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# VIBRATIONAL BEHAVIOUR OF SANDWICH PLATE WITH CORE AS JUTE REINFORCED POLYMER MATRIX COMPOSITES

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## ABSTRACT

*From the last few years, Jute fibers are being looked at as an alternative reinforcement material in the development of composites in a variety of engineering fields. Jute fiber has some exceptional properties such as bio-degradability, low cost, moderate mechanical properties. These properties along with its easy availability have made it suitable to use as a reinforcement material in the ongoing development of composite containing polymer matrix. Hence, Jute fibers can replace commonly used synthetic fiber along the lines of Kevlar, glass fiber etc., in composite material. Also, matrix used here is hybrid polymer matrix which is a mixture of Cashew Nut Shell Liquid and General Purpose Resin instead of pure synthetic matrix. This combination of reinforced composite can be utilized in diverse engineering applications. In this work, Jute fiber reinforced Hybrid resin (CNSL and GP) composites are fabricated by using hand lay up technique. Volume percentage of jute fiber in reinforcement (3%, 6%, 9%), specimen thickness (2mm, 3mm, 4mm) and fiber length (30mm, 100mm, 350mm) are the parameters varied in the respective mold dimensions. The experimental plan was developed according to TAGUCHI's Design of Experiments. The testing is performed using cantilever fixture. By applying impact, the response of the system is analyzed by utilizing "DEWEsoft" software. Using the ANNOVA technique, influence of different vibration frequencies was investigated.*

***Keywords:*** *ANNOVA, Cashew Nut Shell Liquid (CNSL), Hybrid Resin, Jute Fiber, Sandwich Plate, Vibration*

## INTRODUCTION

Jute fibers are long vegetable fibers and these can be strengthened to coarse threads by spinning them. Jute is one of the cheapest natural fibers and is next to cotton as far as its annual production is concerned. Raw jute is off-white to brown in color. Jute fibers are primarily comprised of cellulose and lignin. It comes under the purview of bast fiber category (fiber obtained from the phloem of the plant). Jute fibers are extensively used in textile, agriculture and construction sectorCNSL is derived from the cashew nut shell as a byproduct in the process of eliminating the cashew kernel from the cashew nut. The cashew tree is cultivated majorly in south India and parts of Orissa. It is also cultivated globally in areas such as East Africa, South and Central America etc.

The natural fiber reinforced resin composites are gaining importance due to its biodegradable nature, easy availability and are comparatively ecofriendly. Its moderately appreciable mechanical properties bring wider spectrum and potential for research and development in different engineering domains. Currently, natural fiber reinforced composites are being used in areas related to packing and automotive industries [1]. In alignment with above, response due to vibration on the jute fiber reinforced sandwich plate was analyzed. Sandwich plates, a structured composite material, is used to widen its ongoing study on potential applications in engineering structures including ships, aerospace and automotive applications.

Based on the requirement of test plan, mold dimensions were decided as 350mm×30mm with variable thickness. Using the TAGUCHI's Design of Experiments technique, different configurations of specimens were concluded based on three parameters namely fiber length, fiber volume and the thickness of the specimen.

Attempt was made to analyze the vibrational effects of Natural fiber reinforced composites based on the impact at equally distributed points. The primary objective of this experiment was to find out the variations in the modal frequencies and the damping factor due to changes in the defined parameters. Nine Specimens with respect to derived combinations were prepared using hand lay-up technique. Testing was performed using cantilever fixture and "DEWEsoft (Ver7.11)" software.

## LITERATURE SURVEY

Natural fiber based polymer composites have noticed exceptional research during the last few years due to its biodegradable nature.

Observations of Boopalan et al [2] indicated that mechanical strength (tensile, flexural, impact) increases up to a certain limit with increase in fiber ratio and follow a decreasing trend onwards, in the case of epoxy resin. This is considered to be due to interfacial bonding of fiber and matrix. Studies by Prasad et al [3] concluded that load carrying capacity of the composite is in direct proportion with its fiber volume.

Hybrid jute-sisal reinforced polyester laminate was analyzed by Akash et al [4] for transverse vibration. In this study average damping factor was found to be higher than jute laminate due to its flexural stiffness and change in the fiber angle. Joseph et al [5] examined the result of bonding of interfacial layers on the mechanical properties of short sisal fiber reinforced composites and stated that there is increasing course in properties with fiber volume content. Kumar et al [6] experimented to compare free vibration characteristics of short sisal fiber and short banana fiber. Appreciable difference in natural frequency was found for 3mm fiber length. With higher fiber percentage the frequency were found to collect. Natural frequency was found to be maximum at higher thickness.

## FABRICATION AND EXPERIMENTAL SET UP

Based on TAGUCHI's Design of Experiments, nine different varieties were designed for experimentation and analysis. The combinations of each specimen based on TAGUCHI L9 array are as given in TABLE I.

