Mechanical Properties of Hybrid Polymers for Break pad Applications.

Ravi Raj.V\textsuperscript{1,a}, Vijaya Ramnath.B\textsuperscript{2}, Srinivsan.R\textsuperscript{*3}, Sethuvelappan.P\textsuperscript{4}, Ramanan\textsuperscript{5}

\textsuperscript{1}Research Scholar, Department of Mechanical Engineering, Anna University, Chennai
\textsuperscript{2}Associate Professor, Department of Mechanical Engineering, Sri Sairam Engineering College, Chennai
\textsuperscript{3}Professor, Department of Mechanical Engineering, Sri Sairam Engineering College, Chennai
\textsuperscript{4}UG Scholar, Department of Mechanical Engineering, Sri Krishna College of Technology, Coimbatore
\textsuperscript{5}Engineer, Synce Engineering Service, Chennai

\textsuperscript{*}E-mail: vlbstini@gmail.com

Abstract. Non wear out brake emission is one of the significant issue concerns with health and the environment. In brakes performance, wear debris is released in the atmosphere and pollute the environment. The brake pad is classified into two categories mainly asbestos and non-asbestos. As per the report of WHO and Environment Protection Agencies, some of the metals oxidized and produces toxic gaseous. Toxicity leads and creates a bad effect on human health. This work focuses on remedies over environmental and health issues because of brake pad emission. It is important to reduce the percentage of toxic elements at source and develop novel material compositions that are less dangerous to the environment and human health. Also, it satisfies all requirements of a brake pad material as per international standards. From this investigation, we found an alternate material for brake pad applications. The natural fibers reinforcement material is zero toxic. So, the materials will not create any environmental and human health issues.

Key Words: Recycle Material, Hazard Material, Break Pad Material, Environmental Health

1. Introduction

Particulate matter (PM) in the atmosphere is an important component of air pollution that can cause adverse health effects PM comprises a complex mixture of components derived from different sources, with motor vehicle emissions being one of the most important sources in urban areas.\textsuperscript{1} Several studies have shown that airborne brake wear particles often differ considerably from the bulk friction material.\textsuperscript{2} The emissions and compositions of brake wear particles vary depending on several factors: (a) brake friction material parameters, for example, the contents of non-asbestos organics (NAOs), low-alloy steel, semi-metallic components, Glass composites, and rotor and drum parts.\textsuperscript{3} Brake assembly type, including discs, drums, assembly sizes, surface structures, and depth of grooves and vehicle operating conditions, including initial speed, deceleration, pressure, torque, and brake
temperature. Studies into the mass balance measurement of airborne brake wear particles following braking events have estimated that 30–50% of generated brake wear debris becomes airborne. It is also thought that brake wear substances can be generated from hydroGlasses derived from the gasification of resins in NAO friction materials. Metallic components decompose under triboreduction, which is defined as the reduction of metal oxides associated with friction. However, using actual vehicles and/or roadway tests may result in PM samples that are contaminated by re-entrained road dust and/or tire wear particles. Further research is required to properly determine the emissions of brake wear particles, including the careful assessment of friction under transient driving cycles.

Brake wear particle mass emission studies are typically performed according to initial speed/deceleration driving conditions and brake temperatures. On low-velocity impact behavior, the number of the Glass 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 areas which underwent damage 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 Glass 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/Glass fiber hybrid polymer matrix composite material was studied. It indicated that exposure to 180 °C in the air for 13 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 Glass fibers / UD flax fibers) and Type B (woven Glass 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.

