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# Investigation on Mechanical Properties of Carbon Fiber Composite Using FEM for Leaf Spring Applications

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## ABSTRACT

Nowadays, many industries are shown interest in the hybrid composites, natural fibers, and reinforced materials due to reduction of the weight. The reason is that it will not affect environmental conditions. This experimental investigation identified the mechanical properties of hybrid composites. The hybrid composite materials are extensively used by E-glass/epoxy, carbon, and titanium alloy. Composites have good strength and less weight. The highest challenge of the automobile industry is to replace the steel leaf spring instead of the composite leaf spring. The composite structures have been providing better corrosion resistance. The conventional leaf spring experimental results were compared to analytical results of composite leaf spring. The design, simulation, and maximum stresses were done with the help of Ansys Workbench 15. Ansys Workbench materials are selected by titanium alloy, epoxy glass, aluminum alloy, and epoxy carbon. The design parameters were selected and analyzed to compare stress, deformation, elastic strain, and weight of the composite leaf spring as compared to conventional steel leaf spring. Deflection results were identified in the mechanical properties of the leaf spring. It should absorb shock loads and vertical vibrations due to road abnormalities. The composite experimental samples were analyzed using scanning electron microscopy.

**Keywords:** Hybrid composites; Epoxy carbon; E-glass; Titanium alloy; Mechanical properties; Finite element analysis.

## INTRODUCTION

A leaf spring is mostly used by stainless steel in all the vehicles. The leaf spring arrangements are divided into two different methods in automobile vehicles. The simply supported type is used for the first method, in which all the sides of the leaf spring are attached to the vehicle chassis (Das 2011). The second method, used for cantilever type of leaf spring, is fixed in one end of the vehicle chassis and the last end is attached for free displacement. The leaf springs were mostly used in automobile industries from 1970. The natural fiber produces better strength and less corrosion resistance results when compared to stainless steels (Sen and Babu 2004). Nowadays, with the changes of environmental conditions, the automobile industries are in the need of alternative materials. Polymer-based composite products are very helpful in automobile applications.

Many investigations were performed by using hemp fibers and reinforced materials. The new composite developments have given alternative solutions for environmentally less economic conditions. The hemp extraction process reduces the composites strengths. So, the fibers are attached to hemp (Malingam *et al.* 2019). The properties of fiber and its high strength formed the good

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combination bonding of materials. The natural fibers have given good bonding combinations for polymer matrixes. The interfacial bonding strengths are identified as the surface properties of alkaline treatments. This treatment may not affect the fiber surface body. Ramie fibers are improved by the alkaline water processing method. The plasma treatment improved the good adhesion-based resin (Hanan *et al*. 2020).

The jute fibers appear in the tensile strength investigations by using alkali treatments, and chemical treatments have given better results and strengths. The bamboo fibers are choked in silane agents and NaOH contents (Bilen 2021). All the evaluated results perform well in natural fiber solutions. The fiber contents and bonded surface areas of tensile strength are very high. All kind of tensile tests were taken from the experimental setup. They found the results from the experimental progress, and the alkaline processed results have provided better solution of tensile samples (Arik 2020). The elongation produced by silane treatment is very high in tensile samples. It may increase by 50% the bamboo processed samples.

The hemp fiber modulus strength and chemically preserved composite investigation was done, and the results were identified. The increased fiber contents appeared. Silane and alkaline processed fibers improved the modulus of elasticity and strengths for adhesion on fiber matrix (Naito 2021). The hemp carbon fibers were processed in different time conditions at 35 and 90°C. The identified result behavior was very huge surfaces in fiber contents. The chemically-processed hemp fiber results were very high as compared to non-processed hemp fiber. The harvesting, cultivating and surface fiber properties were identified. Most of the alkaline processed hemp tensile results were very high (Bilisik *et al*. 2019).

The mechanical properties of evaluation predict better solutions and adhesion structures. The natural fibers and synthetic fibers hybridization results provide many advantages, like low cost, renewability, and energy savings for fossil materials. Jute/kenaf/glass fibers are associated with hardness, tensile and flexible properties (Baig and Samad 2021). The effect of hybridization controls the molecular structures and tensile strengths. The results identified better performances of hybrid structures and molecular shapes from the glass fibers. Sisal and epoxy fiber matrix evaluated the addition of filler layers of reinforced composites. The results have identified the strengths of the composites and reduced the void fillers.

Banana and reinforced glass fiber composites are developed by the changing of lengths and material properties. The increment of lengths is identified and at the same time corrosion property is reduced. The investigation of palm oil development experimental setup was conducted by Sebaey (2020). The author identified the improvement of tensile, flexural and yield performances. The mechanical properties combination of pineapple leaf/glass and epoxy composites have been studied. The increment of the strengths of the materials performances and adhesion strengths were identified. Sebaey (2020) has developed the fruit bunch/glass fibers using reinforced composite structures, which carried out better performances and low melting surfaces.

The tensile properties have been evaluated and identified better layer structures combination of composite layers. They proved the tensile test results develop better performances from the fiber/matrix adhesion. All kinds of material property were analyzed and improved successfully. Dhakal and Sain (2020) investigated the palmyra and fiber-glass composite structures adhesion with high strengths of materials structures. It was improved by the addition of glass fibers and palmyra fibers. The authors also investigated the effect of glass fiber and jute composite structures with mechanical properties. All the evaluation results improved the glass fiber strengths and increased the number of counts. The jute fiber results predicted better compositions of composite structures through natural fibers.

