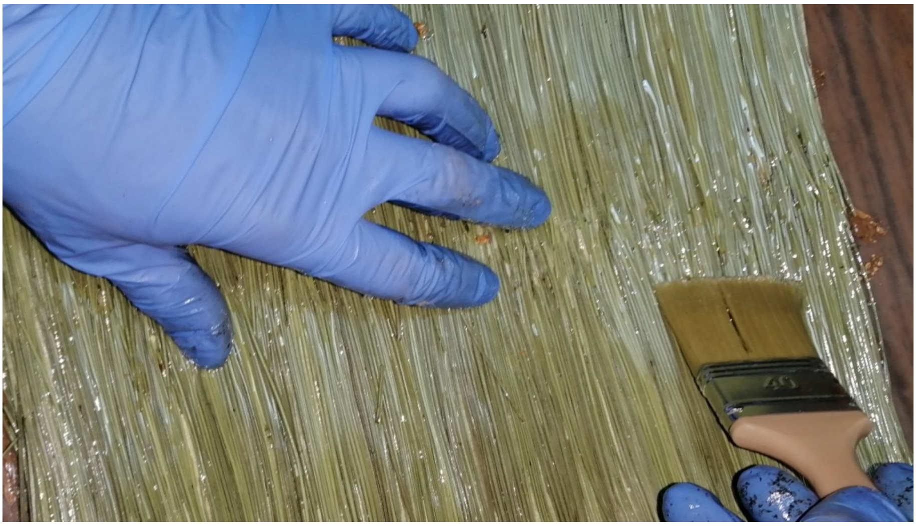


Fig. 2. Applying the epoxy resin on the created sheets (paper+tree firs)

Fig. 3. The final created plate (paper+tree firs)

2.2 Dynamic tests

We have placed an accelerometer at about 10 mm from the free edge and we have clamped the samples on several free lengths. The accelerometer, in order to provide information regarding the samples vibrations, is plugged in a NEXUS-CCLD apparatus which is used for field recording of vibration and acoustic signals. The NEXUS-CCLD is plugged in a SPIDER 8 apparatus which is used to record the experimental data. The interface between

SPIDER 8 and a notebook is obtained through a software called CATMAN EASY which is used to retain the experimental data on the notebook's hard drive. From the experimental setup, the next dynamic parameters are obtained: the eigenfrequency and the damping factor per unit mass. By using equations (4),(5),(6) and (7), the damping factor per unit length, dynamic stiffness, dynamic Young modulus and loss factor are calculated. We have used a similar experimental montage in [17]. Like in [17], we have chosen various free lengths for the samples: 100, 120, 140, 160 and 180 mm in order to determine the stiffness, dynamic Young modulus and loss factors variations through the samples length.

Fig. 4. A sample for the dynamic tests

According to [16], from the experimental recording of free vibrations, the damping factor per unit mass can be calculated using the next steps:

- there are determined the points where the deformation is null;
- there is determined the period where is produced the nullification of motion;
- the eigenfrequency ν, the eigenpulsation ω and the damping factor per unit mass μ are determined with (1), (2) and (3).

$$\nu = \frac{1}{T} \tag{1}$$

$$\omega = \frac{2 \cdot \pi}{T} \tag{2}$$

$$\mu = \frac{1}{k \cdot T} \cdot \ln\left(\frac{\psi_i}{\psi_{i+k}} \right) \tag{3}$$

According to [16], the stiffness *EI* for composite bars can be determined with (4), the dynamic elasticity modulus E_{dyn} with (5), the loss factor η with (6) and the damping factor per unit length *C* with (7).

