Development of Hybrid Friction Material for Brake Pad Application

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Abstract: As per the report of world health organization and environmental protection agencies, the existing brake pad materials produce toxic gases. Toxicity leads to create a bad effect on human health. So, there is a need to reduce the percentage of toxic elements at source and develop novel material compositions. It is known that the natural fiber-reinforced material reduces the toxicity. In this direction, an attempt made to fabricate hybrid natural fiber-reinforced composite material. The hand layup method was used to fabricate the hybrid fiber-reinforced composites. The mechanical test namely tensile, flexural, impact, shear, and interlaminar were performed to characterize the composites. The results revealed that hybrid fiber-reinforced composite materials exhibit superior mechanical properties compared to non-hybrid composites. Scanning Electron Microscope was used to analyze the fracture surface of the tested samples.

Key words: Friction materials, Brake pad, Hybrid fibre reinforced composites, Mechanical properties.

1. Introduction

Composites are formed by combining materials to form an overall structure that is better than the sum of the individual components. When two or more constituent materials having a significant change in the properties combine gives rise to new composite material, with characteristics different from the individual components. The individual components remain completely distinct within the finished
structure in terms of their properties and other characteristics. The composite material thus formed may be preferred for many reasons due to their extensive characteristics when compared to that of traditional materials. The growth of the composite materials, plastics, and ceramics have been tremendous over the last thirty years. The volume and number of applications of composite materials have grown steadily, penetrating and conquering new markets relentlessly. Modern composite materials constitute a significant proportion of the engineered materials market ranging from everyday products to sophisticated niche applications. While exhibiting greater advantage over these composites as weight-saving materials, the present challenge is to make them cost-effective. To provide economically viable and stable composite components several new manufacturing techniques are widely used in the composite industries.

It is obvious, especially for composites, that the improvement in manufacturing technology alone is not enough to overcome the cost hurdle. There must be an integrated effort in designing, and other factors which include material processing, tooling, quality assurance, manufacturing, and even programme management for composites to become competitive in the industry. The composites industry has already begun to recognize that the commercial applications of composites promise tend to offer a wide range of business opportunities than the other sectors. Earlier the applications of the composite materials were mainly focused on aircraft industry, but now the shift has occurred in the applications of other commercial uses, increasingly enabled by the introduction of newer polymer resin matrix materials and high-performance reinforcement fibers of glass, carbon, and aramid, the penetration of these advanced materials has witnessed a steady expansion in uses and volume. The new composite materials even tend to be cost-efficient. The applications of the high-performance FRP widely vary to a greater extent such as composite armoring designed to resist explosive impacts, fuel cylinders for natural gas vehicles, windmill blade industrial drive shafts, support beams of highway bridges and even paper making rollers.

Concerning certain applications, the use of composites has resulted in savings of both cost and weight. Some examples are cascades for engines, curved fairing, and fillets, replacements for welded metallic parts, cylinders, tubes, ducts, blade containment bands, etc. Further, the need for composites for lighter construction materials and more seismic-resistant structures has placed high emphasis on the use of new and advanced materials that not only decreases dead weight but also absorbs the shock and vibration through tailored microstructures. Composites are now extensively being used for rehabilitation strengthening of pre-existing structures that have to be retrofitted to make them seismic-resistant or to repair damage caused by seismic activity.

2. Literature Review
On low-velocity impact behavior, the number of the carbon and aramid layers and fiber orientation were reinforced on the fabric hybrid composites with a stratified filled epoxy matrix. The impact tests were done with the drop weight impact system at 90.629 J of energy level. The damage areas were analyzed by the visual inspection and tomography images. The results indicate that the matrix properties have a great influence over the fracture mode of the hybrid composites, while the fault degree of the damaged areas depending on the fiber orientation. The high impact resistance was obtained in the case of hybrid composites with 0° ply orientation. The carbon fiber reinforced composites perform better in fatigue loading, in comparison to glass fiber reinforced composites; The effect of polymer aging was also evaluated through thermal aging of neat resin specimens. The flexural performance, under both static and fatigue loading, of a glass fiber/carbon fiber hybrid polymer matrix composite material It was found that exposure to 180 °C in the air for 3 months resulted in improved fatigue performance of the composite, with mildly diminished static flexure strength, after six months the performance resulted in moderately degraded fatigue performance and a further reduction in flexure strength, while severely reduced performance (both static and fatigue) for 12 months aging time was found.
The mild improvement in fatigue performance for 3-month aged specimens attributed to the post-cure of the composite. They have the potential to compete with traditional fiber in all thermal and mechanical properties. The thermal degradation of vetiver fiber composite had more thermal decomposition if they undergo acetylation and silane chemical treatment and could treatment and could have still modified the surface of the fiber. In this work, Jute, Pineapple leaf fiber, and Glass fiber reinforced hybrid composites were prepared. The tensile and flexural properties of the composites with these fibers were found to be increased with fiber content, conforming to the reinforcing action of the fibers. Thus the composites of Jute, Pineapple leaf fiber, and Glass fiber epoxy composites were found to be light in weight, possessed better mechanical properties. Hence these composite materials can be used for applications such as automobile parts, electronic packages, building construction.

