Development and Characterization of Natural Hybrid Composite using Banana Peels and Bamboo Leaves As Alternative to Asbestos Based Brake Pad Material

Ranjitha.M
Department of Mechanical Engineering, University Visvesvaraya College of Engineering, Bangalore, Karnataka, India

Veeresh Murthy
Department of Mechanical Engineering, University Visvesvaraya College of Engineering, Bangalore, Karnataka, India

B.M. Rajaprakash
Department of Mechanical Engineering, University Visvesvaraya College of Engineering, Bangalore, Karnataka, India

R. Rajashekar
Department of Mechanical Engineering, University Visvesvaraya College of Engineering, Bangalore, Karnataka, India

Abstract—**The use of asbestos fiber is being avoided due to its carcinogenic nature that might cause health risks. A new brake pad was produced using Bamboo leaves powder, Banana peel powder, silicon carbide is to replace asbestos and phenolic resin as a binder is evaluated in this study. A Bamboo leaves sieved into sieve grade of 100microns and Banana peel sieved into sieve grade of 50microns were used. The sieved bamboo leaves and banana peel particles were then combined with silicon carbide and resin in varying condition. The mechanical properties (Tensile strength, hardness, wear rate, and coefficient of friction) of the produced samples were investigated. This study is to optimize the process by applying the taguchi method with orthogonal array design. This approach is based on signal-to-noise (S/N) ratio and the analysis of variance (ANOVA) are employed to study the performance characteristics. A 55% bamboo leaves powder, 7%banana peel powder, and 4%Silicon carbide resulted in better hardness. 55% bamboo leaves powder, 7%banana peel powder and 3.5% silicon carbide resulted in better wear rate and coefficient of friction of the produced samples. The result of this work when compared to asbestos brake pad which is not recommended due to carcinogenic property showed close agreement.**

Keywords— ***Banana peel, Bamboo leaves, Harness, Friction, Asbestos brake pad Introduction.***

Brake pads are important parts of braking system for all types of vehicles that are equipped with disc brake. Brake pads are steel backing plates with friction material bound to the surface facing the brake disc. There are two basic types of automobile brakes: drum brakes and disc brakes. In drum brakes, the brake shoes are located inside a drum. When the brakes are applied, the brake shoe is forced outward and presses against the drum. One of the major differences between drum brakes and disc brakes is that drum brakes tend to be enclosed where disc brakes tend to be exposed to the environment [1].

The formulation of a brake pad material requires the optimization of multiple performance criteria. The brake pad material should achieve a stable and adequate coefficient of friction and should produce low fade and low wear. Resin is one of the most important ingredients for ensuring firmness and allows the part produced to contribute effectively to the desired performance. However, when excessive frictional heat is generated during adverse braking, performance of the brake pad material deteriorates. This drop in performance may be related to the degradation of resin which is associated with loss of its binding ability. Therefore the brake pad material's thermal stability, its ability to suitable mechanical properties, and its ability to bind its ingredients together under adverse braking conditions all depend on the resin [2].

It is reported that asbestos is carcinogenic by the arrangements; particulate materials that gradually wear from brake pads, especially those from disc brakes are carried away by air into the environment. The health risks that the use of asbestos based brake pads pose have brought about the need to explore other non-asbestos based alternatives that would not expose users to any health risks as well as meeting the basic requirements of selecting materials for the friction lining of brake pads. Various agro-waste products have been used over the years to replace the asbestos content in brake pads; some of them are maize husk, palm kernel, bamboo stem, banana peelings, palm slag, periwinkle shell, coconut shell, oil palm shell, bagasse, etc [3].

Brake pads from periwinkle shells have also been produced with formulation which included periwinkle shell powder, phenolic resin (phenol formadehyde), engine oil (SAE 20/50) and water. Kaolin clay properties were examined and processed for automotive friction lining material and found to be of good heat resistance for friction lining material in automotive industry [4]. The commercially available friction materials have been considered for the study of their abrasive properties and these are compared with those of the designed and fabricated materials.

I. MATERIALS AND METHODOLOGY

A. *Materials used*

The reinforcement materials and matrix material used in the present research are tabulated in Table 1 with their specific properties and suppliers.

