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VIBRATION ANALYSIS OF NATURAL FIBER COMPOSITES BEAM UNDER VARIOUS END CONDITIONS USING ANN

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Abstract - *The today's research trend in composite is for the development of composite with natural fibre instead of synthetic fibre. It is because of properties like light weight, low cost, bio-degradability, low environmental impact and ease to manufacture. It becomes necessary to study the vibrational behaviour of composite in addition to mechanical strength and chemical properties for effective utilization in real world applications as they subjected to many types of loading condition and different types of vibration with different configurations. In present work a natural fibre composite beam is manufactured with unidirectional and bidirectional orientation for measurement of transverse vibration with different end configurations. Results are obtained from analytical method and analysis through ANN are compared. The mechanical properties are considered by performing tensile and flexural strength of the beam according to ASTM standards. Jute (bidirectional and unidirectional) and sisal (unidirectional) fiber are taken as fiber component and unsaturated polyester resin / Epoxy is as matrix material.*

Key words: *free vibration, natural fiber, composite material, properties of composite, Neural Network.*

I. INTRODUCTION

Natural fiber composites are attracting the researchers because of advantages that these fibers make available over conventional reinforcing synthetic fiber. Natural fibers possess properties like light weight, low environmental impact, biodegradability and non-abrasive characteristics. In fact, certain drawbacks like poor moisture resistance, lower stability, hydrophilic nature, lower life cycle and poor fire resistance properties create the resistance in use of natural fiber composite. However nowadays new surface treatments are developed which increases mechanical properties of natural fibers makes them available for certain industrial applications. In the light of mechanical and economical properties, there are different type of natural available from different species and different origin. Mechanical properties of various fibers are compared with synthetic fibers. Since glass fiber has occupied more than 90% of market for reinforcement in composite industry, lower mechanical properties and improper (poor) bonding characteristics of fiber with matrix material limited the use of natural fiber. With the development of improved technology mechanical properties of this natural fiber are started improving. Despite that natural fibers are currently facing the problem of poor fire resistance, lack of dimensional stability and hydrophilic nature, which tends to affect the mechanical properties.

The researchers also studied effect of volume fraction of fiber on mechanical properties, which shows increasing trend in mechanical properties of composite as volume fraction of fiber increased up to 50%. After that the mechanical properties of composite shows decreasing trend due to poor adhesion of fiber with matrix material [1].In spite of having lower life cycle compared to synthetic fiber, natural fiber composites are looking like to be superior to glass fiber as they required larger fraction of fiber which tends to reduce the overall weight and also they have less environmental impact compared to glass fiber composites. [2]. The reduction in overall weight improves the fuel efficiency which in turns results in fuel saving [3] and also reduction of cost.

Effect of layering pattern is carried out by different researchers [4, 5]. Various combinations has been studied and compared with glass fiber composite to replace synthetic fibers in as many as possible ways and to promote use of natural fiber composites. Effect of addition of Nano clay is also studied with different layering pattern of glass and coconut sheath to reduce the fraction of glass fiber [6] The research is also on going to study the vibrational behaviour of natural fiber composite beam in addition to other mechanical properties [7]. Different researcher examined free vibration characteristics of natural fiber composite beam with different fiber length [8], with different weightage fraction [9] and analysis of mechanical properties are carried out for various composites [10] to find effect of such parameters. The short length fiber shows better results as they have less surface damage as compared to long fibers and 50% weight shows the higher mechanical properties while better damping properties are achieved with 35% w/w ratio of fiber to matrix. There is some functional relationship between damping and temperature, but there is inverse relationship between first natural frequency and temperature as increased in temperature reduce the natural frequency as increase in temperature will decrease the young modulus and there is a relation between natural frequency and young's modulus [11]. Composites are anisotropic material, so, weightage fraction increases along with initially increase in the transverse, compressive and shear strength takes place but after at certain point starts decreasing [12]. The effect of cut out on the centre of the composite plate has been studied as cut out is commonly used as an access port to connect other appliances [13].