This paper characterized the impact response of a new hybrid composite material made using Type A (woven carbon fibers / UD flax fibers) and Type B (woven carbon fibers / cross-ply flax fibers) configurations in an epoxy matrix. The Type B composite had better overall impact performance as indicated by lower absorbed energy, higher penetration energy, smaller crack lengths, smaller indentation depths, smaller damage areas, lower temperature rise, and higher impact strength vs. the Type A version of the material. Both the Type A and B hybrid composite improved various impact properties compared to neat flax fiber composites reported in prior literature.

The impact properties of the current composite may potentially have various research and industrial uses depending on the particular needs of the application. In a new hybrid polymer composite with banana, a natural fiber, as reinforcement and also to study the machining characteristics of the composite. Response surface methodology was used to analyze the influence of machining process parameters on the material removal rate and surface roughness. The effect of machining parameters on the material removal rate and surface roughness were obtained through regression equations and different plots obtained from ANOVA analysis, employed through MINITAB and ANFIS. It is concluded that feed rate has maximum influence on the material removal rate and surface roughness followed by speed and depth of cut. It is observed that cardanol and Cashew nutshell liquid-based composites have similar material removal rates but they vary significantly in surface roughness. Further scope of this investigation is to find the optimum values of feed rate, speed, and depth of cut for material removal rate and surface roughness. It is also planned to investigate the various mechanical properties like tensile behavior, flexural behavior, dynamic behavior, etc. to suggest suitable applications. In recent days, technology needs a high demand for the growth of future generations. Hence, to produce a good product which needs to satisfy the customers, it should be developed in an economical way, high quality with minimum possible time challenging among the competitors.

Natural fiber-based polymer composites are the most shows the potential option for synthetic fiber and powerful polymer composites. It enhances the awareness of eco-friendly material makes it crucial to utilize natural fiber as potential reinforcement in polymer composites. Natural fibers are plentifully existing, biodegradable, and recyclable, which makes them conventional in the automobiles industries. The major negative aspect of testing is stretched time, the manufacturing cost is high, mistakenness, machine error, today, most bio composite researchers are moving toward computational methods to model the NFRPC to simulate the mechanical and thermal properties. Studied the tensile properties of flax/basalt hybrid composites with loading conditions. They reported that the tensile properties of composites decreased with increasing aging conditions. The rigidity and modulus diminished because of the embrittlement of the matrix materials. Comparative attributes were observed for sisal fiber reinforced PP composites. The affiliation between the cross-section of the natural fiber and the tensile properties.

They modeled and evaluated the tensile performance of hemp fiber with dissimilar elliptical cross-sections. The results appeared that the tensile properties have a physically powerful manipulate on the
degree of elasticity. The micro fibril angle and the viscoelastic properties played a very important role in the geometry of the natural fiber. Presently, we have used natural fiber material as used in a wind turbine material. Because it is used less weight and observed high wind turbine energy efficiency.

3. Materials and Methods
The prime ingredient of the composite material is Carbon fiber known for its toughness, high tensile strength, having good resistance to abrasion and resistance to organic solvents being Non-conductive, Low flammability, Good fabric integrity at elevated temperatures elasticity, good luster and thermal insulators because of their high ratio of surface area to weight. However, the increased surface area makes them much more susceptible to chemical attack with thermal conductivity of the order of 0.05 W/(mK). By trapping air within them, blocks of Carbon fiber make good insulation. The addition of Carbon fibers improves the bending load-carrying capacity of both symmetric and asymmetric Wind Turbine blades. Carbon polymer matrix composites material (90:10) 1kg is prepared by taking 900 grams of Carbon fiber in the shape sheet form (90%) and 10 grams of Epoxy Resin. In addition to coconut and vetiver fiber, to add strength, the hybrid Composite Material has been made by the Hand layup Method.

