A. B. VINAYAKA PATIL
PRASHANTH BANAKAR
and
LOKESHA. K

Experimental investigations of vibration characteristics of jute fibre polymer composites

Natural fibre reinforced polymer (NFRP) is a renewable, recyclable and biodegradable polymer found in many industrial applications. Few among many naturally available plants which are categorised under natural fibre reinforced polymer such as jute, pineapple, cotton hemp, coir, sisal, banana, bamboo, ramie and kenaf. These plants are found to be rich in lingo cellulosic fibres and hence they are often used as reinforcement for composites. Among these plants, jute is the most commonly available natural fibre in third world countries and recognised as the second most important fibre in the world. It has found its vast applications as a decorative and furnishing material. In the present study, an effort has been made to investigate one of the critical and most influential vibration characteristics of one such natural reinforced polymer, jute fibre polymer composite. In this investigation, the jute fibre has been fabricated with unsaturated polyester resin and maleic anhydride and the experimental trials were conducted for varying percentages of maleic anhydride using Fast Fourier transform. The damping factor for each trial was computed and analysed to retrieve the vibration characteristics of jute fibre polymer.

Keywords: Natural fibre reinforced polymer, jute, damping factor, polyester resin, maleic anhydride.

1.0 Introduction

Wood-based materials are extensively used in the application of decoration and furnishing due to its availability and cost. However, the use of this material due to rapid growth in the demand is driving us towards depletion of forest reserve and affecting environment. It is always appreciated to have an alternate source to support the demand and create a sustainable business development. In this context, NFRP composites have a good strength as a alternate in many applications for wood-laminated material. It is accepted in wide range of applications due to its properties such as high specific strength, light weight, biodegradability, low cost as compared to artificial fibre reinforced polymer like glass and carbon, renewability and recycling. Jute, sisal, coir, pineapple are few popular natural composite reinforced materials which are greatly influenced the acceptance as an alternate due to low raw material cost. Jute composite, stands tall as an ideal substitution for wood by considering its building structure, which consists of ultimate cells as bundled in which each fibre have micro fibrils as spiral orientation. The jute-coir composite boards are proved that they are huge potential and superior than plywood boards so they are used in doors, interiors, windows besides in transportation sector as backings for backrest and seat in buses and sleeper berth backing in railway coaches. For plywood industry, a wood supply have been stopped indigenously due to increasing in cost of land for imported plywood veneers, so that the jute composite boards have very good customer value without compromising the properties. There have been enormous research activities around the world, to investigate, characterize and evolve newer and better possible natural fiber composite to cater wide range of industrial applications. An extensive review was performed by A. Treviso et al., to explore the damping properties in composite materials [1]. The review stressed on the need of finer input parameters for better performance characteristics and establishment of prediction models to translate the physical observations into mathematical terms. Fiber–matrix interfacial adhesion in natural fiber reinforced composite with variety of coupling agents was reviewed and presented by Yanjun Xie et al. [2]. The review summaries, trialkoxysilanes is the most commonly used coupling agent for NFRP composites. The review also shows that due to this kind of coupling agent improves some properties such as mechanical and also performance in outdoor environment. Vincenzo Fiore et al., evaluated the damping properties of natural fiber reinforced composite, exposed to salt-fog environment for a predefined time frame [3]. The study revealed that all natural fiber reinforced polymer composites exhibit decrease in storage modulus and glass transition temperature and increase in loss factor peaks when exposed

Mr. A.B. Vinayaka Patil, Assistant Professor, Department of Mechanical Engineering, Bapuji Institute of Engineering and Technology, Davanagere 577004, Dr. Prashanth Banakar, Principal, Jain College of Engineering and Technology, Hubballi 580032 and Mr. Lokesha. K, Assistant Professor, Department of Mechanical Engineering, M.S. Ramaiah Institute of Technology, Bangalore 560 054. Karnataka., India. E-mail: abvinayakapatil@gmail.com / prashanthbanakar77@gmail.vom / lokesha.krish@msrit.edu

salt-fog environment for a period of 60 days. Dynamic mechanical properties of hybrid sisal/jute fiber reinforced epoxy composite were evaluated by M. K. Gupta et al., under a range of temperature [4]. The hybrid composite has shown that the minimum coefficient of friction and specific wear rate and also with maximum loss modulus and storage modulus.