Şansveren and Yaman (2019) developed the mechanical properties of sugar palm/fiber composite structures by the glass structures. In the test results, the increased tensile strengths and flexural shapes of adhesion layers were identified. The hybridization effect on the curaua fibers and glass combinations identified the adhesion strength for the tensile properties. Rahmat and Hubert (2019) developed the jute/glass fiber mixed composite structures and identified its bonded effects with molecular strengths. It identified the tensile, impact and flexural strengths for adhesion of better joint solutions, but degreased the water absorption levels and stages from the composite structures. Rahmat and Hubert (2019) have done the investigation samples on Kenaf/pineapple leaf fibers (PALF) fiber-reinforced structures with shapes.

The investigation pointed out a positive-method way by observing the composite combinations. Better performances of the composite impact strengths were identified by adding fibers. Friedrich (2018) fabricated the hemp and basalt fiber combination of composite samples and found the evaluation of added matrix samples. All the evaluated results predicted better sample results and successful performances evaluations. The hybrid composites were developed for the structural combinations. Flax/basalt fibers processed the tensile and flexural test performances by adding the fiber layer. The results improved in 25% the strength in tensile and in 10% the bending when compared the reinforcements.

Friedrich (2018) generated the process of creation in composite directions and orthogonal properties by using Ansys software. The author mixed the fiber directions and angles based on the stresses. The changing of steel to hemp permitted good environmental stages and fewer weights. All the adhesion structure results were linear with dynamic controls. The material has been designed by structural and dynamic analysis with help of Ansys Workbench. All the boundary conditions and structural elements were done with composite elements. The finite element method adopted the boundary structures layers and added the fiber contents. It defined the stress-strain relationship between the reinforced structures. From the Ansys results, the hemp and steel results have shown almost the same values.

Hemp carbon fiber results offer good economical support and control of environmental effects. All the boundary value elements are shown in the best compositions in hemp composite structures. Many of the researchers identified the stress-strain performances from the Ansys simulation software. The water absorption test results predicted better combination in composite structures. In the element, results pointed out the strengths and the behavior of the material. American Society for Testing and Materials (ASTM) standard specimens have used the tensile test. Its results are very safe for environmental conditions. All the interfacial characteristics, failure mode and internal structures were analyzed by scanning electron microscopy (Yang and Jian 2019). It developed molecular behavior and structures. All the equivalent structures and mechanical arrangements were done by composite added fibers.

## MATERIAL AND METHODS

### Materials used

In the experiment setup formation, the used materials were E-glass/epoxy, epoxy carbon, and titanium alloy. The epoxy carbon material has high strength hardness and low cracked surfaces. The E-glass braking level is very high in atmospheric conditions. All kinds of natural element and layer were performed in less cracked composites (Yang and Jian 2019). The mechanical properties of the materials were used for mechanical conditions and composite fabrication.

### Method of preparation

The automobile industries main target is to change the suspension leaf spring materials instead of composites. The main reasons are to reduce the weight and to increase the size of leaf springs. The strength was gradually increased from 10 to 25% in samples of composites. The main advantage of the composite leaf spring is a better quality of strengths. It develops the quality of materials without the cost of increases. It strains energy and designs very high performances when compared to stainless steel (Wei and Ren 2020). The density levels and strain energy rates are much better in stainless steel. The fiber added composite structures are increased from lower modulus strengths. Without changing load conditions, the weight of composite structures reduces gradually. The composite materials behaviors are compared to steel behavior properties.

### Design of sample leaf spring modules

The three-layered composite fiber was used to identify the tensile strengths. It was coated on the bottom end with soft wax. The upper part was applied by resin with low pressure. All the pressures were evenly applied to top ends. After applied pressure, the material was formed in the dry condition in 10 minutes. After heating, both surfaces were coated with silicone gel. The proportion of silicone gel and resin-coated mixed level was 80:20 (Wei and Ren 2020). The stopwatch content was used to be performed by the coated zones. The helical leaf spring design was done with the help of Catia V5R20. The design was also made separated in clamps and bolt. All the designed parts were assembled through Catia. The Catia assembled model was also performed by using surface contact methods. The leaf spring assembles model were also successfully designed and developed. E-glass, epoxy carbon and titanium alloy material properties are shown in Table 1.

**Table 1.** Properties of E-glass, epoxy carbon and titanium alloy.

| Properties of materials | E-glass | Epoxy carbon | Titanium alloy |
|---|---|---|---|
| Density (kg/mm$^3$) | 3.9063 | 2.2384 | 6.9412 |
| Young's modulus | 2.4e5 | 4.3e5 | 2.6e5 |
| Poisson's ratio | 0.23 | 0.221 | 0.13 |
| Tensile strength (MPa) | 36.2 | 46.45 | 43.67 |
| Compressive strength (MPa) | 60-80 | 90-175 | 40-70 |
| Flexural strength (MPa) | 30-70 | 30-100 | 40-60 |
| Flexural Modulus (GPa) | 2-5 | 3-5 | 4-6 |

### Fiber processed surface method

The interfacial bonding surface strength was modified in-between matrix and fibers. The chemical process generated the interfacial structures for these fibers. The treatment of alkaline soaking process is one of the methods to identify the fiber strengths. The freshwater was used before chemical treatment and fully washed the epoxy carbon. In the investigation, arrangement cut the 45-cm long in fiber and soaked in 5 Wt % sodium hydroxide for 24 hours in ambient temperature. Several time fiber content, samples were washed in running water conditions to remove the sodium hydroxide sticked to the fibers. The running water method removed the sludge particles from the combined composite structures. Then, the fibers were dried at 45°C for 12 hours (Zhu *et al.* 2020).