However, for varied shaped structures or system may be analysed with soft computing techniques more effectively. Soft Computing techniques constitute Artificial Neural Networks (ANN), fuzzy logic, machine learning and genetic algorithm [14] etc. Soft computing methods are different from classical computing method, unlike classical computing method it is tolerant of imprecision, an uncertainty, a partial truth to achieve tractability, an approximation, robustness, decreases solution cost and a better relation with reality [15]. On over all, ANN has a benefits of parallelism, high speed evaluation, less time consumption, optimization to problem, well suited to constrained problem, easy to design, understandable. So, ANN is one of the beneficial method for soft computing technique and also an optional method used to obtain solutions of mathematical form of dynamic systems, represented with the help of ordinary differential equations. [16, 17].

II. EXPERIMENTAL WORK

For testing of mechanical properties, the standard specimens of Jute _epoxy Bi-directional (BD), Jute_polyester Bi-directional (BD), Jute Uni-directional (UD) and Sisal Uni-directional (UD) with 10% w/w ratio of fiber to matrix weight have prepared. To investigate mechanical properties, tensile and flexural test are performed.

2.1 Tensile test

Tensile test is performed using ASTM standard on Universal Testing Machine (UTM) machine. The beam is prepared according to ASTM D638 and ASTM D3039. The Figure 1 shows the standard specimen and the dimensions are given in Table 1. The specimen before and after tensile test shown in Figure 2.

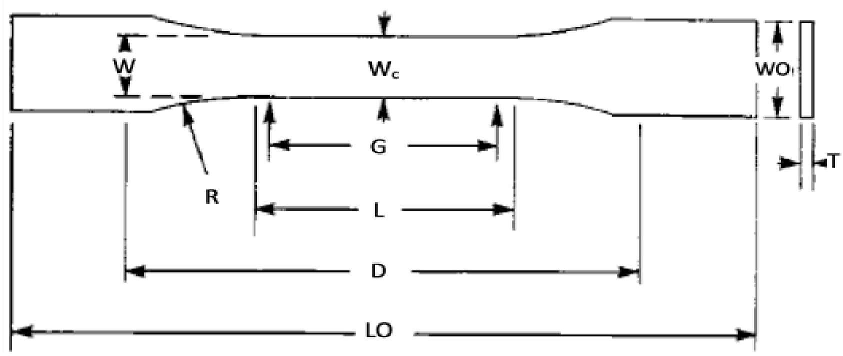
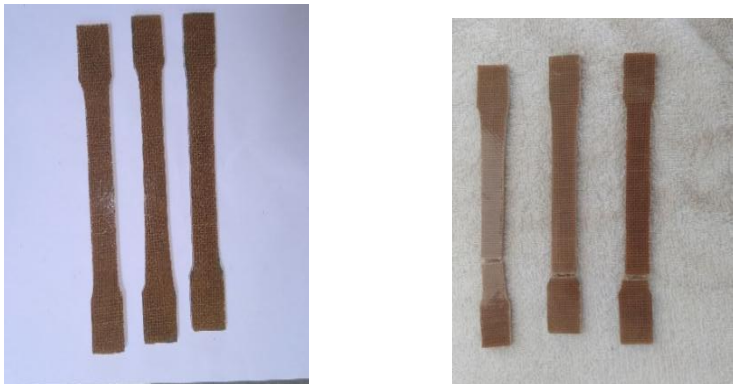


Figure 1: Dimensions of dumbbell shape

Table 1: Dimensions of dumbbell shape

Notation	Meaning	Thickness up to 7 mm (mm)
W	Width of narrow section	13
L	Length of narrow section	57
WO	Width overall	19
LO	Length overall	165
G	Gauge length	50
D	Distance between grips	115
R	Radius of fillet	76



(a) Before (b) After

Figure 2: Test specimen before and after tensile test

In Table 2, the results of tensile test are shown. The Jute _epoxy (BD) shows the greater tensile strength compared to Jute_polyester (BD) and Jute (UD) shows the greater tensile strength compared to Sisal (UD).