Table 1 Specification of the Materials Used

Sl. No	Materials	Specifications	Suppliers
01	Phenolic resin	Density: 1.2g/cm³	Mangaldeep Chemicals, Bangalore
02	Banana peels powder	Density: 0.45g/cm³	Local supplier
03	Bamboo leaves powder	Density: 1.05g/cm³	Local supplier
04	Silicon carbide	Density: 3.21g/cm³	Bangalore Chemicals, Bangalore

The raw materials used in the production of brake pads were Banana peels (Fig 1), Bamboo leaves (Fig 2), Phenolic resin (phenol formaldehyde), and Silicon carbide (SiC). The laboratory equipment used for the production of the test-samples are hammer milling machine, sieves (grade sizes 50µm and 100 µm), mixing pan, beaker, and digital weighing machine.


Fig. 1: Banana Peel


Figure 2: Bamboo leaves

The banana peels and fresh leaves from a bamboo tree were collected and washed in order to remove contaminants and impurities. They were sun dried for four (4) weeks and cleaned. The peels and leaves were ground into powder using a hammer mill and then sieved into different sieve sizes. The size of banana peels powder considered is 50 µm and the size of bamboo leaves powder considered is 100 µm in the brake lining formulation as shown in Fig. 3 and Fig. 4.


Fig. 3: Banana peel powder


Fig. 4: Bamboo leaves powder

B. Hand layup method

The development and characterization of natural hybrid composite using banana peels and bamboo leaves has been studied. The details of methodology followed from blending of powder in different composition to scope for future work has been shown in Fig 5. The main objective of this work is to prepare composite material with banana peels and bamboo leaves and that composite material is to replace a brake lining material with a hazardous free material.

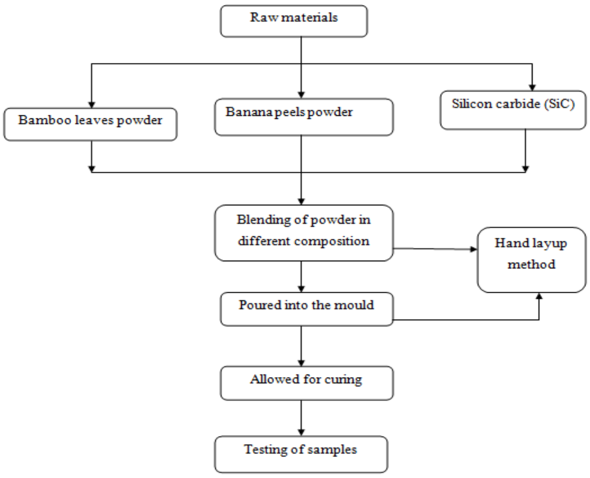

Fig. 5: Methodology

II. EXPERIMENTATION

A. Selection of volume fraction of reinforcements for Compliance test

In order to confirm the best combination of various reinforcement and resin at different volume fractions, compliance testing is carried out at different volume fraction for different powders. For bamboo leaves compliance test was conducted at 35, 40, 45, 50, 55 percent volume fractions. For banana peels compliance test was conducted at 3.5, 7, 10.5, 14, 17.5, 21, 24.5, 28, 31.5 percent volume fractions. From compliance test, the best range of volume fraction that resulted in acceptable condition of the specimen for fabrication is identified for bamboo leaves and banana peels powder. For Silicon carbide, powder the range is directly selected based on literature review. Based on the range of values of volume fractions of banana peels powder, bamboo leaves powder and Silicon carbide, design of experiment is conducted using Taguchi method to find the best volume fractions for different fibers that gives optimum result (Hardness, Wear, Coefficient of friction).

B. Method of production of brake pad samples

Production of brake pad consists of a series of unit operations including mixing, cooling, post-curing and finishing [5]. The constituent ingredients are, banana peels, bamboo leaves, silicon carbide, and phenolic resin. Different composition and sieve grades (50μm banana peel powder, 100μm bamboo leaves powder), silicon carbide powder and resin were added together, the ratio of raw materials is based on using Taguchi L9 method shown in Table 2.