### Preparation of composites

Initially, the epoxy carbon was dried for 10-12 hours in solar lights. The fabrication was completed by hand process. First, the epoxy glass and epoxy carbon were attached tougher with the help of polyester resin. The fabricated structures were provided with three unique structures. Two structures were connected in glass epoxy, and the third layer was attached to epoxy carbon. The three layers were filled with fiber carbons, and the remaining third and fourth layers with titanium alloys. The volume extraction progress generated the sizes of 40% in glass epoxy and 60% in carbon fiber (Zhu *et al.* 2020). It developed fast and better adhesion strengths. The pressure was acted in the bonded layer of 5 MPa, and the temperature was 30°C. The humidity levels were maintained at 60%. The weight lift was attached in 1 hour.

## PROPERTIES OF COMPOSITE MATRIX

### Tensile test

The fundamental materials sample controls getting failure at tensile boundary conditions acted. They got at the brake point in all the surface ends. The materials properties can directly be measured in tensile results of maximum elongation, ultimate tensile strengths, and area reductions. The composite layers were performed in the tensile by ASTM D633 procedures and standards (Zhu *et al.* 2020). The universal testing machine got load in the tensile samples continuously. It passed load until failure was achieved. The stress and tensile strength analysis results were taken from all samples which followed the same procedures. The force results are shown against the elongation structures.

### Flexural test

The flexural experimental setup produced the three-point samples and different bending elasticity results. It identified the stress-strain relationship of composite materials. The ASTM D70 procedures were followed by the flexural test samples. The same universal testing machine (UTM) machine setup was carried out to apply the load in all the composite samples equally. The displacement and flexural strength results were compared from all samples. The flexural calculations identified the samples structures of molecules and adhesion quality. The strain rate was performed by Eqs. 1 and 2:

$$\sigma_f = \frac{3PL}{2bd^3} \tag{1}$$

$$£_f = \frac{6Dd}{L^2} \tag{2}$$

In which: $\sigma_f$: outer fiber stress and unit in MPa; $£_f$: strain for out surface (mm/mm); P: load (N); L: length (mm); D: maximum deflection (mm); d: beam depth (mm).

Composite equations were generated in different samples (Sanjay *et al.* 2019).

## Impact test

Impact test defined the materials impact resistance and variation methods. The constant potential energy was absorbed from a specific height of arms. Impact strength effect is normal in the composite bonded structures. It determined the impact strength and wear resistance. As per the ASTM standards, the Izod impact test was conducted. V-notched pendulum struck the impact setup. In the test period, maximum energy levels were stored in entire specimen results.

## Shear test

This study prepared samples of 20 × 20 × 5 mm. The center of the specimen was drilled by a 10-mm hole mount through the machining setup. As per the ASTM standards, shear test samples were prepared. The prepared samples were used according to ASTM D3518 method. The samples were tempered for 8 hours continuously from 60 to 100°C, process which removed entire moisture, and slowly cooled for 1°C, generating the strength before conducting the test setup. The sample UTM cross head conducted the test for 5 mm/min. The samples shear strengths were identified using Eq. 3:

$$\text{Shear strength } (\tau) = \frac{P}{\Pi dl} \tag{3}$$

In which: P: the force measurement; d: the thickness of the samples; l: the fiber matrix length (Vijaya Ramnath *et al.* 2016).

## Water absorption method

The method of water absorption technique was investigated for carbon fiber matrix. All the carbon fiber samples were tested as per ASTM standard D570. The specific temperature heat sources are reduced from the initial weight. The normal room temperature generated the process for water absorption test in a continuous method. It was performed continuously for 5 hours. The surface waters were removed using tissue paper. The samples reached the saturation limits with the regular intervals. The water absorption percentage results were calculated by Eq. 4.

$$\text{Absorption of water } (\%) = \frac{w_1 - w_2}{w_2} \times 100 \tag{4}$$

In which: $w_1$: the weight of the immersion specimen; $w_2$: the initial sample weight.

## Finite element analysis

Finite element analysis (FEA) determined the elastic behavior and materials properties. The analyzed results of mechanical properties and experimental properties were almost the same. These property behaviors were obtained from elastic-plastic regions. It required theoretical modelling and calculations. Transaction behavior study was not easy to predict the results. So, it required theoretical modelling. The cycle time represents the behavior of materials. The maximum results and deformation structures were identified with the help of FEA. The maximum stress and shape deformation predicted the mechanical boundary conditions by using Ansys 15.0.

The composite materials based on the three-dimensional structures were modelled successfully. All kinds of simulate performance were used for the static and composite structures. The orthogonal coordinate system was used for the composite structures. Layer by layer, the fiber was attached in different orientations. All the mechanical and material properties were gathered from the setup. The solid 187 elements meshed for the model. Uni-axial tensile condition based on the boundary conditions were applied in-between the bonding of fiber and matrix. The assigned addition strength was carried out by the adhesion of layers (Vijaya Ramnath *et al.* 2016). The orientation process, material properties, and boundary condition results were collected from the literature review.