Table 2: Result of tensile test

Beam	Max. Load (N)	Max. Extension (mm)	Elongation (%)	Tensile strength (MPa)	Modulus of Elasticity (MPa)
Jute _epoxy(BD)	4310	2.57	2.24	60.3	3315
Jute_polyester(BD)	2580	1.92	1.70	42.2	4240
Jute(UD)	4242	2.80	1.898	44.19	2185
Sisal(UD)	2904	2.22	1.593	24.19	1788

2.2 Flexural test

The flexural test is also performed on UTM machine. The specimens are prepared with standard ASTM D790. The beam prepared with the dimensions of 12.7×127×5 mm^3. The Figure 3 shows test specimen before test and after test while Table 3 shows the results of test

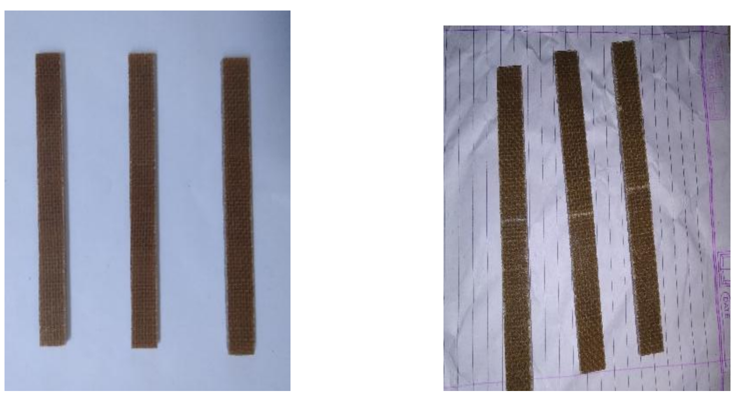


Figure 3: Test specimen before test and after flexural test

III. THEORETICAL ANALYSIS

For theoretical analysis, considering the beam as continuous and free undamped system. Since the beam is made of composite material, so data regarding the physical properties of matrix material and resin like density, young's modulus and poison's ratio of individual material and by weightage or volume fraction of matrix material used for making the composite are to be theoretically calculated and subsequently the natural frequency for respective END condition by theoretical analysis.

Table 3: Flexural test results

Specimen	Width (mm)	Thickness (mm)	Max. force (N)	Flexural strength (MPa)	Flexural strain (%)	Flexural Modulus (MPa)
Jute _epoxy(BD)	12.7	6	272	85.6	2.13	4200
Jute_polyester(BD)	12.7	6	119	37.6	2.05	2030
Jute(UD)	12.7	6	231	72.8	2.33	3900
Sisal(UD)	12.7	6	253	79.8	1.86	6030

For analyzing natural frequency,

3.1 Natural frequency (f)

$$w = \beta^2 \sqrt{\frac{EI}{\rho A}} = (\beta l)^2 \sqrt{\frac{EI}{\rho A l^4}}$$

$$w = 2\pi f$$

There is many possible type of beam configuration. Following Table 6 shows the governing equation for some of different beam configuration. Satisfying equation of Natural Frequency we get different values of β for known length of beam and from these values of β natural frequency at different mode can be found out.

Table 4: Governing equation for different beam configuration

Beam configuration	**Frequency equation**	**Value of βl for**		
		[1st] ***natural frequency***	[2nd] ***natural frequency***	[3rd] ***natural frequency***
Clamped-free	$\cosh(\beta l)\cos(\beta l)+1=0$	1.875104	4.694091	7.854757
Clamped-clamped	$\cosh(\beta l)\cos(\beta l)-1=0$	4.730041	7.853205	10.995608
Clamped -supported	$\tan(\beta l)-\tanh(\beta l)=0$	3.926602	7.068583	10.210176
Supported-supported	$\sin(\beta l)=0$	π	2π	3π

IV. NEURAL NETWORK ANALYSIS

Neural Network Tool of MATLAB R2017a for analysis purpose. Neural Network is prepared consisting of Hidden Layer Size of 10 with 3 input variables and 1 output. Training, Validation and Testing of Network is done and analysis results are obtained. Figure 4 shows Neural Network while Figure 5 shows regression pattern of network at different mode for Cantilever beam and Table 5 shows the results of ANN analysis.