Raw Jute fiber along with CNSL and General purpose resin were procured from local sources. Mold dimensions of 350mm×30mm were fabricated using Steel sheets. Mold section was an open "C" type to enable easy placement of the fiber and to help in pouring. Clay was applied on both the ends to restrict the flow of resin mixture as well as to hold the inserted fibers tensed and intact.

TABLE I. TAGUCHI L9 ARRAY

| Sr. No. | Thickness of Mold (mm) | Fiber Volume (%) | Fiber Length (mm) |
|---|---|---|---|
| 1 | 2 | 3 | 350 |
| 2 | 2 | 6 | 100 |
| 3 | 2 | 9 | 30 |
| 4 | 3 | 3 | 100 |
| 5 | 3 | 6 | 30 |
| 6 | 3 | 9 | 350 |
| 7 | 4 | 3 | 30 |
| 8 | 4 | 6 | 350 |
| 9 | 4 | 9 | 100 |

Mold releasing agent (silicon spray) was used to ensure that the hardened specimen does not stick to the facing surfaces of the mold. With reference to the above table, required amount of CNSL and GP along with catalyst (Methyl Ethyl Ketone Peroxide) and hardener (Cobalt Napthanite) was taken. After mixing thoroughly, this mixture was poured cautiously, to make sure there is uniform distribution of the mixture in the mold. Resin mixtures were obtained based on the calculation of volume percentage of CNSL-GP Resin, Hardener and Catalyst. Number of fibers and its placement were also configured based on the calculation of volume ratios. Fig. 1 shows the fabricated specimens.

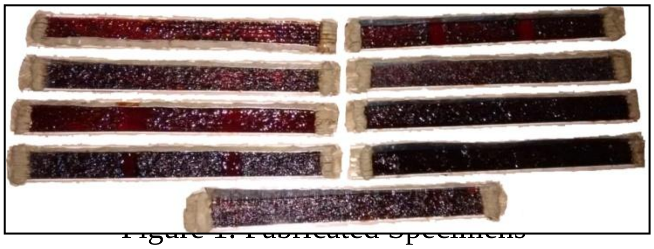


Figure 1. Fabricated Specimens

After gently removing the hardened specimens, sandwich plate structure was prepared by gluing Aluminum sheets on both the largest surface areas of the specimen. Fig. 2 presents a schematic view of the sandwich plate. Structure was marked at 10 equal divisions of 30mm each, leaving 50mm for fixture.

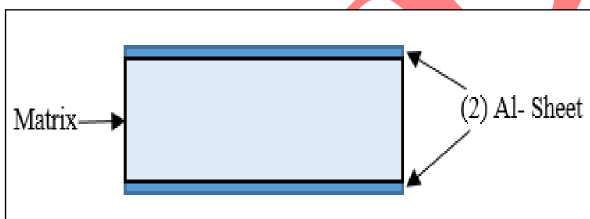



Figure 2. Schematic View of Sandwich Plate

Experiment was carried out on each structure to determine the vibrational behavior. One end of structure was held in a fixture and the other end was kept free to resemble as a cantilever system. In this experimental setup, miniature accelerometer and impact hammer were connected to data acquisition system. 'DEWEsoft' (Ver7.11) Software was used to generate output from four channel DAQ system. Readings were obtained by exciting at each division using impact hammer. Data obtained was normalized and first three natural

Frequencies and associated damping factors for each structure were retrieved with the help of 'DEWEsoft' software

## RESULTS AND FINDINGS

Vibrational analysis was done using the cantilever system. Fig. 3 illustrates the experimental setup of a typical structure. Values of natural frequency and damping ratio of the system were obtained for the nine specimens under consideration.

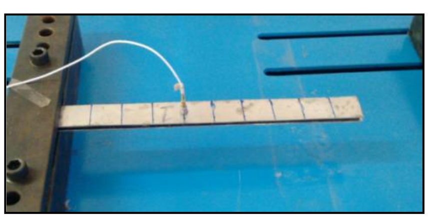


Figure 3. Experimental Setup

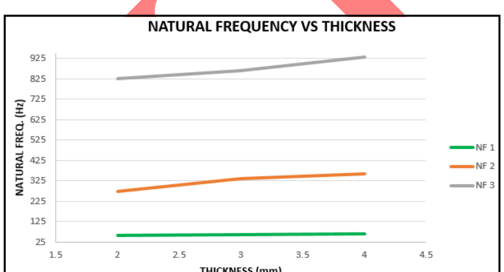
Table II describes the results of the experiments performed on the nine structures. Based on the above results, ANNOVA technique was performed using Minitab software to obtain and analyze plots.