## RESULTS AND DISCUSSION

The echo-friendly characteristics of hybrid reinforced composites need to be increased day by day. The natural composites strength is very high as compared to other samples. Nowadays, many countries and research scientists have been working continuously in the field of hybrid composite fibers. These fibers do not affect the load capabilities and maintain the same quality aspects to replace alloys and metals. The experimental tested results and mechanical properties of composite results are shown in Table 2. The deformation results and maximum stress results were identified by the Ansys 15.0. It resulted values are in Table 3.

**Table 2.** Composite results of the experimental setup.

| List | Tensile strength (MPa) | | Flexural strength (MPa) | | Impact strength (J/mm$^2$) | | Shear strength (MPa) | |
|---|---|---|---|---|---|---|---|---|
| | Unprocessed | Processed | Unprocessed | Processed | Unprocessed | Processed | Unprocessed | Processed |
| T1 | 46 | 56 | 102 | 119.2 | 1.6 | 3.7 | 11.7 | 22.8 |
| T2 | 47 | 57 | 103 | 118.4 | 1.4 | 3.6 | 10.7 | 21.6 |
| T3 | 48.35 | 56.4 | 105 | 121.8 | 1.7 | 3.5 | 11.8 | 25.2 |
| T4 | 47.22 | 62.5 | 107.2 | 124.5 | 2.1 | 4.0 | 10.3 | 24.3 |
| T5 | 48.43 | 58.6 | 105.3 | 121.7 | 2.2 | 3.9 | 11.5 | 23.5 |
| AVG | 47.4 | 58.1 | 104.5 | 121.12 | 1.8 | 3.74 | 11.2 | 23.48 |

AVG: average.

**Table 3.** Deformation structures and maximum stress performed in Ansys 15.0.

| | | Deformation | |
|---|---|---|---|
| Type of loading | Max stress (MPa) | Predicted | Experimental |
| Tensile load | 46.1 | 8.46 | 11.4 |
| Flexural load | 2.3 | 1.24 | 1.56 |
| Impact load | 1.2 | 0.7 | 0.3 |

### Experimental tensile analysis

The prepared samples were tested in the UTM and identified the stress and strain curve results. The generated test results are shown in Fig. 1. The observed results identified the composite tensile withstand strain rate of 42.57 MPa. The load applied at the top end was of 0.2 mm long with 3.82 kN. The results identified the bonding for fibers. Improper distribution of resin created the inside void formations. The hybrid composite tensile strength comparison results are presented in Fig. 2. These results represented the tensile strength in-between the samples: 40.27 to 43.87 MPa. The average value of the tensile strength was 42.68 MPa. The composite experimental samples and its results gave better bonded efficiency and contact surfaces. Unprocessed composite samples results did not provide better quality. Surface molecular and fiber contents provided the mixed resultant matrixes. Similar results were taken from the other published researchers' result (Sathyaseelan *et al.* 2020).

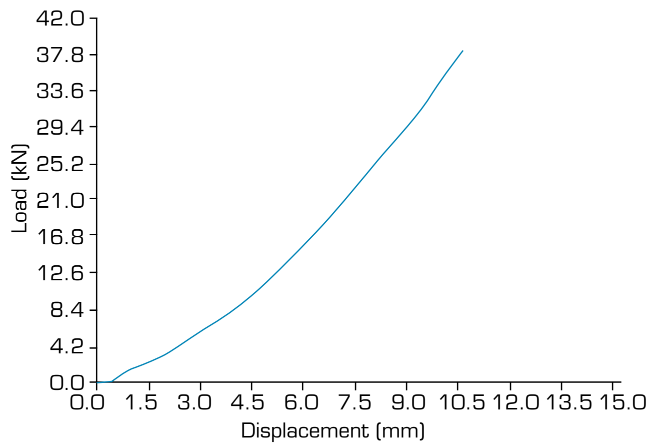


**Figure 1.** Stress-strain curve.

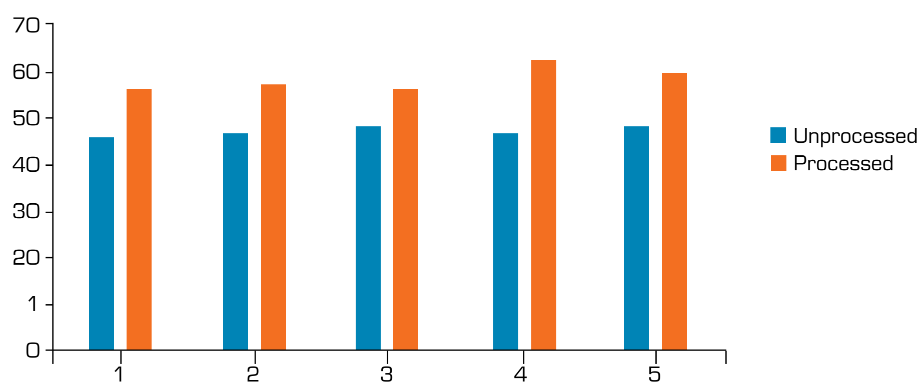


**Figure 2.** Tensile strength *vs.* composite process comparison.

## The result analysis with the finite element method

Hybrid composite tensile test based on finite element analysis simulation plots was defined by tensile results. The tensile load carried composite materials deformation and maximum stress distributions results are shown in Fig. 3. Composites of tensile properties results showed 45.2 MPa. It determined the stress plotted in the middle of the sample in which maximum load acted. The results were predicted in the form of brittle structures and shapes. It also defined the linear elastic deformations. The maximum tensile load acted deformation observed was 8.47 mm, in the analytical results published by Sathyaseelan *et al.* (2020).