Murugan Rajesh et al., performed experimental examination to evaluate and compare the mechanical properties of conventional and braided yarn fabric composite [5]. The braided yarn fabric reinforcement shown increase in mechanical properties as compared to conventional woven fabric. The braided yarn fabric composite exhibits more improvement in impact property compared to tensile and flexural properties. S. Senthilrajan et al., carried out experimental investigation of vibration characteristics of jute composite by the effect of ageing [6]. The study involves the influence of several input parameters such as fiber length, weight percentage, normal water, seawater and room temperature. The evaluation revealed that the ageing significantly affected the bonding between fiber and matrix which lead to decrease in natural frequency of the composite. C. Y. Wei et al., employed resonance technique to evaluate the damping properties and stiffness of glass fibre reinforced polymer composites and optical cables [7]. The study reveals that the specimen dimensions have no influence on stiffness and damping within a large range, however a proper range of specimen weight and dimensions are necessary to achieve a good resonance response. Yashwant S Munde et al., experimentally investigated the influence of fiber weight fraction on damping and acoustic characteristics [8]. Vibration and acoustic characteristics of the polypropylene will be altered significantly with increasing in load on fibre. The damping property of the composite becomes worse at higher fiber content whereas the acoustic property such as sound absorption coefficient and transmission loss will be enhanced with incorporation of fibers at higher fraction. K.T.B.Padal et al., investigated that the properties of mechanical and thermal of virginal jute nano-fibre and jute fibre composite with resin as epoxy [9]. In the comparative study, among these two composites, the nanofiber composites exhibit improved storage modulus, loss modulus, thermal stability and shortfall in mechanical loss factor. An experimental investigation was carried out to determine the free vibration characteristics of epoxy polymers reinforced with phoenix sp. fibers and nano-clay by G Rajesh Kumar et al., [10]. The experimental study reveals that there is an enhancement in the natural frequency of the epoxy polymer of up to 240%. S. Prabhakaran et al., executed an experimental approach to compare acoustic and vibrational characteristics of glass fibre reinforced composite with flax fibre reinforced composite [11]. The study revealed that there is a considerable enhancement of sound absorption of up to 25% and damping of up to 51% in the flax fiber reinforced composite as compared to glass fiber reinforced composite. An experimental comparative study by Ajith Gopinatha et al., on jute fibre reinforced polymer composite with epoxy and polyester resin matrices proves that the JFRP composite with epoxy resin exhibits better mechanical properties than the JFRP composite with polyester resin [12]. The two different combinations were tested for tensile, flexural and impact strength under predefined weight fraction percentage of fibre and resin as 18:82. M Jawaid et al., explored the tensile and dynamic mechanical characteristics of oil palm epoxy hybrid composite with jute fibers [13]. The experimental investigation reveals that the tensile strength was found to be greatly influenced by the ratio of jute fibers and it exhibits lower damping along with good fiber/matrix adhesion. The evolve of this kind of hybrid composites provide an opportunity to compete with the synthetic composites and to be a part of aerospace, construction, and automotive applications. S. Ramakrishnan et al., investigated the effect of variation of weight percentage of nano-clay and NaOH concentration on free vibration characteristics and dynamic mechanical properties of jute fiber reinforced epoxy composite [14]. It was observed that increase in natural frequency of hybrid composite due to the existence of superior interfacial bonding between jute fiber and epoxy resin and also confirms a positive shift in glass transition temperature. The review provides an insight of dearth of information for natural fiber reinforced composites combined with different coupling agent and fiber orientations. In the present work, an experimental attempt is made to examine the vibration characteristics natural fiber reinforced composite with several combinations of fiber orientation and coupling agent.

2. Experimental procedure

The jute fibre reinforced polymer composite is prepared by using hand layup fabrication process. The sample building process includes jute fibre (reinforcement), methyl ethyl ketone peroxide (hardener), cobalt naphthalene (accelerator) and maleic anhydride (coupling agent). In this work, experimental test samples were fabricated with different combinations of fibre shape, fibre orientation and percentage of coupling agent. The details of input parameter and their levels are presented in the Table 1.

TABLE 1: INPUT PARAMETERS

	Input parameter	Levels
1	Fibre shape	1, 2, 3, 4
2	Fibre orientation	30°, 45°
3	Percentage of coupling agent	0%, 3%, 6%

Each sample was subjected to vibration testing procedure to acquire the vibration data. The vibration testing procedure includes the test rig to hold the sample, accelerometer (motion transducer) to pick-up the vibrations, impact hammer to induce load for generating natural frequency and FFT to receive and record the vibration data from accelerometer. In