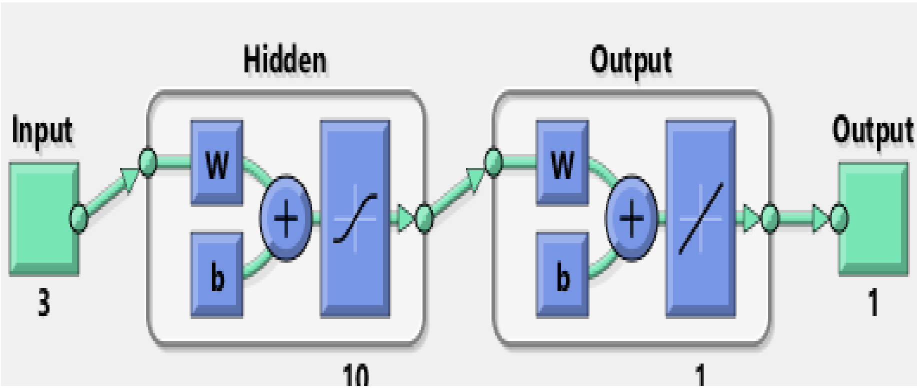
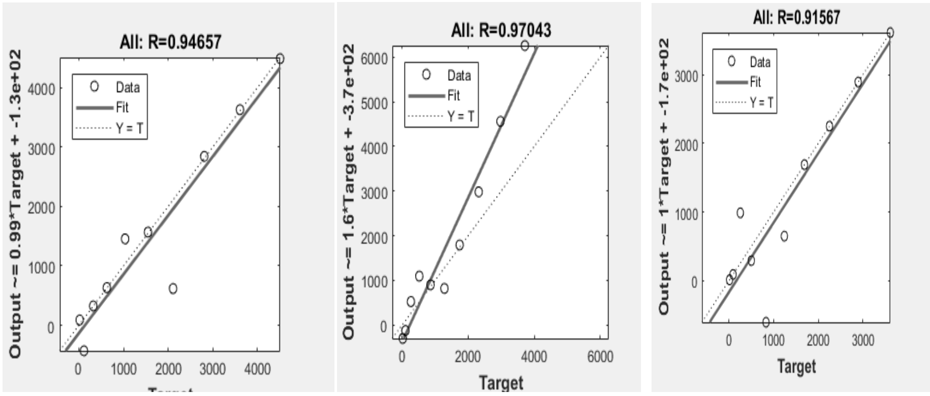


Figure 4: Neural Network (Inputs: βl, E and ρ and Output: Frequency)



(a) Jute _epoxy (BD) (b) Jute (UD) (c) Sisal (UD)

Figure 5: Regression pattern of network at different mode for Cantilever beam

Table 5: ANN results of Natural frequency at various modes

beam	Mode no	Natural frequency (Hz)			
		End configuration			
		Cantilever	Clamped-Clamped	Clamped-Supported	Supported-Supported
Jute _epoxy (BD)	1	15.810782	99.945962	69.127517	44.250578
	2	98.111449	274.97473	224.01748	176.04104
	3	261.32993	538.40213	467.39454	398.24675
Jute_polyester (BD)	1	15.136245	96.317004	66.375365	42.489614
	2	94.861036	265.50153	215.09875	169.23134
	3	265.60859	519.00363	448.83156	382.39229
Jute (UD)	1	16.293214	103.6735	71.423153	45.648615
	2	102.31193	285.66719	231.52719	183.09182
	3	285.90486	560.74495	483.13516	412.59337
Sisal (UD)	1	17.685556	112.53764	77.555392	49.644342
	2	110.83349	310.21433	251.32294	198.57105
	3	310.33695	608.36897	524.36506	445.55219