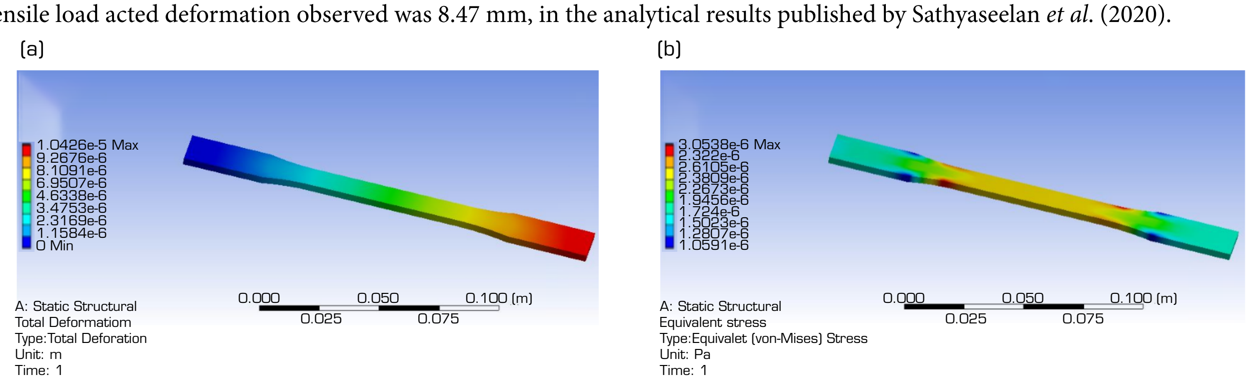


**Figure 3.** Finite element simulation plot (a) acted deformation and (b) stress distribution.

## Flexural strength analysis

### *Analysis of experimental results*

The epoxy carbon fibers to analyze the properties of composites tested results are presented in Table 2. Figure 4 represents the stress *vs.* strain curve performed from UTMs acted with the flexural boundary loads. The highest stress performances are represented within the materials rupture moment. The load was applied in the experimental setup at 0.6 kN and it performed the stress measured result of 102.74 MPa. The hybrid composite results were compared with flexural strength, and the results are shown in Fig. 5. The flexural results were performed in the hybrid composite variation observed from 102 to 105.73 MPa. The tensile strength of composite performances followed similar patterns. The predicted results were compared and analyzed from other research experiments (Ramesh *et al.* 2019).

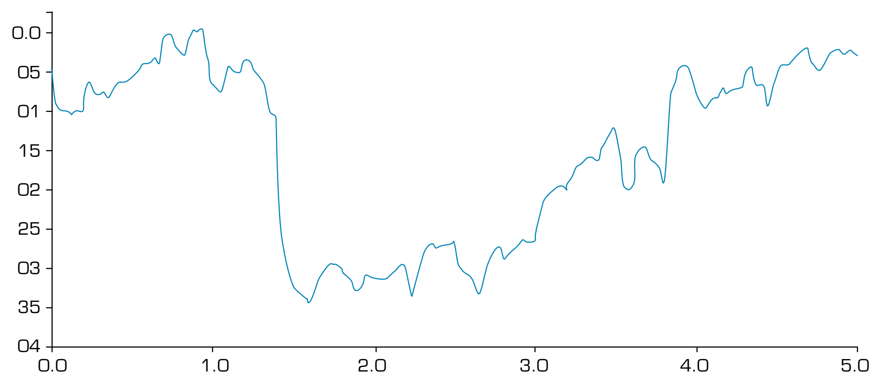


**Figure 4.** Flexural loading results of stress-strain relationship.

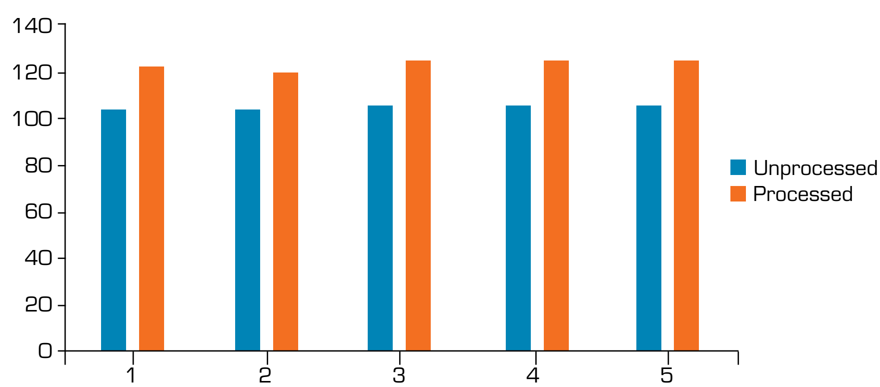


**Figure 5.** Flexural strength *vs.* composite process results.

### *FEA simulation results*

The epoxy carbon composite results plot of flexural loading is shown in Fig. 6. The simulation results were compared and analyzed in-between the loading conditions. The results of flexural stress performed in the middle of the sample materials and located at 2.22 MPa were observed. The elastic state deformation controls the composite indicated the linear deformations. The observed maximum flexural loading was 1.2 mm in hybrid composite structures. The predicted results were compared and verified through the experimental results of hybrid composites (Ramesh *et al.* 2019).