The combination was properly dry mixed in a mixer for 10 minutes until a homogenous component was formed and the mixture was transferred into a mould for cold pressing with a hydraulic press at 80 kN/cm2. After removing from cold mould, the brake pad was cured at room temperature for 8 hours. The different composition variations led to the production of various samples with each sample weighing 75 g (samples 1-9). Table 3 shows the various compositions by mass of the various samples.

Fig. 6: Plate of finished brake pad samples

Table 2: Levels of process parameters used Taguchi L9 Orthogonal Array

Experiment Number	Levels		
	(Bamboo leaves powder) A	(Banana peels powder) B	(Silicon carbide) C
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

Table 3: Process parameters and their values at 3 levels

Process parameters	Levels		
	L1	L2	L3
Volume fraction of Bamboo leaves powder (%)	35	45	55
Volume fraction of Banana peels powder (%)	7	16	25
Volume fraction of silicon carbide (%)	3	3.5	4

C. Method of sample characterization

- Brinell hardness Test

The hardness test was conducted in Brinell hardness test machine and the size of the ball indenter is 5mm. A load of 25Kgf is applied on the composite and the holding time was 10 seconds. The Brinell hardness number (BHN) eqn (1) of each of the samples was then calculated by using Equation (1).

$$\text{Brinell hardness number, BHN} = \frac{2P}{\pi D\left[D-\sqrt{D^2-d^2}\right]} \quad (1)$$

Where, BHN = Brinell hardness number in kg/mm2
P = load in kgf
D = steel ball diameter in mm
d = depression diameter in mm

- Wear rate test

The wear and friction test has been conducted in pin on disc testing machine. The length of the specimen considered is 20mm and the diameter is 12mm.The wear rate for the samples was measured using pin on disc machine by sliding it over a cast iron surface at loads of 10 N, 50 N and 100N at sliding velocity of 5m/sec and sliding distance of 3000 m. All tests were conducted at room temperature. The initial weight of the samples was measured using a single pan electronic weighing machine with an accuracy of 0.01 g. During the test, the pin was pressed against the counterpart rotating against a cast iron disc of counter surface roughness of 0.3 µm by applying the load. A friction detecting arm was connected to a strain gauge held and the pin samples were vertically loaded into the rotating hardened cast iron disc. After running through a fixed sliding distance, the samples were removed, cleaned with acetone, dried, and weighed to determine the weight loss due to wear. The difference in weights measured before and after tests gave the wear of the samples. The wear rate of each of the samples was then calculated by using Equation (2).

$$\text{Wear rate} = \Delta w/S \quad (2)$$

Where,

Δw = Weight difference of the sample before and after the test in milligrams (mg)

S = Total sliding distance in meters (m)

III. RESULTS AND DISCUSSION

A. Brinell hardness test

Fig. 7 shows the results of Brinell hardness test carried out as per Taguchi L9 orthogonal array. The results obtained from the hardness test for this material (bamboo leaves and banana peels) were better when compared with the standard, commercial (asbestos based) brake pads.

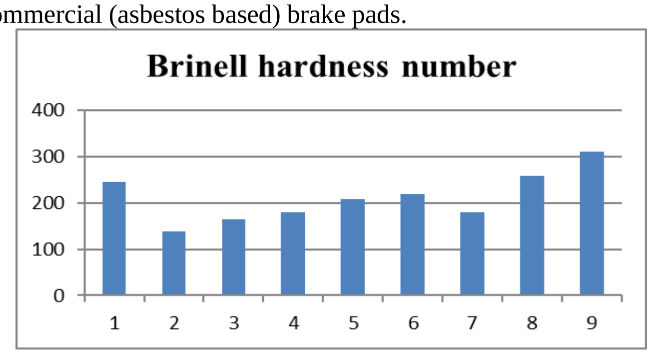

Fig. 7: Brinell hardness number v/s sample numbers

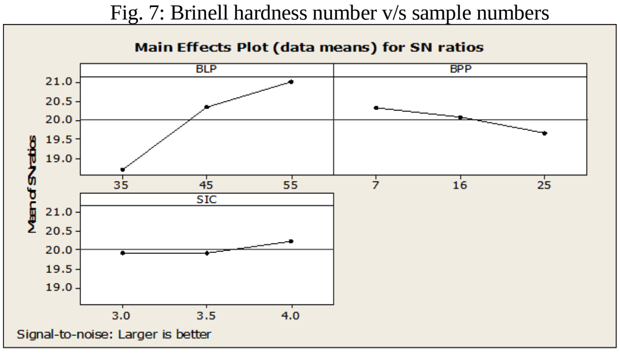

Fig. 8: Main effects plot for SN ratios for brinell hardness

From Fig 8, the optimum percentage of reinforcements for maximum hardness has been identified with larger the better as criteria and is shown in Table 4.

