Modeling And Simulation Of Applied Load On Lenin Fiber Composite Materials Using COMSOL

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Abstract. Nowadays, composite materials become important and very useful due to eco-friendly and have no adverse impact. In this study, fabrication of the natural fiber composite performed using Lenin fiber as reinforcement and epoxy as resin materials. Four samples of laminates if fabricated using different proportions of the fiber and resin. This research article also presents the simulation performed to investigate the effects of the different loads on the different forms of the von Mises stresses developed during the application of the loads. The various forms of the von Mises stress include von Mises stress (Principal stress), layered material von Mises stress, through-thickness von Mises stress, and line graph von Mises stress developed in the laminates. In addition, the influence of different loads on the stress-induced is also investigated and observed that on increasing applied load, von Mises stress also increases.

Keywords: Composite, Simulation, von Mises Stress, Lenin Fiber, Laminates.

1. Introduction
Recently, the demand for the plant fiber composites increased very significantly due to lightweight, biodegradable, no adverse effects on health, abundantly available, less costly. Plant fiber composites can be an alternative to synthetic fiber-based composites due to their less environmental impact [1-3]. In the automobile industry, the demands for lightweight parts are increasing day by day in the manufacturing of various parts such as door, ceiling, bumper, windshield, etc. In addition, the manufacturing of the plant fiber composites is required relatively less effort as compared to the synthetic fiber composites [4]. Many researchers are trying to increase the mechanical properties of the plant fiber by proper selection and addition of the filler and reinforcement materials [5,6]. [7] Investigated to evaluate tensile properties of hybrid natural fiber composite using rules of hybrid mixture method and experimentally. The author has reported that the rules of the hybrid mixture method give higher values of the tensile properties as compared to the experimental method. Whereas [8] reported the fabrication of hybrid composite using areca sheath–jute–glass. The investigation shows the fabricated hybrid composite possesses excellent tensile, flexural, and shear properties due to the addition of high strength jute fiber. Besides, a good fiber bonding and less pull out in the fabricated composites as seen from the SEM images. However, [9-13] carried out investigation on design, fabrication and characterization of different types of composite materials by choosing suitable
reinforcement and the binders. They also studied the properties of various types of reinforcement that includes WC, titanium diboride, silicon carbide, tin etc. and reported that these materials increase the strength of the fabricated composites. Whereas [14-18] conducted investigation to find different mechanical properties of the various types of the composite materials. However, [19] studied the thermomechanical characteristics of jute fiber-reinforced epoxy composites filled with powder of calotropis gigantea stem. The author has reported that the superior improvement of both mechanical and thermal properties due to high filler contents. They also investigated the average fiber full out, distribution nature of filler, voids, and fractured interface. However, [20] investigated to study the performance of jute fiber epoxy composites filled with wood dust filler in terms of biodegradability, water absorption capacity, thermal and mechanical properties. It is reported that the mechanical properties of the fabricated composites are enhanced very significantly due to fine distribution and excellent bonding. Besides this, the thermal properties of the composite also improved due to the presence of coarse redwood dust particles. In this investigation, Lenin fiber composite is fabricated with different proportions of Lenin fiber and epoxy resin. To study the effects of different loading conditions on the strength of the fabricated laminates, simulation has been performed using COMSOL Multiphysics software. This study presents different stresses such as von Mises stress (Principal stress), layered material von Mises stress, through-thickness von Mises stress, and line graph von Mises stress in the laminates for different samples.

2. Materials and Methods

The composite materials in the form of laminates are prepared using hand layup techniques. The required size of the Lenin fiber is cut from the fiber bundle. Fiber mat and resin along with hardener were also weighted in equal proportions. The chosen epoxy and hardener were mixed in the equal weight. In addition, during preparation of resin hardener solution, specific amount of catalyst and accelerator are also added for better joint strength. The prepared solution is kept for 2 to 3 hours. First, one layer of wax is applied on the glass plate for easy removal of the laminates and kept for 10 min. A thin layer of the prepared solution is applied with the brush and is kept for few minutes to dry. Next, one layer of Lenin fiber mat was placed and followed by application of another layer of the epoxy hardener solution. In this way, total three layers of epoxy hardener solution and fiber mat were placed. On the top of the last layer, again waxing is done which serves to ensure a good surface finish. Finally, a releasing sheet was placed on the top and a light rolling was performed. Then the mold is heated to 80°C for 24 hrs. to allow sufficient time for curing and subsequent hardening. The entire experimental procedure as shown in figures 1. When the prepared specimen is cooled it is de-molded and then the specimen is cut to the required dimensions for further testing and characterization.
3. Modeling and simulation of composite materials with COMSOL