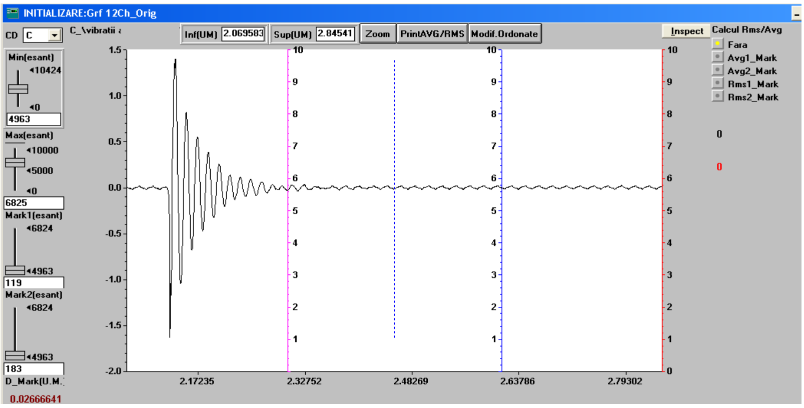
$$EI = 39.478418 \cdot \rho \cdot g \cdot w \cdot \left(\frac{\nu \cdot l^2}{\xi^2} \right)^2 \tag{4}$$

$$E_{dyn} \approx 38.32 \cdot \rho \cdot \left(\frac{l^2 \cdot \nu}{g} \right)^2 \tag{5}$$

$$\eta \approx 0.3183099 \cdot \mu \cdot \nu^{-1} \tag{6}$$

$$C = 2 \cdot \mu \cdot \rho \cdot g \cdot w \tag{7}$$

In the relations (4), (5), (6) and (7), the next parameters were marked in this way : ρ the material density, *g* and *w* the samples thickness and width, ξ is a parameter from the samples supporting conditions which is 1.875 for a bar clamped at one end and free at the other [16], *l* is the bar free length. All the experimental results and the dynamic parameters are presented in **Table 1**. In Fig. 5 there is presented the experimental recording for the free vibrations of a sample made from pines/paper+epoxy and the free length of 180 mm. In Fig. 6 there is presented the calculus of damping factor per unit mass and the eigenfrequency of the first eigenmode for the sample made from pines/paper+epoxy and the free length of 180 mm. In Fig. 6 there is presented the calculus of damping factor per unit mass and the eigenfrequency of the first eigenmode for the sample made from pines/paper+polyester and the free length of 140 mm.



CD C
C_\vibratii
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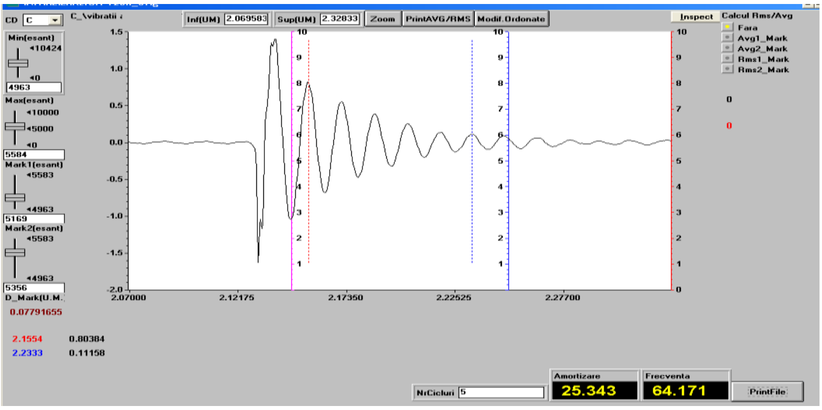
Sup(UM) 2.84541
Min(esant) 4963
Max(esant) 6825
Mark1(esant) 119
Mark2(esant) 183
D_Mark(U.M.) 0.02666641

Fig. 5. Experimental recordings for a sample made from needles and paper with epoxy resin as matrix, and the free length of 180 mm