2. Material and Method

Vetiver fiber belongs to the hibiscus family which is 4000 years old crop and originated in ancient Africa. Vetiver plant can grow with an average height of 1.5m to 4.5m tall in 5 months yielding 500-1000 kg of dry fiber/acre. Vetiver is very much suitable as biological resources, fossil fuels, wood pulp, etc due to its extensive application in the engineering field. GFRP consist of minute particles of fiberglass. The main advantage of using this fiber is due to its lightweight, robust, and strong. It can be easily molded into any shape. The particles are called filaments that are formed and bundled together to form a roving like structure. Bulk strength and weight properties are also very favorable when compared to metals. In the hand layup method, resins are impregnated into fabrics by manual feed which is mainly of roving form. The fibers and resins have impinged 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 twisted GFRP& Vetiver fiber. in addition to that glass-reinforced polymer fiber. Glass fibers are laid at the top and bottom most of the composite laminate for better finishing purposes. Three different categories with three 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 ad then the glass fiber is laid on the surface. A weight of 5 kg is placed over the glass fiber to remove air bubbles if any and it is kept undisturbed for about 3 hours. Fibers are also dried in the normal condition to make the fibers moisture-free.

The below percentage ratio added vetiver and fibers

| orientation | Fibers       | Matrix |
|-------------|--------------|--------|
| type 2      | Glass 90%    | Vetiver10    | Epoxy       |
3. Manufacturing method

In the method of hand layup, the resins are impregnated into fabrics by the process of manual feed which is mainly of roving form. The rollers help the fibers and resins to get impinged onto the surface which has been fed into the mould. Then the fibers are made free under standard atmospheric conditions. It is one of the simpler and easiest methods but it requires high skill to fabricate the composite. The fibers used here are the glass and vetiver. For better finishing purposes the glass fibers are placed on both the top and bottom side of the composite. Three different categories with each containing two samples are fabricated using the hand layup method. All the fibers are laid in the normal direction and are kept in a dry condition before it is fed into the laminate. To remove the laminate easily the releasing agent is applied over it. A weight of 5 kg is placed over the Glass fiber to remove the air bubbles if any and is kept undisturbed for 3 hours. Also, fibers are dried in the normal condition to make the fibers moisture-free. The laminate thus obtained after removal are used in a variety of engineering applications.

4. Result and discussion

4.1. Tensile Test

For determining the tensile strength of the hybrid composite, a universal testing machine is used. The table shows that the tensile properties of the hybrid composite sample. The graphs have been plotted between the stress and the strain and also a comparison between categories concerning each property has been shown in Figure 1.

![Figure 1: Tensile Test result](image)

The above graph indicates the tensile test results. The results indicate that it has maximum ultimate stress of 4.9 Kn/m2 and the yield stress of 0.4 N. The graphs are shown in ductile fracture, less porosity occurs here hence the ultimate stress value increases. The maximum of the ultimate tensile value occurs at 5.0 Mpa. As the ultimate stress value increases the corresponding yield point also increases. The above graph shown is the correlated value of UTS and Yield stress values.
4.2. Flexural stress

The flexural test can be determined by a three-point bending test. Table 5 furnishes the experimental results of various parameters and also comparison has been done among the properties as shown in Figure 5. The graphs plotted as shown in Figure 5 for all the categories are summarized. It is clearly understood that category 3 of sample 2 shows higher flexural strength with a maximum load of 1.65kN. The bending due to the flexural test has been restricted to the minimum level due to the presence of fibers that resist bending during loading conditions. Flexural modulus of 403.95MPa is recorded high when compared to category . The flexural result shown in figure2. The maximum displacement up to 1.4 mm. and the maximum stress 1.2 KN and maximum displacement up to 1 mm. Hence material are high elongation are to occur.

As per the ASTM D368 standards, the flexural tests are undertaken, the flexural tool acting as axial stress. The axial stress varies proportionately to that of the increase in bending loads. The above figure indicates the bending stress, the maximum bending occurs at 1.5 kN, and having a maximum displacement up to 1 mm.