Table 4: Optimum percentage of reinforcement for brinell hardness number

Parameter	Level	Optimum Value
Volume fraction of bamboo leaves powder in %	3	55
Volume fraction of banana peel powder in %	1	7
Volume fraction of silicon carbide in %	3	4

Brinell hardness has been conducted for hybrid composite with 55% Bamboo leaves powder, 7% Banana peels powder and 4% Silicon carbide specimens and the results are shown in Table 5.

Table 5 Hardness of hybrid composite (55%BLP+7%BPP+4%SiC)

Trial #	Brinell hardness (BHN)	Average Brinell hardness (BHN)
1	180.128	179.304
2	177.004	
3	180.128	
4	179.957	

B. Wear test

The wear rates for the samples are presented in Fig 9; this may also be due to the wear rate of the samples obtained as the varying composition which was in agreement with what was observed in [6]. In order to produce a durable and acceptable brake pad that will not fade away quickly, it is advisable to use taguchi method identified samples for least wear property. The Fig 9 shows the wear rate and coefficient of friction of the all samples.

From Fig 10 the optimum percentage of reinforcements for minimum wear rate and coefficient of friction is identified and shown in Table 6. Wear test has been conducted for hybrid composite with 55% Bamboo leaves powder, 7% Banana peels powder and 3.5% Silicon carbide specimens. Table 7 lists the wear rate and coefficient of friction of hybrid composite.

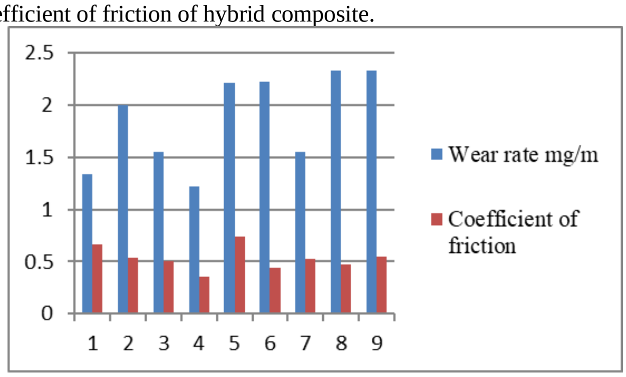

Fig. 9 Wear rate and coefficient of friction v/s sample numbers

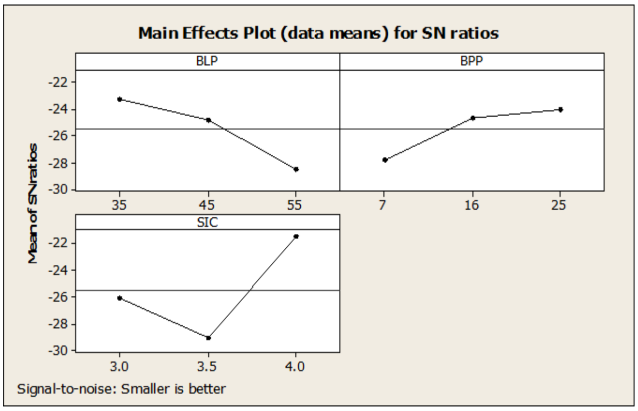

Fig. 10 Main effects plot for SN ratios for wear rate and coefficient of friction

Table 6 Optimum percentage of reinforcement for wear rate and coefficient of friction

Parameter	Level	Optimum Value
Volume fraction of bamboo leaves powder in %	3	55
Volume fraction of banana peel powder in %	1	7
Volume fraction of silicon carbide in %	2	3.5

Table 7: Wear rate and coefficient of friction of hybrid composite

Trial #	Wear rate (mg/m)	Average wear rate (mg/m)	COF	Average COF
1	2.921	2.571	0.34	0.34
2	2.571		0.37	
3	2.434		0.32	
4	2.328		0.33	

Table 8: Comparison between properties of asbestos brake pad and hybrid composite brake pad produced

Properties	Asbestos	Hybrid composite
Hardness (BHN)	101	179.304
Wear rate (mg/m)	3.8	2.571
Coefficient of friction	0.3-0.4	0.34

IV. CONCLUSIONS

The development and characterization of natural hybrid composite using banana peels and bamboo leaves as alternative to asbestos based brake pad material leads to the following conclusions. The successful development and fabrication of a new class of phenolic based composite has been done.