4. Hand lay-up method
In the hand layup method, resins are impregnated into fabrics by manual feed which is mainly of roving form. The fibers and resins impinge on the surface with the help of the rollers which has been fed into the mold. Then the fibers are made free under standard atmospheric conditions. This method is very simple and easy but it requires high skill to fabricate the composite. The fibers used are Carbon, in addition to that Coconut and Vetiver fiber are used. Carbon fibers are laid at the top and bottom in most of the composite laminate for better finishing purposes. Three different categories with two samples have been fabricated using hand layup method. All the fibers are laid in a normal direction and kept in a dry condition before it is fed to the laminate. Initially, the releasing agent is applied over the surface to remove the laminate easily. After applied, a thin layer of resin is applied and then the Carbon fiber is laid on the surface. A weight of 5 kg is placed over the Carbon fiber to remove air bubbles if any and it is kept undisturbed for about 3hours. Fibers are also dried in the normal condition to make the fibers moisture-free. After 3 hours the laminate removed from the die material and used various test for engineering applications.

5. Testing
5.1 Tensile testing
Strength of the specimen can be found when the material is subjected to tension or compression. Standard dog bone shaped specimens were handlay up according to the ASTM D638 specifications for tensile testing. Each specimen having 30 mm width and 280 mm gauge length, as shown in Figure. 1. The specimen is loaded in computer controlled Universal Testing Machine (ASE – UTN 10) until the failure of the specimen occurs.

![Figure 1. Tensile test specimen](image-url)
Tests are conducted on composites of different combinations of reinforcing materials and ultimate tensile strength and ductility are measured. Simultaneous readings of load and elongation are taken at uniform intervals of a load. A tensile test is carried out at room temperature. Uniaxial tensile test is conducted on the constructed the specimen to obtain information regarding the behavior of a given material under gradually increasing stress-strain conditions. The Tensile stress test results the elasticity limit of the Polymer Matrix composite.

5.2. Flexural Testing
The Flexural stress is the quantitative measure that defines the variations of Load concerning the displacement. The rigidity of the Polymer composite fiber can be studied through the flexural testing method. The flexural specimens are equipped as per the ASTM D790 standard (fig2). The 3-point flexure test is the most common flexural test for composite materials. Specimen Deflection is considered by the crosshead position. Test results take account of flexural strength and displacement. The testing process involves placing the test specimen in the universal testing machine and applying force to it until it fractures and breaks. The specimen used for carrying out the flexural test. The tests are regulating at a condition of an average relative humidity of 50%. A graph is drawn for each sample between the force and the displacement in the flexural test.

Figure 2. Flexural test specimen

5.3. Impact Test
Impact Test tests the condition for absorbing the energy

Case (i) - When the striker impacts the composite specimen, the specimen absorbs energy until the yield point, then the specimen begins to undergo plastic deformation by absorbing energy, and work hardening occur at the plastic zone.

Case (ii) - When the composite can absorb no more energy, eventually failure occurs.

The Izod impact test is a standardized high strain-rate test which determines the amount of energy takes up by a material. during fracture. This test is carried out on the samples that are made as per the ASTM D256 standard. The absorbed energy by the specimen is noted until fracture takes place during testing.

6. Result and discussion

6.1. Tensile Test
Concerning the figure1 standard dog bone-shaped specimens were hand lay up according to ASTM D638 specifications. Each specimen has a 30 mm width and 280 mm gauge length and the following observations were taken.
Table 1. Ultimate tensile strength of composites

| Orientation | Fibers       | Matrix | UTS1   | UTS2   | UTS3   |
|-------------|--------------|--------|--------|--------|--------|
| type 1      | Carbon 100%  | Vetiver0 Epoxy | 12.27  | 12.29  | 13.02  |
| type 2      | Carbon 90%   | Vetiver10 Epoxy | 12.24  | 12.27  | 12.99  |
| type 3      | Carbon 80%   | Vetiver20 Epoxy | 12.23  | 12.36  | 12.78  |
| type 4      | Carbon 70%   | Vetiver30 Epoxy | 12.25  | 12.45  | 12.64  |
| type 5      | Carbon 60%   | Vetiver40 Epoxy | 12.26  | 12.35  | 12.56  |
| type 6      | Carbon 50%   | Vetiver50 Epoxy | 12.1   | 12.02  | 12.45  |
| type 7      | Carbon 40%   | Vetiver60 Epoxy | 12.02  | 12.35  | 12.05  |
| type 8      | Carbon 30%   | Vetiver70 Epoxy | 11.56  | 12.36  | 11.95  |
| type 9      | Carbon 20%   | Vetiver80 Epoxy | 11.28  | 12.09  | 11.64  |
| type 10     | Carbon 10%   | Vetiver90 Epoxy | 11.02  | 11.23  | 11.54  |
| type 11     | Carbon       | Vetiver100 Epoxy | 10.98  | 11.05  | 11.27  |