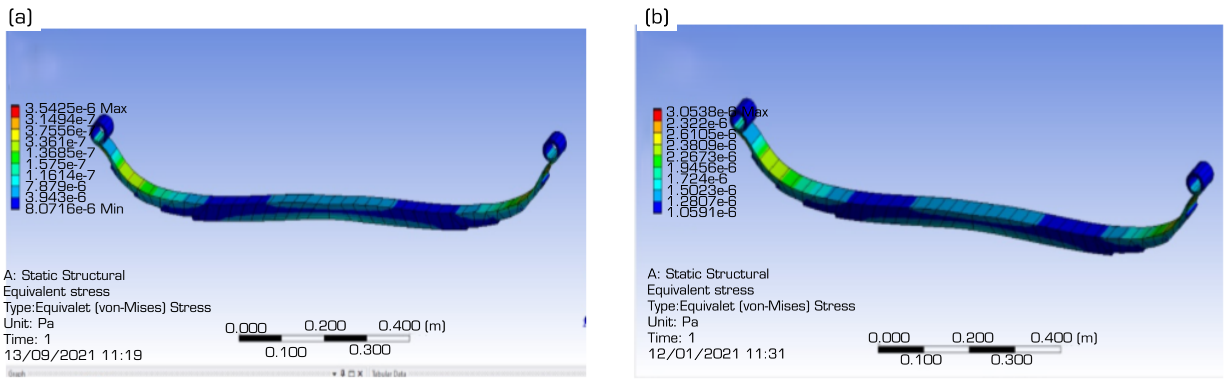


Figure 6. Composite finite element analysis simulation plot results for (a) deformation and (b) flexural stress

### *Impact result analysis of Ansys simulations*

Impact machine setup performed the result of energy dissipations from the hybrid composite structures. The various composite structures performed the results shown in Fig. 7. The varied results obtained the maximum impact strength of 1.9 j/mm$^2$. The results were compared to other published researches (Kandasamy 2020).

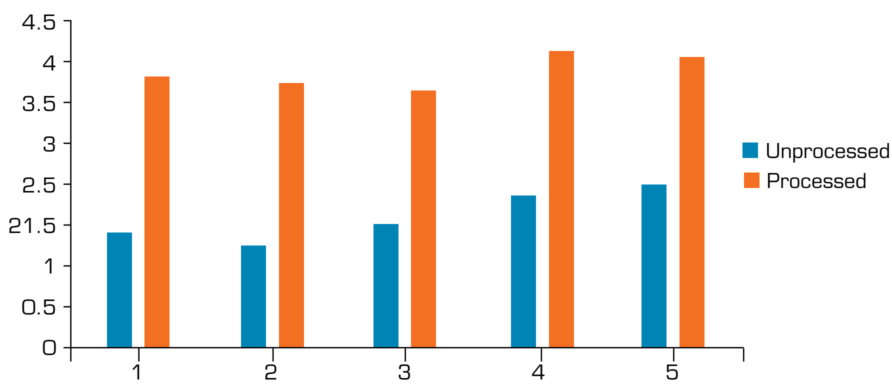


**Figure 7.** Hybrid composites impact strength *vs*. composite process.

## Finite element analysis of impact results

Impact results for the FEA simulations predicted the plot residuals for the samples. It determined the deformation shapes and maximum stress distribution observed under loading impacts. The specimen middle location was performed in maximum load actions, at 0.4 mm. The results were compared with other researches (Venkatasudhahar *et al*. 2020).

### *Shear stress analysis*

Processed and unprocessed alkali epoxy carbon fibers shear stress results are presented in Table 2. Its ranges were observed from the results from 12 to 21 MPa. Figure 8 represents the comparisons of shear stress results. The processed alkali epoxy carbon results showed better performances in comparison to the unprocessed samples. Alkali processed average shear stress of epoxy carbon result was 23.11 MPa. The average result of unprocessed shear stress result observation value was 12.32 MPa. In Fig. 9, results predicted the processed shear stress performances twice for the unprocessed samples. It has shown the results of surface modifications and shapes of epoxy carbon fibers. These results meet the comparison of other researches (Venkatasudhahar *et al.* 2020). Standard error design is represented in Fig. 10.