TABLE II. EXPERIMENTAL RESULTS

Fig. 4 indicates the first three natural frequencies with respect to variation in thickness. It can be seen that there is general increase in the natural frequencies with increase in thickness. Moreover, increase in fiber volume increases natural frequencies of the system. This is shown in the Fig. 5. However, as it can be seen from the Fig. 6, a continuous fiber has higher natural frequency than a discontinuous fiber. With increasing discontinuity of fibers, the natural

| **Sr. No.** | **Thickness** | **Fiber Volume** | **Fiber Length** | **Natural Frequency 1** | **Natural Frequency 2** | **Natural Frequency 3** | **Damping Factor 1** | **Damping Factor 2** | **Damping Factor 3** |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 350 | 57.80 | 311.48 | 826.71 | 0.029 | 0.0394 | 0.0163 |
| 2 | 3 | 3 | 100 | 58.81 | 294.02 | 787.56 | 0.0473 | 0.0468 | 0.0524 |
| 3 | 4 | 3 | 30 | 57.69 | 323.56 | 837.57 | 0.0679 | 0.0467 | 0.0373 |
| 4 | 2 | 6 | 100 | 51.82 | 237.69 | 715.68 | 0.0301 | 0.0512 | 0.0701 |
| 5 | 3 | 6 | 30 | 60.96 | 344.90 | 932.87 | 0.0417 | 0.0598 | 0.0469 |
| 6 | 4 | 6 | 350 | 67.51 | 367.13 | 989.17 | 0.0299 | 0.0520 | 0.0194 |
| 7 | 2 | 9 | 30 | 55.50 | 267.51 | 943.77 | 0.0599 | 0.0702 | 0.2428 |
| 8 | 3 | 9 | 350 | 61.66 | 364.69 | 881.34 | 0.0225 | 0.0462 | 0.0238 |
| 9 | 4 | 9 | 100 | 67.25 | 387.68 | 967.33 | 0.0429 | 0.0380 | 0.0132 |

frequency is declining with an exception of an increase at 100mm fiber length.



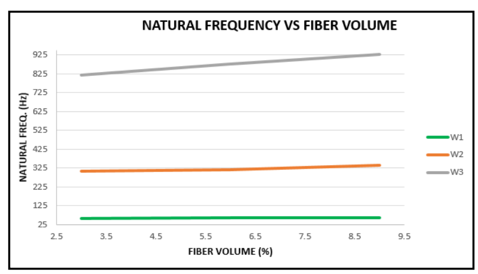




Figure 6. Natural Frequency Vs Fiber Length Figure 7. Main Effect Plot for Damping Factor 1

Fig. 7 and Fig. 8 mention the main effect plots of the three varying parameters with respect to Damping factor and first Fundamental frequency respectively. As the thickness of specimen increases, the damping factor first decreases and then increases further. Fiber volume also shows a similar trend. However, with increase in discontinuity of fibers, damping factor increases steadily.

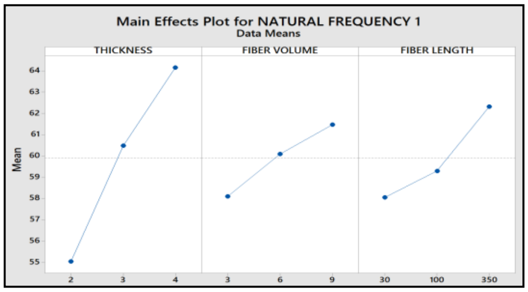



Figure 8. Main Effect Plot for Natural Frequency

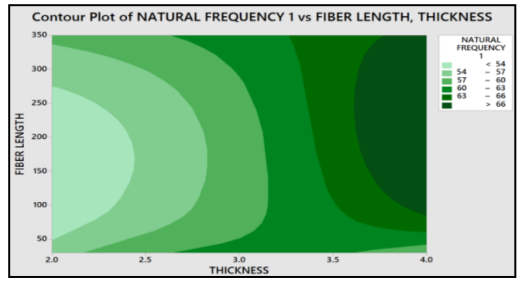



Figure 9. Contour Plot for Natural Frequency 1

Fig. 9 indicates the contour plot of the Natural frequency 1 vs Fiber length and thickness. It aligns with previous observation that natural frequency increases proportionally along thickness and decreases with increase in discontinuity. It can be inferred that maximum thickness with continuous fibers gives larger frequency of vibrations. The regression equation for this is:

$$\text{Natural Frequency 1} = 40.76 + 4.56\ \text{Thickness} + 0.562\ \text{Fiber Volume} + 0.01302\ \text{Fiber Length}$$

## CONCLUSION

Unique combinations of sandwich plate with core as jute reinforced CNSL-GP matrix were studied for vibrational behavior. Natural frequencies along with damping factors were obtained using TAGUCHI's experimental approach. This constellation has ginormous potential in future to replace synthetic fibers. This also is a step forward to implement an eco-friendly product.

## ACKNOWLEDGMENT

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