4.3. Double End shear

The experimental results obtained are tabulated below. Graphs between the load and the UTs are shown in Figure 6. The comparisons of various properties are also shown in Figure 6. It is found that superior property which has a break load of 4.04kN with a maximum displacement of 34mm due to the presence of glass and vetiver exists in the composite laminate which shows considerably good shear properties. Both the glass and vetiver fibers tend to improve the shear property proportionate with the matrix medium.
In this double end shear test, the test load acts at the axial points. The test results indicate that it has maximum ultimate stress of 4.2 N/mm and the maximum stress occurs at 4.9 kN. It has a maximum bending strength of 8 kN. The bending strength increases correspondingly to that of the increase in bending shear. This results in the material having higher durability.

4.4. Hardness

Hardness mainly depends on the material property in which the intended portion tends to absorb sudden shock which results in testing the hardness of the material. Category The hardness value is shown in a figure. The values are shown in up to 100 HRL. The material is shown in higher hardness. The material compares to metallic material are also equal.

4.5. Wear Testing

This work tells us about the dry sliding wear behavior of Aluminium-Hexagonal Boron Nitride- Cubic Boron Nitride using a pin on disc apparatus (DUtCOM™ make). Figure 4.1 shows the arrangement of the pin-on-disc apparatus. The disc material was made of EN-32 steel with a hardness of 65 HRC. The pin specimen is pressed against the disc at a specified load usually employing an arm and attached weights. The dry sliding wear tests were carried out at room temperature (30°C ± 3°C, RH 55 % ± 5%)
under the dry sliding condition following the ASTM G 99 standard. Cylindrical pins of 10 mm diameter and 25 mm long were machined and polished by the metallographic method. Immediately before testing, were cleaned and dried using acetone to remove all dirt and foreign matter from the specimens. The initial and final weight of the specimen was measured using a Mitutoyo™ to make an electronic weighing machine with an accuracy of 0.0001 grams. Wear measurement is carried out to determine the number of materials removed (or worn away) after a wear test, (and in reality after a part in service for some time). The material worn away can be expressed either as weight (mass) loss, volume loss, or linear dimension change depending on the purpose of the test, the type of wear, the geometry and size of the test specimens, and sometimes on the availability of a measurement facility. The specimen was fixed in the arm and the disc was made to rotate below the pin. Mass of the specimen before and after the test is measured using digital balance and mass loss is found out for each set of input parameters.

4.6. Wear Results

The Experiments were conducted according to the Taguchi’s L27 Orthogonal Array- 3 level and 4 Factors. The Input Parameters and their Levels is given in Table 2. The result of the Wear Test is given in Table 3. for further analysis MINITAB 16 software is used.

Table 2: Input parameters for Wear Test

| Input Parameter                  | Level 1 | Level 2 | Level 3 |
|----------------------------------|---------|---------|---------|
| % coconut fibre addition         | 0.5     | 1.0     | 1.5     |
| % Glass fibre Addition           | 1.0     | 2.0     | 3.0     |
| Load in Newton                   | 10      | 30      | 50      |
| Sliding Speed (SS) in m/s        | 1       | 2       | 3       |
| Sliding Distance in m            | 2000    |         |         |

Calculating the Signal-to-Noise ratio (S/N) Wear Rate has to be minimized; it is smaller- the better type of quality characteristics. Hence, S/N ratio for Mass Loss is computed from the following equation: Smaller the better \( \eta = -10 \times \log_{10} \left( \frac{1}{n} \sum y_i^2 \right) \) (1)