Figure 3. Ultimate tensile strength with % of fibers

The Figure 3 shows the variation between the UTS Values in Mpa to that of the % of fibers. The peak values are recorded at 13, 12.25, 12.25, for UTS 3, UTS 2, UTS 1 curves respectively, and the trough values are recorded at 11, 11.25, 11.25 for UTS 1, UTS 2, UTS 3 curves. This indicates that with the % of the increase in fibers the UTS value decreases.
6.2. Flexural Test
For the figure 2, the flexural specimens are equipped as per the ASTM D790 standard. Each specimen having 100 mm length and 12.7 mm width and the following observations were recorded

| Orientation | Fibers   | Matrix  | Flexural Strength N/mm² | Flexural Strength N/mm² | Flexural Strength N/mm² |
|-------------|----------|---------|-------------------------|-------------------------|-------------------------|
| type 1      | Carbon 100% | Vetiver0 | Epoxy                   | 21.5                    | 21.9                    | 22.23                   |
| type 2      | Carbon 90%  | Vetiver10 | Epoxy                   | 21.2                    | 21.7                    | 22.28                   |
| type 3      | Carbon 80%  | Vetiver20 | Epoxy                   | 21.8                    | 21.6                    | 21.98                   |
| type 4      | Carbon 70%  | Vetiver30 | Epoxy                   | 21.4                    | 21.4                    | 21.78                   |
| type 5      | Carbon 60%  | Vetiver40 | Epoxy                   | 21.6                    | 21.8                    | 21.64                   |
| type 6      | Carbon 50%  | Vetiver50 | Epoxy                   | 21.2                    | 21.3                    | 21.23                   |
| type 7      | Carbon 40%  | Vetiver60 | Epoxy                   | 20.8                    | 21.1                    | 21.89                   |
| type 8      | Carbon 30%  | Vetiver70 | Epoxy                   | 20.2                    | 20.9                    | 20.05                   |
| type 9      | Carbon 20%  | Vetiver80 | Epoxy                   | 20.4                    | 20.7                    | 19.9                    |
| type 10     | Carbon 10%  | Vetiver90 | Epoxy                   | 19.58                   | 20.4                    | 19.92                   |
| type 11     | Carbon     | Vetiver100 | Epoxy                  | 19.23                   | 20.7                    | 19.85                   |

The result shown that the various combinations in mould method and are discussed with the graph in Flexural testing. The Figure 4 shows the variations between the Flexural strength and the % of fibre.
the peak values are recorded at 22.25, 22, 21.5 corresponding to the flexural strength values 3, 2, 1 respectively and the trough values are observed at 19.25, 20 and 20.5 for the flexural strengths 1, 3 and 2 respectively.

6.3. Impact Test
This test is carried out on the samples are made as per the ASTM D256 standard. The absorbed energy by the specimen is noted until fracture takes place during testing.

Table 3. Impact strength of composites

| Orientation | Fibers     | Matrix | impact valve in j | impact valve in j | impact valve in j |
|-------------|------------|--------|-------------------|-------------------|-------------------|
| type 1      | Carbon     | Vetiver0 | 9.8               | 9.5               | 9.7               |
| type 2      | Carbon     | Vetiver10 | 9.7               | 9.2               | 9.9               |
| type 3      | Carbon     | Vetiver20 | 9.6               | 9.3               | 9.5               |
| type 4      | Carbon     | Vetiver30 | 9.4               | 8.7               | 9.8               |
| type 5      | Carbon     | Vetiver40 | 9.3               | 8.5               | 9.7               |
| type 6      | Carbon     | Vetiver50 | 9.2               | 8.2               | 9.6               |
| type 7      | Carbon     | Vetiver60 | 8.8               | 8.4               | 9.2               |
| type 8      | Carbon     | Vetiver70 | 8.6               | 8.3               | 9.1               |
| type 9      | Carbon     | Vetiver80 | 8.5               | 8.2               | 8.8               |
| type 10     | Carbon     | Vetiver90 | 8.4               | 8.1               | 8.2               |
| type 11     | Carbon     | Vetiver100 | 8.3              | 8.5               | 8.1               |