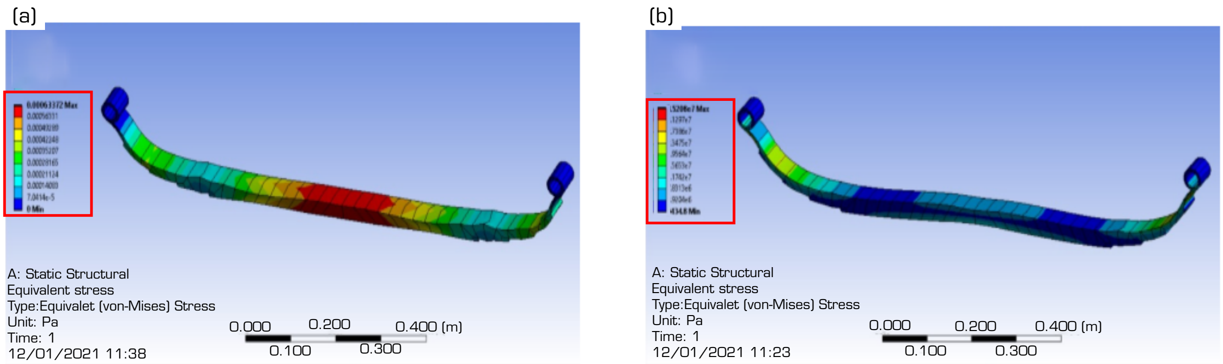


**Figure 8.** Composite finite element analysis impact plot results for (a) deformation and (b) flexural stress.

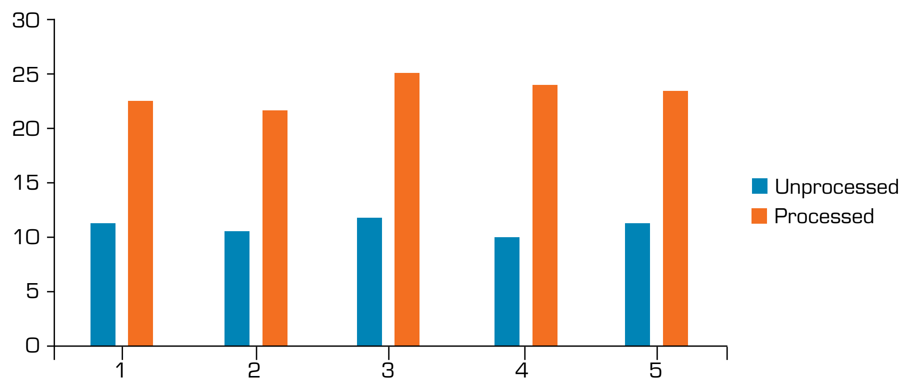


**Figure 9.** Hybrid composites shear stress comparison: shear strength *vs.* composite process.

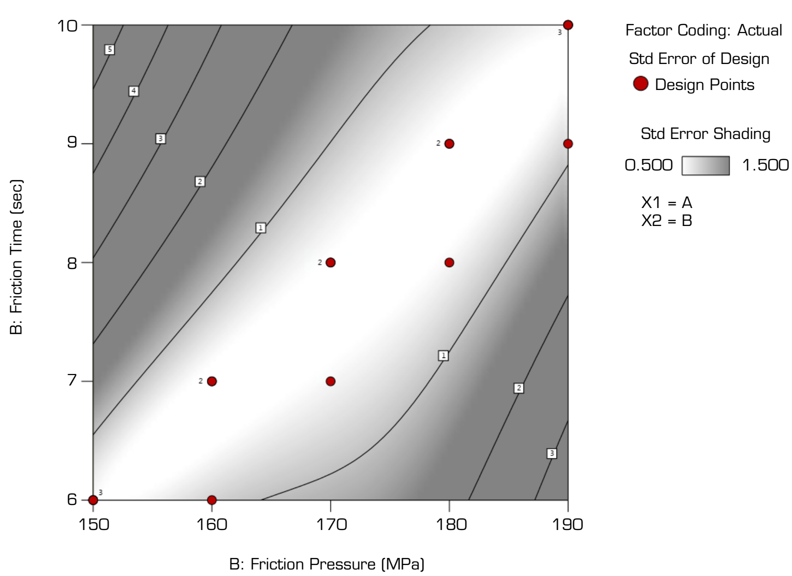


**Figure 10.** Standard error design in the experimental samples.

## Scanning electron microscopy analysis

The scanning electron microscopy (SEM) analysis examined the failure morphology results from epoxy carbon fibers. It executed the experimental simulations. The epoxy carbon subjected to the SEM micrographs tensile results are shown in

Fig. 11. Due to the tensile load, the fracture results were represented in the fiber matrix. The morphology results identified the cracked areas and structures. NaOH processed samples fracture cracks were very less when compared to an unprocessed zone. The microstructure results are represented in Fig. 12. Flexural load performance results predicted the fiber breakages and are shown in Fig. 12(a). Alkali processed fibers concentration surface is clearly shown in Fig. 12(b). Impact load subjected SEM samples results are shown in Fig. 12. The results rectified the fractured edges of fiber specimens and due to dislocation of impact loading.