Table 3: Results of the Wear Test

| Expt.No | % 1 | % 2 | Load (N) | Sliding Speed (m/s) | Wear Rate (mm³/m) |
|---------|-----|-----|----------|---------------------|-------------------|
| 1       | 0.5 | 1   | 10       | 1                   | 0.002             |
|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 2 | 0.5 | 1 | 30 | 2 | 0.004 |
| 3 | 0.5 | 1 | 50 | 3 | 0.001 |
| 4 | 0.5 | 2 | 10 | 2 | 0.007 |
| 5 | 0.5 | 2 | 30 | 3 |   |
| 6 | 0.5 | 2 | 50 | 1 |   |
| 7 | 0.5 | 3 | 10 | 3 |   |
| 8 | 0.5 | 3 | 30 | 1 | 0.006 |
| 9 | 0.5 | 3 | 50 | 2 | 0.005 |
|10 | 1  | 1  | 10 | 2 | 0.002 |
|11 | 1  | 1  | 30 | 3 | 0.004 |
|12 | 1  | 1  | 50 | 1 | 0.001 |
|13 | 1  | 2  | 10 | 3 | 0.006 |
|14 | 1  | 2  | 30 | 1 | 0.008 |
|15 | 1  | 2  | 50 | 2 | 0.007 |
|16 | 1  | 3  | 10 | 1 | 0.004 |
|17 | 1  | 3  | 30 | 2 | 0.002 |
|18 | 1  | 3  | 50 | 3 | 0.001 |
4.7. Main Effect Plots for S/N Ratios for Wear Rate

The regression equation for the Wear Rate of Al-1-2 Metal Matrix Composites is given by:

\[
\text{Wear Rate} = 0.64631 - (0.378127 \times \%1) - (0.0451929 \times \%2) + (0.00144872 \times \text{Load}) - (0.00146963 \times \text{SS}) + (0.0018006 \times \%1 \times \%2) - (1.68476 \times 10^{-06} \times \text{Load} \times \text{Load}) + (0.00661419 \times \text{SS} \times \%1) + (0.0172865 \times \%1 \times \%2) + (0.000393297 \times \text{Load} \times \text{SS})
\]

\[
S = 0.0109444 \quad R^2 = 99.21\% \quad R^2(\text{adj}) = 98.29\%
\]

The mean effect wear ration result was arrived in 98.29\%. generally wear rate result above 90 \% it is more sufficient. Here the result shown in table 3 and wear ratio was concluded that the result will be more sufficient for wear parameter. Hence the material used for break bad application
4.8 Fracture surface Images (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 large variations in the mechanical test results as well as variation in the composition and melting temperature. The sem image is shown in the figures.

Fig 5: Tensile Fracture
Figure 10 depicts the damage that occurred due to the tensile test of the specimen. Fiber breakage occurs here due to the sheer effect which is not uniform throughout the surface because of the presence of the twisted fiber which resists each other in the opposite direction thereby attaining stability in a particular stage. The images are taken from a scanning Electron microscope. The figure 5 shown here is a ductile fracture. The porosity occurs due to exothermal heat formation. The load is given on the fiber material keep on increasing up to the elastic limit after then it will be failed.

Fig 6: Double End shear Fracture
It is an internal mode failure that occurs due to the layer separation of fibers in the composite laminate. The above figure 6 shows the delaminated specimen which has its voids, blowholes. It has also been
observed that during the separation of layers the adhesion of the medium has not much affected which in turn reduces the damage to the laminate. This damage has occurred due to the double shear test on the specimen. Due to the shear effect, the fiber breakage occurs which is not uniform throughout the surface because of the twisted fiber which resists each other in the opposite direction, and thereby it attains a stable state.

5. Conclusion

The tensile test results that the sample having high tensile properties rather than the other two categories in this section because of their material composition such as composites and glass fiber which is imposed on the outer layer of the laminate. The samples show a high tensile value of 4.9 Mpa with a maximum break load of 0.4 kN when compared to others. The result of the double shear test shows, the maximum value is obtained in a sample of 4.2kN. It indicates that the glass fibers have high shear properties when compared to the other two categories. The vetiver and glass fiber is made by hand layup method. The test result is shown in figures and graphs. The tensile test value results in higher UTS value in vetiver and vetiver and glass 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 is shown in SEM images. The SEM images have shown that the Voids occur in a vetiver fiber. the vetiver and coconut fiber results in low voids and porosity. Hence It can be concluded that Vetiver and glass Fibre can be used in a Break Pad material because it has no exothermic heat, no voids, porosity, and excessive tensile strength. In the present investigation, an attempt was made in the development of the hybrid friction brake pad material to minimize the environmental and health issues and it satisfies all requirements of a brake pad material as per international standards. From this investigation, we found an alternate material for brake pad applications. The natural fibers reinforcement material is 0% toxic. Thus the materials will not create any environmental and human health issues.