Figure 5. Impact strength with % of fibers

The Figure 5 plots the variation of Impact value to that of the % of Fibre, the peak values are observed at 10 for all the impact value trials and the trough values are observed at 8. This shows that the Impact value decreases with the increase in % of fibres.
Hardness
Barcoll hardness test is carried out to find out the hardness of the specimen. Taking major load as 150 grams and minor load as 50 grams this test is carried. After applying the minor load for a minute then the major load should be applied. This test is specifically suited for polymer samples. Hardness scale C should be noted having its pin type indenter. Size of the specimen used for testing is 10*10 cm having a thickness of 4 cm.

Table 4. Hardness of composites

| Orientation | Fibers  | Matrix | Hardness1 | Hardness2 | Hardness3 |
|-------------|---------|--------|-----------|-----------|-----------|
| type 1      | Carbon  | 100%   | Vetiver0  | Epoxy     | 33        | 11        | 35        |
| type 2      | Carbon  | 90%    | Vetiver10 | Epoxy     | 35        | 36        | 32        |
| type 3      | Carbon  | 80%    | Vetiver20 | Epoxy     | 36        | 35        | 31        |
| type 4      | Carbon  | 70%    | Vetiver30 | Epoxy     | 32        | 32        | 38        |
| type 5      | Carbon  | 60%    | Vetiver40 | Epoxy     | 31        | 33        | 32        |
| type 6      | Carbon  | 50%    | Vetiver50 | Epoxy     | 33        | 35        | 34        |
| type 7      | Carbon  | 40%    | Vetiver60 | Epoxy     | 32        | 36        | 39        |
| type 8      | Carbon  | 30%    | Vetiver70 | Epoxy     | 29        | 35        | 37        |
| type 9      | Carbon  | 20%    | Vetiver80 | Epoxy     | 27        | 32        | 34        |
| type 10     | Carbon  | 10%    | Vetiver90 | Epoxy     | 29        | 31        | 34        |
| type 11     | Carbon  |        | Vetiver100| Epoxy     | 30        | 30        | 32        |

Figure 6. Hardness with % of fibers
The Figure shows that the various combination in mould method and discussed with the graph in Hardness. The highest Hardness values are observed at 35-40 for all the the hardness tests respectively and the through values are recorded at 30 , 35, 37 for the hardness tests 2 , 1 , 3 respectively.

7. Fracture surface using SEM

A scanning electron microscope (SEM) is a group of electron microscope that generates images of a sample by scanning it with a focused beam of electrons which are used to observe the topography and morphology of a specimen. The electrons collaborate with atoms in the sample, generating various signals that can be detected and that contain information about the sample's surface topography and composition. The analysis of fractured surfaces of impact test specimens is analyzed using SEM. The samples are taken for the SEM Analysis as they have the large variations in the mechanical test results as well variation in the composition and melting temperature.

7.1 SEM Image of vetiver

The following fracture observations are obtained through the SEM and correspondingly the Fig.7 indicates the tensile fracture surface and Fig.8 indicates the flexural fracture of the specimen and Fig.9 depicts the impact fracture.

8. Conclusion

The vetiver and coconut fiber are made by hand layup method. The test result is shown in figures and graphs. The tensile test value results in higher UTS value in Coconut fiber. Hence that material would withstand in the above elastic region. UTS improved when the hardness value is increased hence the material withstand in a loading condition. Corresponding wear resistance is improved. The wear resistance is improved when the material withstands in corrosion wear and flexural and impact value also show the higher flexural strength and joules. The Flexural is improved when the corresponding bending strength is improved. And the impact value is improved when the ballistic load condition also improved. The fracture surface shown in SEM images. The SEM images have shown that the Voids occur in a vetiver fiber. But the coconut fiber results in low voids and porosity. Hence It can be concluded that Coconut Fibre can be used in a Break Pad material because it has no exothermic heat, no voids, porosity, and excessive tensile strength. The wear, corrosion TGA tests will be taken for wind turbine material is an added advantage.
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