- By Taguchi's design of experiments, the optimum volume fraction for the hybrid composite for tensile strength is determined as 55% bamboo leaves powder, 7% banana peel powder and 4% silicon carbide.
- The hardness value of hybrid composite is increased compared to asbestos and some of other composites of brake lining material. The degree of polymerization tends to the hardness of composite. The inclusion of reinforcements

tends to the polymerization resulting in the increasing of hardness of hybrid composite compared to asbestos and some of other composite.

- The mechanical properties such as wear rate and coefficient of friction of hybrid composite with bamboo leaves powder; banana peel powder and silicon carbide are studied. It is found that at 55% Volume fraction of bamboo leaves powder, 7% volume fraction of banana peel powder and 3.5% volume fraction of silicon carbide of hybrid composite has a wear rate is 2.571mg/m and coefficient of friction is 0.34.
- It is observed that, there is a considerable enhancement in the wear arte and coefficient of friction of bamboo leaves powder reinforced phenolic resin composite until the volume fraction of bamboo leaves powder reaches 55%, thereafter wear rate and coefficient of friction decreases as the volume fraction of bamboo leaves powder is decreased. Similarly, the banana peels powder reinforced phenolic resin composite shows a decreasing wear rate and coefficient of friction until the volume fraction of banana peel powder reaches 7%. In case of silicon carbide, the volume fraction for optimum wear rate and coefficient of friction is 3.5%.
- By Taguchi's design of experiments, the optimum volume fraction for the hybrid composite for wear rate and coefficient of friction is determined as 55% bamboo leaves powder, 7% banana peel powder and 3.5% silicon carbide.
- The wear rate and coefficient of friction of hybrid composite is decreased compared to asbestos and some of other composites of brake lining material.
- The hybrid composite developed shows superior wear rate and coefficient of friction when compared with other hybrid composites including bagasse, palm kernel shell, sawdust, lemon peel powder, coconut shell powder, pineapple leaf powder cashew shells, sugarcane composites.
- Conclusion of this work is to compare asbestos material and also produce asbestos free material with better properties.

REFERENCES

[1] Idris U. D., Aigbodion,V. S., Abubakar I. J., Nwoye C. I., Eco-friendly asbestos free brake-pad: using banana peels, Journal of King Saud University - Engineering Sciences, 2015, 27, p.185-192.

[2] Masrat Bashir, Sheikh Shahid Saleem, Owais Bashir, (2015),"Friction And Wear Behavior Of Disc Brake Pad Material Using Banana Peel Powder", IJRET: International Journal of Research in Engineering and Technology. Vol-04, p.650-659

[3] Adekunle N. O, Oladejo K. A, Kuye S. I. and Aikulola A. D. "Development of Asbestos-free Brake Pads Using Bamboo Leaves". Nigerian Journal of Environmental Sciences and Technology (NIJEST), Vol 3, No. 2 October 2019, pp 342 – 351.

[4] Sadiq Sius LAWAL*, Katsina Christopher BALA, and Abdulkareem Tunde ALEGBEDE., "Development and production of brake pad from sawdust composite", Leonardo Journal of Sciences ISSN 1583-0233 Issue 30, (January-July 2017) p.47-56.

[5] Aigbodion, V.S., Akadike, U., Hassan, S.B., Asuke, F., Agunsoye, J.O., 2010. Development of asbestos – free brake pad using bagasse. Tribol. Ind. 32 (1), 45–50.

[6] Elakhame, Z. U., Alhassan, O. A. and Samuel; A. E. (2014). Development and Production of Brake Pads from Palm Kernel Shell Composites. International Journal of Scientific and Engineering Research, 5(10), pp. 735-744.