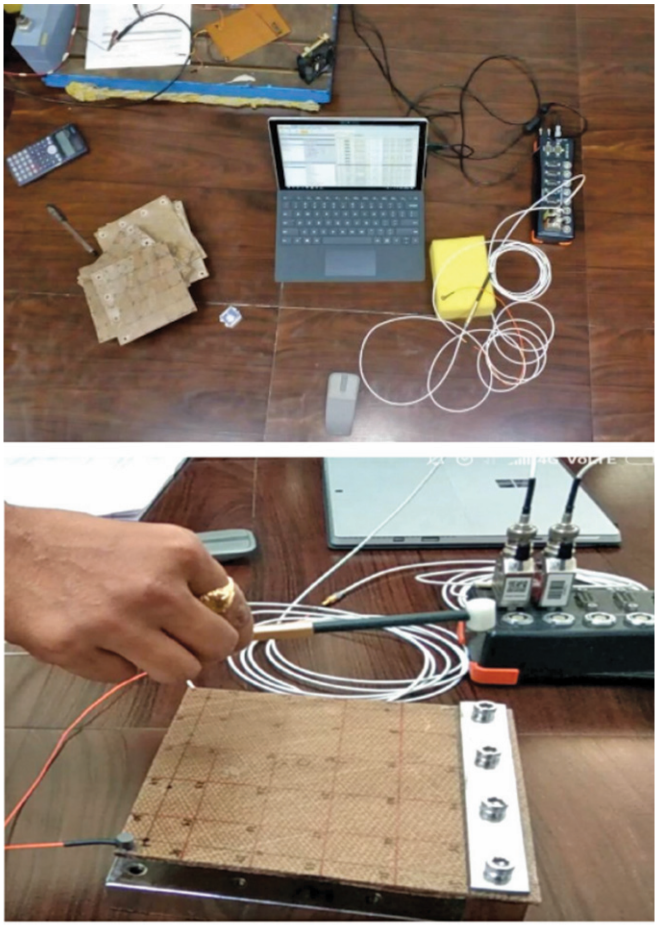

Fig.1. Details of experimental set up

this process, an impact force was applied on to the sample (structure) through impact hammer with suitable indenter, the generated vibration signals were picked up by the motion transducer. For estimation of frequency response function, the signals are used which are digitized and processed by FFT analysis system. This procedure is repeated for several times to get excitation and response combinations. In disc memory of the FFT analysis system, all frequency response functions are stored. After the first phase investigation, the FFT analysis system will determine the modal characteristics such as mode shapes and system poles. Fig.1 shows the experimental set up. The natural frequency and damping ratio for each trial was recorded and presented in the Table 2.

TABLE 2: EXPERIMENTAL OUTPUT DATA

Experimental trial No.	Orientation of fibre	Percentage of coupling agent	Frequency (Hz)	Damping Ratio %
1	30°	0%	528	2.27
2	30°	3%	604	2.38
3	30°	6%	703	3.66
4	45°	0%	545	2.40
5	45°	3%	635	2.63
6	45°	6%	734	4.67

3.0 Results and discussions

When NFRP composite materials are fabricated, the fibres are always oriented along with direction of load. In case, the load direction is varied and non-parallel to the orientation of fibres, it is very important to investigate the mechanical behaviour of laminate composite. We are selected that ±30º and ±45º fiber orientation to investigate behaviour in this study. As discussed earlier, specimens are prepared with different fibre orientations under the same conditions.

The data acquired in the experimental trials carried out on jute fiber reinforced composite material with varying jute fiber orientation and coupling agent was being analysed to investigate the vibration characteristics. Fig.2 shows variation plot of percentage of coupling agent and damping ratio. The variation exhibits there was a drastic increase of percentage of damping ratio of up to 53% when the coupling agent increases from 3% to 6%. However, the increase in percentage of damping ratio was found to be minimum of up to 4.85% when the coupling agent increased from 0% to 3%.

The plot also reveals that the damping ratio is more for 45° fiber orientation than 30° orientation. The increases of up to 23% of damping ratio was documented when the orientation changed from 30° to 45° from this investigation. Fiber axes is not parallel to the direction of load leads to the off axis pulling of fibres and decrease the stress concentration may cause the failure of fibre laminates delay. In study of 30° and 45° fibre orientations, the displacement of JFRP laminates of 45° fibre orientation is more when compared to the JFRP laminates of 30° orientations because of the non-parallel axis loading and maximum strength of fiber pull out before failure.