3.1. Geometric model

In this study, the layerwise theory is used for the modeling i.e. layered shell interface. This theory has a degree of freedom which is distributed in the thickness direction. It predicts correct inter-laminar stresses and is suitable for delamination and detailed damage analysis. It supports the non-linear material model and does not require a shear correction factor. The composite laminate considered has 3 layers with 0/90/0 sequence. To investigate the effects of the different loading conditions on the mechanical properties, simulation has been performed for the bending of the fabricated composites. The geometrical modeling for the bending is developed in software package COMSOL 6.1 and various dimensions of the specimen are shown in figure 2.

3.2. Boundary conditions and applied load

The boundary conditions in this bending test simulation are given one end fixed and another end free. The free end is applied with different loads in the downward direction as mentioned in the table.

3.3. Material parameters

The material properties such as density, bulk modulus, shear modulus, young’s modulus, and Poisson’s ratio of the laminates considered for the simulation are listed in table 1.

| Property            | Symbol | Value       | Unit          |
|---------------------|--------|-------------|---------------|
| Density             | rho    | 1.63        | kg/m³         |
| Bulk modulus        | K      | 10          | N/m²          |
| Shear modulus       | {Gvector1, Gvector2, Gvector3} | 4.6e9, 4.6e9, 4.6e9 | N/m²         |
| Young's modulus     | E      | 13e9, 9e9, 9e9 | Pa            |
| Poisson's ratio     | nu     | 0.32, 0.32, 0.32 | 1             |

4. Results and Discussion
Table 2 presents the amount of load applied during the simulation, the evolution of von Mises stress (Principal stress), layered material von Mises stress, through-thickness von Mises stress, and line graph von Mises stress in the laminates for different samples.

4.1. Prediction von Mises Stress

Recently, many researchers have used von Mises methods for investigation of virtual stresses developed during the application of the loads. In this investigation, the von mises stresses are predicted along with the interface of the laminates as shown in the figure for different samples. It can be observed from this figure that the maximum value of von mises stress is 5KN/mm\(^2\) and the minimum 2KN/mm\(^2\) corresponding to variation in the applied load as mentioned in the table. The maximum stress is observed at the fixed end which is indicated in the figure in red color. Different forms of the von mises stresses that are developed during the loading in the simulation are presented in figure 3.

| Sample No | Load (N) | von Mises stress (KN/mm\(^2\)) |
|-----------|----------|---------------------------------|
| I         | 10       | 2                               |
| II        | 15       | 3                               |
| III       | 20       | 4                               |
| IV        | 25       | 5                               |

Fig. 3. Different colours showing the stress distribution area. von Mises stress includes (a) Principal stress appeared near the fixed end, (b) in through thickness, (c) on sliced layer, and (d) line graph
4.2. *Effects of loading load on the von Mises stresses*

On the variation of the applied load during the simulation, it is observed that the variation in the von Mises stresses with the load is linear which is represented in figure 4. The maximum value of the applied load is 25N and the minimum of 10N during the simulation. It is also observed that the extent of the damage is very little which can be seen at the fixed end of the laminates. The region where the highest von Mises stresses is observed is known as the highest load-bearing region.

![Fig. 4. Effects of different loads on the von Mises stress](image)

5. *Conclusions*

In this investigation, Lenin fiber composite is fabricated with different proportions of Lenin fiber and epoxy resin. To study the effects of different loading conditions on the strength of the fabricated laminates, simulation has been performed using COMSOL Multiphysics software. This study presents different stresses such as von Mises stress (Principal stress), layered material von Mises stress, through-thickness von Mises stress, and line graph von Mises stress in the laminates for different samples. The following conclusions are:

- The maximum values of the surface von Mises stress is observed near the fixed end of the laminates.
- On increasing the loads in different simulation test, the values of the von mises stress increases linearly.
- In through-thickness, the von Mises stress was minimum in the middle of the laminates.

6. *References*

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