Reference

1. Pierson, Ford motor company, Emision of ammonia and amine from vechicle on the road, environment science technology 1983
2. Österle et al., Variation in the Sustained Effects of the Communities That Care Prevention System on Adolescent Smoking, Delinquency, and Violence School of Social Work, University of Washington 2001
3. Sanders The Ira Revised Bright Galaxy Samplethe Astronomical Journal, , 2003 October Received 2003 February 7; accepted 2003 May 12
4. Garg et al., Identification of brake wear particles and derivation of a quantitative tracer for brake dust at a major road Atmospheric Environment Volume 44, Issue 2, January 2010, Pages 141-146
5. Sanders The Human Amygdala: An Evolved System for Relevance Detection, Reviews in the neuroscience, Feb 2003
6. Garg , Identification of brake wear particles and derivation of a quantitative tracer for brake dust at a major road, Atmospheric Environment Volume 44, Issue 2, January 2010, Pages 141-146
7. Varrica , Inorganic geochemistry of roadway dust from the metropolitan area of Palermo, Environment GeologyItaly 2013
8. Sanders et al., THE /IRA REVIS BRIGHT GALAXY SAMPLE THE ASTRONOMICAL JOURNAL 2003
9. Hagino et al., Revisiting the extremely fast disc wind in a gravitationally lensed quasar APM MNRAS 000, 1–12 (2017) Preprint 29 September 2018
10. Iijima Metabolite annotations based on the integration of mass spectral information us national library of medicine, year of publication 2008.
11. M. Buneaa,* A. Circiumaru, etal, fiber orientation on low velocity impact behavior of the fabric reinforced hybrid compositesdoi.org/10.1016/j.compscitech.2018.11.024.
12. Brian Burks, James Middleton, Maciej Kumosa, the comparison of Glass fiber glass fiber reinforced composites, August 2012, Composites Science and Technology
13. Brian Burks, Maciej Kumosa, the flexural performance. dx.doi.org/10.1016/j.compscitech.2012.07.018,
14. saravana Bavan D. and Mohan Kumar G.C.A Simple hand lay-up method. Tensile and flexural test creativecommons.org/licenses/by-nc-nd/3.0/). Procedia Materials Science 5 (2014) 605 – 611
15. M. Indra Reddy a*, M. Anil Kumar a, Ch. Rama Bahadri Raju a, the tensile and flexural characterization of polymer hybrid composites, (July 29th – 30th) 2016, Materials Today: Proceedings 5 (2018) 458–462
16. Al-Hajaj, Z., Sy, B.L., Bougherara, H., Zdero, R., Impact Properties of a New Hybrid Composite Material, Composite Structures (2018), doi: https://doi.org/10.1016/j.compstruct.2018.10.033
17. Sivakiran.Ga, Yash Gangwal etal., Investigations on Hybrid Polymer Matrix Composite Materials, Materials Today: Proceedings 5 (2018) 7908–7914
18. Finite element analysis of fiber-reinforced polymer composites J. Naveen Mohammad Jawaid Modeling of Damage Processes in Biocomposites,
19. Fibre-Reinforced Composites and Hybrid Composites https://doi.org/10.1016/B978-0-08-102289-4.00009-6
Azwa ZN, Yousif BF, Manalo AC, Karunasena W. A review on the degradability of polymeric composites based on natural fibres. Mater Des 2013;47:424e42.
21. .Mahzan S, et al. UV radiation effect towards mechanical properties of natural fibre reinforced composite material: a review. IOP Conf Ser Mater Sci Eng 2017;165:1e9.
22. Bakare FO, Ramamoorthy SK, Akesson D, Skrifvars M. Thermo mechanical properties of bio-based composites made from a lactic acid thermoset resin and flax and flax/basalt fibre reinforcements. Composites Part A 2016.