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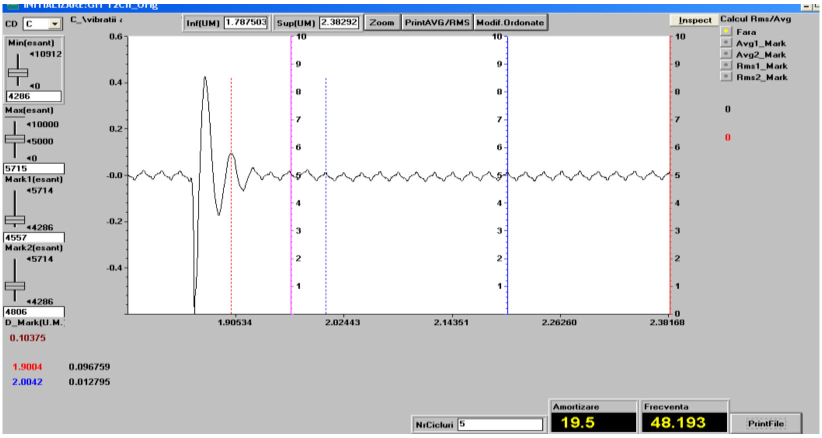
Mark1(esant) 5169
Mark2(esant) 5356
D_Mark(U.M.) 0.07791655

2.1554 0.80384
2.2333 0.11158

NrCicluri 5
Amortizare 25.343
Frecventa 64.171

Fig. 6. Damping factor per unit mass and eigenfrequency determination for a sample made from needles and paper with epoxy resin as matrix, and the free length of 180 mm



CD C
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Mark2(esant) 4806
D_Mark(U.M.) 0.10375

1.9004 0.096759
2.0042 0.012795

NrCicluri 5
Amortizare 19.5
Frecventa 48.193

Fig. 7. Damping factor per unit mass and eigenfrequency determination for a sample made from needles and paper with polyester resin as matrix, and the free length of 140 mm

Table 1. All the dynamic results resulted from the experimental investigations

No. Crt.	Free length (mm)	Damping factor per unit mass (Ns/m/kg)	Eigen frequency (1/s)	Density (kg/m^3)	Specific mass (kg/m)	Young modulus (MPa)	Dynamic stiffness (Nm^2)	Loss factor	Damping factor per unit length (Ns/m/m)
1	100	51.175	155	550	0.11	729	0.849	0.105	11.258
	120	39.141	107	550	0.11	728	0.848	0.115	8.611
	140	30.123	91.6	550	0.11	974	1.135	0.105	6.627
	160	25.65	75.0	550	0.11	1115	1.289	0.109	5.643
	180	20.35	64.1	550	0.11	1304	1.519	0.101	4.477
2	100	68.335	207	550	0.11	1299	1.513	0.105	15.034
	120	53.141	143.	550	0.11	1295	1.508	0.118	11.691
	140	41.563	105.	550	0.11	1295	1.508	0.125	9.144
	160	30.95	81.0	550	0.11	1300	1.514	0.122	6.809
	180	25.343	64.1	550	0.11	1304	1.519	0.126	5.575
Mean value						1298.6	1.5124		

In Table 1, with 1 there are marked the polyester samples and with 2 there are marked the epoxy samples.

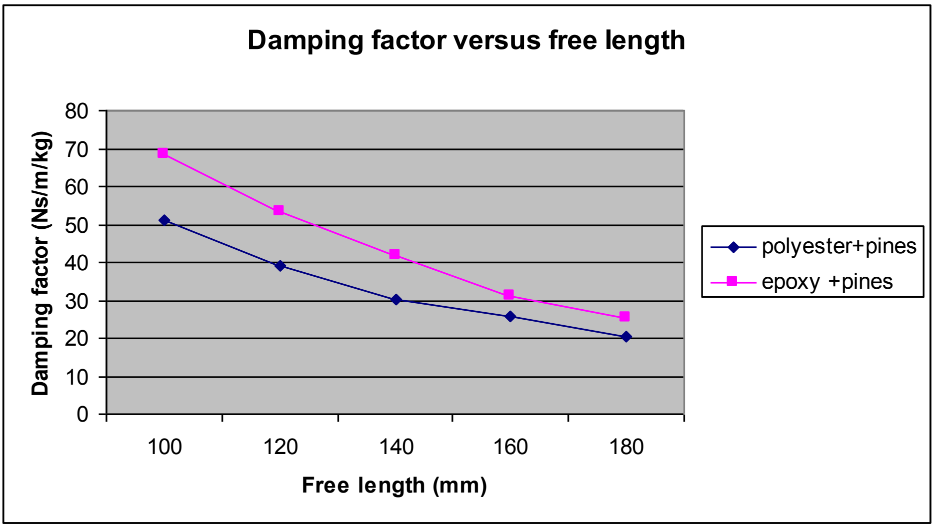

Fig. 8. The damping factor per unit mass versus samples free length

In Fig. 8 and 9 there are presented the damping factor and eigenfrequency variation versus the bars free length.