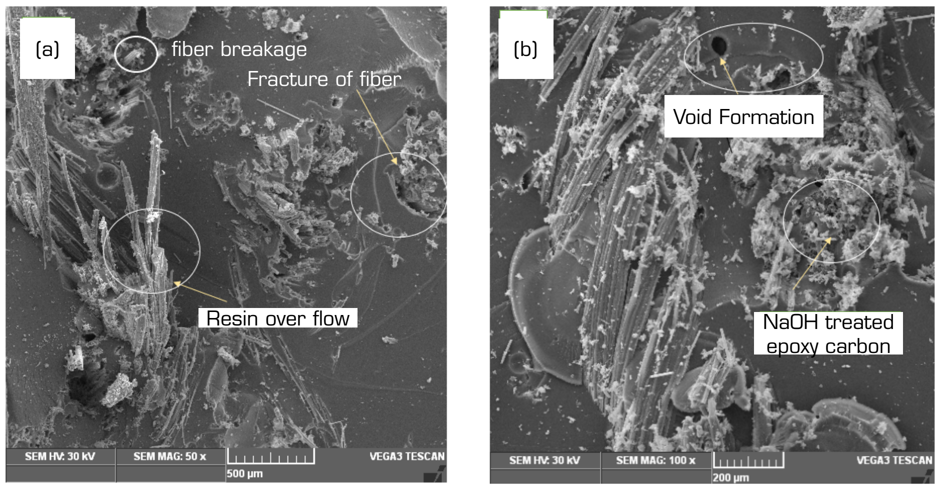


**Figure 11.** Scanning electron microscopy images of composites (a) processed and (b) unprocessed tensile results.

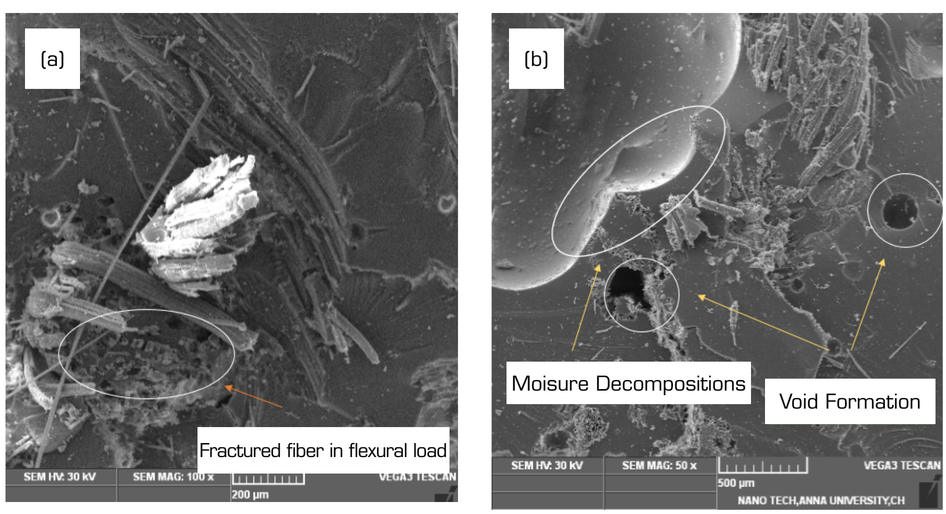


**Figure 12.** Scanning electron microscopy images of composites (a) processed and (b) unprocessed flexural load.

The shear load samples subjected results are shown in Fig. 11. From the result, decomposed surface fibers peeling the fibers were observed. All the combination of welded particles and tensile performances gave better contact behaviors. Water absorption performed results are represented in Fig. 11.

A different interval of time samples is shown in Fig. 12. Water processed samples of fiber structures are visible in Fig. 12(a). The maximum water amount was absorbed from the results and performed 2 hours continuously of immersion. Alkali processed fiber surface solutions are represented in Fig. 13. The long period of water processed composite structures represented immersed matrix fibers for long period.

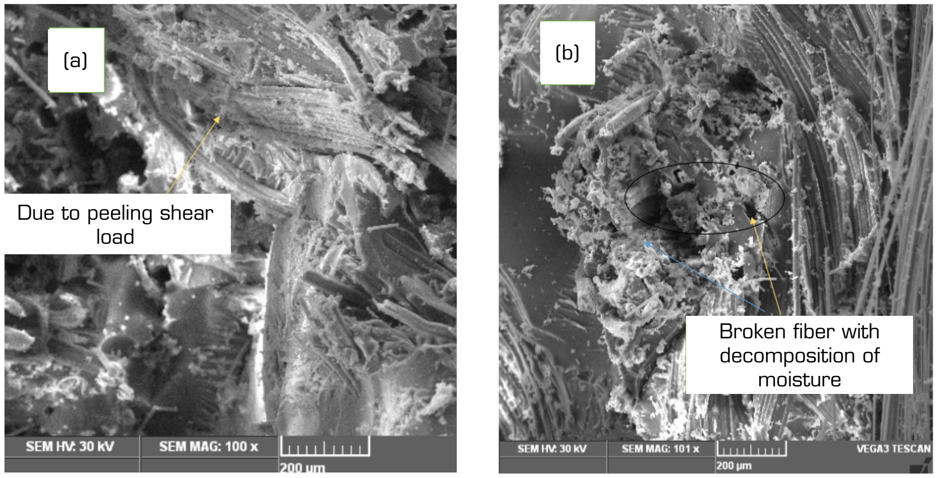


**Figure 13.** Scanning electron microscopy images of composites (a) processed and (b) unprocessed shear load.

## CONCLUSION

The hand lay-up method was used to fabricate epoxy carbon fiber matrix. The fabricated sample properties such as flexural, tensile, shear and impact strengths were evaluated. Water absorption properties were also evaluated successfully. FEA predicted the mechanical properties results. The FEA investigations have arrived from the conclusions of the experimental investigations:

- The maximum tensile strength can withstand hybrid composite structures. It determined the maximum tensile stress of 62.54 MPa, impact result of 3.2 J/mm$^2$, flexural result of 112.4 MPa, and shear result of 24.25 MPa;
- The processed hybrid composite samples strengths are much better than non-processed hybrid composite samples;
- The alkali-processed samples gathered less water absorption from the non-processed samples of hybrid structures. The results were studied from water absorption tests;
- Finite element results showed the maximum tensile stress of 42.54 MPa, impact result of 1.2 J/mm$^2$, flexural result of 97.4 MPa, and shear result of 18.25 MPa;
- SEM results clearly pointed out the surface fractures, the failure mode of fiber, alkali-processed fiber surface, impregnation of fiber matrix and moisture adopted to fiber-matrix decompositions.

## AUTHORS CONTRIBUTION

**Conceptualization:** Ramesh Kumar R.; **Formal Analysis:** Rajesh D.; **Supervision:** Rajesh D.; **Investigation:** Ramesh Kumar R.; **Writing – Review & Editing:** Sundarraj M.

## DATA AVAILABILITY STATEMENT

All dataset was generated or analyzed in the current study.

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Not applicable.

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