V. RESULT AND DISCUSSION

Table 6 shows the comparison of natural frequency obtained by different method namely experiment, analytical and ANSYS. From Table 6, it is clear that cantilever beam configuration have minimum natural frequency for same mode compared to other end configuration, while natural frequencies are maximum for clamped-clamped condition followed by clamped-supported and supported-supported configuration. Jute _epoxy (BD) has natural frequency greater than Jute_polyester (BD) while Sisal (UD) has natural frequency greater than Jute (UD) for same mode.

Jute _epoxy (BD) possess maximum tensile strength of 60.3 MPa with maximum elongation of 2.24 % (2.57 mm), followed by Jute_polyester (BD) with tensile strength of 42.2 MPa and maximum elongation of 1.70 % (1.92 mm) and Jute (UD) possess maximum tensile strength of 44.19 MPa with maximum elongation of 2.80 % (1.898 mm), followed by Sisal (UD) with tensile strength of 24.19 MPa and maximum elongation of 2.22 % (1.593 mm).

Table 6 Comparison of results obtained by different methods

END Configuration			Cantilever			Clamped-Clamped			Clamped-Supported			Supported-Supported		
Mode			1	2	3	1	2	3	1	2	3	1	2	3
Natural frequency (Hz)	Jute_Epoxy (BD)	Analytical	15.659	98.131	274.769	99.639	274.658	538.440	69.128	224.017	467.395	44.251	176.997	398.247
		Neural Network	15.811	98.111	261.330	99.946	274.974	538.402	69.128	224.017	467.395	44.251	176.041	398.247
	Jute_Polyester (BD)	Analytical	15.136	94.858	265.606	96.317	265.502	520.488	66.375	215.099	448.786	42.489	169.950	382.391
		Neural Network	15.136	94.861	265.609	96.317	265.502	519.004	66.375	215.099	448.832	42.490	169.231	382.392
	Jute (UD)	Analytical	16.293	102.108	285.905	103.678	285.792	560.266	71.448	231.537	483.084	45.736	182.938	411.615
		Neural Network	16.293	102.312	285.905	103.673	285.667	560.745	71.423	231.527	483.135	45.649	183.092	412.593
	Sisal (UD)	Analytical	17.686	110.833	310.337	112.538	310.214	608.143	77.554	251.323	524.366	49.644	198.571	446.790
		Neural Network	17.686	110.833	310.337	112.538	310.214	608.369	77.555	251.323	524.365	49.644	198.571	445.552

VI. CONCLUSION

Due to comparative properties like light weight, low cost, good mechanical properties, low environmental impact, less energy requirement, safety in manufacturing and bio-degradability natural fibres are now become the major area for research in composites to replace the synthetic fiber. So now it is necessary to study the vibrational characteristics of composite beam with the study of mechanical properties. Here analytical modelling is presented considering the transverse isotropy, which gives an idea about nature frequency of composite beam. Mathematical modelling is also done in ANN tool of MATLAB R2017a to verify the validity of mathematical modelling. Natural frequency obtained by mathematical modelling is supported by Neural Network Analysis result. It also gives an idea about natural frequency of beam.

Results shows that Jute_Epoxy (BD) possess higher tensile strength, modulus of elasticity higher impact strength and comparative flexural strength which enable it to available for various applications than Jute_Polyester (BD). Similarly, Jute (UD) possess higher tensile strength, modulus of elasticity higher impact strength and comparative flexural strength which enable it to available for various applications than Sisal (UD).

These composites are preferably used in household applications aerospace structure application, high speed turbine machinery and in automobile applications such as bumper of car, side panel back panel of door, roof and dash board in place of glass fiber composite.

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