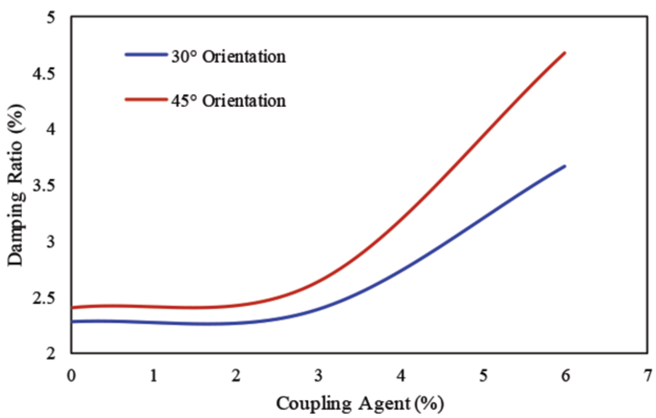

Fig.2: Plot of coupling agent and damping ratio

4.0 Conclusions

The experimental study on the effect of orientation and coupling agent on vibrational behaviour of jute fibre reinforced polymer composite was carried out. The investigation revealed that fibre orientation and percentage of coupling agent significantly influences the different properties of composites. The percentage of damping ratio increases with the increase in the percentage of maleic anhydride (coupling agent). The maximum increase in percentage of damping ratio was found to be 77.5% with 45° of fiber orientation and 6% of coupling agent combination. The composite also exhibits the increase of percentage of damping ratio of up to 5.4% without coupling agent, with variation in fiber orientation from 30° to 45°. The combined effect of coupling agent and the fiber orientation provides a notable enhancement of percentage of damping ratio. This improved property in the jute fiber reinforced composite provides more opportunities in the application.

References

[1] A. Treviso, B. Van Genechten, D. Mundo, M. Tournour, (2015): Damping in composite materials: Properties and models, *Composites Part B*, 78, 144-152.

[2] Yanjun Xie, Callum A.S. Hill, Zefang Xiao, Holger Militz, Carsten Mai, (2010): Silane coupling agents used for natural fiber/polymer composites: *A review, Composites: Part A*, 41, 806–819.

[3] Vincenzo Fiore, Carmelo Sanfilippo, Luigi Calabrese, (2020): Dynamic Mechanical Behaviour Analysis of Flax/Jute Fiber-Reinforced Composites under Salt-Fog Spray Environment, Polymers, 12, 716.

[4] M K Gupta, R K Srivastava, (2016): Tribological and dynamic mechanical analysis of epoxy based hybrid sisal/jute composite, *Indian Journal of Engineering & Materials Sciences*, Vol. 23, 37-44.

[5] Murugan Rajesh, Jeyaraj Pitchaimani, (2017): Mechanical Properties of Natural Fiber Braided Yarn Woven Composite: Comparison with Conventional Yarn Woven Composite, *Journal of Bionic Engineering*, 14, 141-150.

[6] S. Senthilrajan, N. Venkateshwaran, (2019): Ageing and Its Influence on Vibration Characteristics of Jute/Polyester Composites, *Journal of Polymers and the Environment*, 27, 2144-2155.

[7] C. Y Wei, S. N. Kukureka, (2000): Evaluation of damping and elastic properties of composites and composite structures by the resonance technique, *Journal of Materials Science*, 35, 3785-3792.

[8] Yashwant S Munde, Ravindra B Ingle, I Siva, (2019): Vibration damping and acoustic characteristics of sisal fibre–reinforced polypropylene composite, *Noise and Vibration Worldwide*, Vol. 50(1), 13-21.

[9] K.T.B. Padal, S.Srikiran, and P. Surya Nagendra, (2014): Dynamic Mechanical and Thermal Properties of Jute Nano Fiber Reinforced Polymer Composite, 5th International & 26th All India Manufacturing Technology, Design and Research Conference, IIT Guwahati, Assam, India, PP 128-1 to 128-6.

[10] G. Rajesh Kumar, V. Hariharan, S. S. Saravanakumar, (2021): Enhancing the Free Vibration Characteristics of Epoxy Polymers Using Sustainable Phoenix Sp. Fibers and Nano-Clay for Machine Tool Applications, *Journal of Natural Fibers*, Vol.18, No. 4, 531-538.

[11] S. Prabhakaran, V. Krishnaraj, M. Senthil kumar, R. Zitoune, (2014): Sound and Vibration Damping Properties of Flax Fiber Reinforced Composites, Procedia Engineering, 97, 573-581.

[12] Ajith Gopinath, Senthil Kumar. M, Elayaperumal A, (2014): Experimental Investigations on Mechanical Properties Of Jute Fiber Reinforced Composites with Polyester and Epoxy Resin Matrices, Procedia Engineering, 97, 2052–2063.

[13] M. Jawaid, H.P.S. Abdul Khalil, Azman Hassan, Rudi Dungani, A. Hadiyane., (2013): Effect of jute fibre loading on tensile and dynamic mechanical properties, *Composites Part B*, 45, 619-624.

[14] S. Ramakrishnan, K. Krishnamurthy, G. Rajeshkumar, M. Asim, (2021): Dynamic Mechanical Properties and Free Vibration Characteristics of Surface Modified Jute Fiber/Nano-Clay Reinforced Epoxy Composites, *Journal of Polymers and Environment*, 29, 1076-1088.