The presented material from this paper can be used for making furniture parts, in-house decorations, reinforcing the boats floors, inner masks for covering pipes or cables or to make marts for the automotive industry like the examples presented in [18].

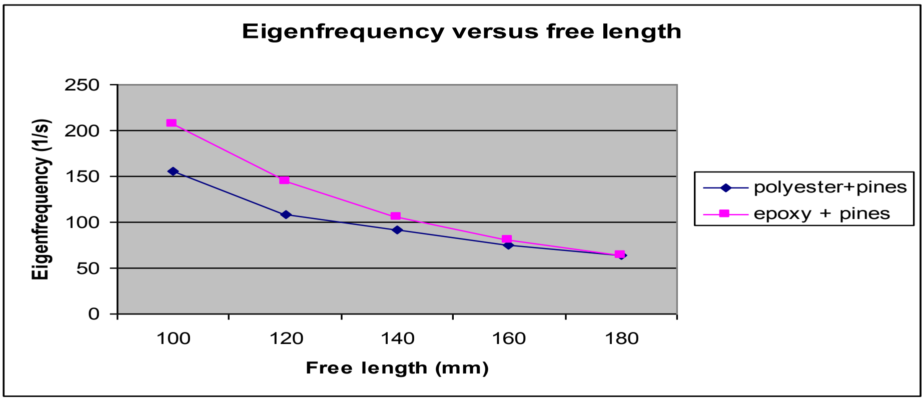

Fig. 9. The eigenfrequency versus samples free length

3 Conclusions

In this paper some new original composites are moulded and manufactured at the room temperature. There are used two different matrices: polyester and epoxy ones. The reinforcement is compound of sheets of paper and on those sheets of paper there are placed, side by side, needles from tree firs. Then a plate is obtained in the end and some samples are cut from this plate, with the next dimensions: 200 mm free length, 8 mm thickness and 25 mm width. For those new created materials, the dynamic behaviour is studied and some dynamic mechanical parameters are determined. There is used the sample experimental procedure described in [17].

From the table 1 and Fig. 8 and 9, we can extract the next conclusions:

- the damping factor per unit mass and per unit length decreases with the bars free length increase, and the correlation between these parameters is exponentially
- the eigenfrequency decreases with the sqare of the samples free length
- the dynamic stiffness for the polyester samples has high variations which means that there are deffects in the sample layers (it may also suggest that the reinforcement sheets did not joined well with the polyester resin applied on them); the same conclusion can be extracted from the high variations of the Young modulus values
- the samples with epoxy matrix have increased mechanical properties (dynamic stiffness and Young modulus)
- the samples with epoxy matrix have small variations for the dynamic stiffness and Young modulus which suggest that there are not deffects in the samples structure and also the reinforcement sheets joined very well after the moulding process
- for the samples with epoxy matrix there are determined the mean values for the dynamic stiffness and Young modulus: 1.5124 Nm^2 and 1298.6 MPa
- the samples were moulded in the same experimental conditions and we recommend the epoxy resin instead of the polyester one because we obtained increased mechanical properties and the samples do not present deffects in their structure (this can be seen from the small erors obtained between the Young modulus and stiffness values).

The damping factors values investigation show that these factors are different for each type of material and specimen and it is very difficult to obtain a quantitative connection between the factors that influence the damping.

We have observed that the damping factors depend on the samples thickness, width and the mechanical properties for the compound materials. The specimens width determine the area where the air friction acts upon the samples during the free vibrations.

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