Fluid Dynamics &
Materials Processing

Tech Science Press

DOI: 10.32604/fdmp.2022.022187

ARTICLE

Analysis of a Cashew Shell and Fly Ash Rich Brake Liner Composite Material

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Received: 12 November 2021 Accepted: 12 April 2022

ABSTRACT

Hybrid materials collected from organic and inorganic sources, which are traditionally used as brake lining materials, generally include fly ash, cashew shell powder, phenolic resins, aluminium wool, barites, lime powder, carbon powder and copper powder. The present research focuses on the specific effects produced by fly ash and aims to provide useful indications for the replacement of asbestos due to the health hazards caused by the related fibers. Furthermore, the financial implications related to the use of large-volume use of fly ash, lime stone and cashew shell powder, readily available in most countries in the world, are also discussed. It is shown that many manufacturing and automotive industries, which are currently experiencing difficulties in meeting the increasing demand for brake lining material, may take advantage from the proposed solution.

KEYWORDS

Friction coefficient; wear; composite; brake lining; binders

1 Introduction

A frictional material is designed and developed to control the speed in vehicles by revamping the kinetic energy into warmth, and it is likely to repeat the result under a wide range of temperatures, speeds, and environmental factors. The modern automobile system improves its efficiency as well as its braking geometry. From the liner material and counter shoe, no noise, less wear, and vibration were also noted. Constituent materials were chosen and bound according to individual character requirements. The friction material can be classified according to its characteristics as (i) Binders (ii) Friction modifiers, (iii) Filler, and (iv) Fiber [1].

Many of these materials can serve more than one purpose in these categories, which makes the formulation of new composites more efficient. Although asbestos plays a significant role in brake liners, the government has put a higher tax on its production due to health concerns. The durability and temperature stability of asbestos make it an ideal constituent for friction formulation [2,3].

1.1 Objective of the Project

The present study focuses on the design, development and analysis of a brake lining material using fly ash and cashew shell powder. Composites are reinforced with fly ash to ensure frictional behavior. The mixture of fly ash, cashew nut shell powder, and lime stone is intended to replace asbestos, which causes health issues. Additionally, the production cost of such materials can also be reduced by using large volumes of fly ash readily available in most countries. Thus, the purpose of this project is to develop an improved brake lining frictional material using fly ash [1,2,4].

1.2 Need for Study

- To meet the increasing demand for effective brake linings, it is important to develop alternate sources of suppliers for automotive industries.
- Most of the materials used for the brake linings are of high cost and they do not specify the ingredients as these are kept as a trade secret by the suppliers and many of the suppliers have collaborations with foreign firms.
- Low cost and the use of fly ash as a filler material.
- Fly ash is plentifully available [5–7].

2 Hybrid Composite for Brake Lining Requirements

Friction linings have an inexhaustible profile, while safety-relevant aspects merit special attention. In the end, vehicles must be manageable and stoppable under all circumstances, at the same time; there are many requirements in the comfort area that are desirable, but not safety-related. All necessities can be roughly divided into three categories (Table 1).

- Physical/chemical characteristics
- Friction technical behaviour
- Comfort

Society of Automobile Engineering suggests codes and associated friction coefficients as shown in Table 2 [4–6].

Table 1: Requirements for Friction Linings

S. No.	Friction technical requirements and lifespan	Comfort	Physical/Chemical requirements
1	Friction level	General sounds	Compressibility (cold, hot)
2	Friction level stability	Squealing	Damping
3	Disc thickness variation (DTV)	Vibration of steering	Shearing strength
4	DTV–regeneration	Wheel	Young's modulus
5	Initial fading	Groaning	Corrosion (sticking material)
6	Cold friction level/wet friction	Squelching	Growth/stretching/shrinking
7	Level	Creep groaning	Porosity
8	Hill hold characteristics	Judder	Strength (flexibility, pressure)
9	Short brake distances	Mooing	Internal shear strength
10	Momentum course responsive	Grunting	Heat conductivity, heat transfer
11	Behavior	Pedal feeling	Ecology

Table 2: Edge codes

Code	Friction coefficient
C	≤0.15
D	>0.15 but ≤0.25
E	>0.25 but ≤0.35
F	>0.35 but ≤0.45
G	>0.45 but ≤0.55
H	>0.55

3 Selection and Composition of Ingredients

The fundamental materials carefully chosen for this work are primarily used in cars but also have application in commercial vehicles and motorcycles which are given in Table 3. The proportion of material is shown in Tables 3–5.

Table 3: Breakdown of the material

S. No.	Type	Material	Volume (%)
1	Binder	Powdered phenolic resin	20–30
2	Fillers	Barytes Magnesium oxide	25–35
3	Friction modifier	Graphite, antimony trisulfide, metallic particles	25–35
4	Structural strength	Organic mineral and metallic fibers	3–10
5	Other	Rubber, vermiculite	10–20

Table 4: Method of manufacture

S. No.	Process	Conditions
1	Dry mixing	High velocity magnetic stirrer machine
2	Pre-forming	Amount of charge–80 g Molding pressure–150 Kg/cm^2
3	Time	15 min
4	Curing	Pressure–175 Kg/cm^2 Temperature–160°C
5	Post baking	Temperature–160°C Time–6 h

Table 5: Material used for the development (Pad material)

S. No.	Type	Material	Sample 1		Sample 2	
			Wt. in (gms)	Wt. in (%)	Wt. in (gms)	Wt. in (%)
1	Fiber	Steel wool	25	5.6	35	7.8
		Hydrated lime	25	5.6	35	7.8
		Glass fiber	15	3.3	20	4.4
2	Filler	Fly ash	200	44.4	150	33.3

(Continued)

Table 5 (continued)

S. No.	Type	Material	Sample 1		Sample 2	
			Wt. in (gms)	Wt. in (%)	Wt. in (gms)	Wt. in (%)
		Barites	50	11.1	50	11.1
3	Binder	Phenolic resin	100	22.2	100	22.2
4	Friction modifier	Graphite powder	10	2.2	20	4.4
		Cashew shell powder	10	2.2	20	4.4
		Copper powder	10	2.2	10	2.2
		Rubber chip powder	5	1.1	10	2.2
			450	**100**	**450**	**100**

4 Method of Manufacturing

Pre-forming is the first step in preparing brake liner material. The mixture is generally a combination of dissimilar materials blended together in a specified ratio to produce a new brake liner material. A chemically homogenous material developed by a desired weight/volume with a consistent particle size distribution, color, and texture. In addition to reducing tooling costs and downtime, pre-forming techniques are used to make brake pads.

4.1 Formulation of Non-Asbestos Organic Friction Material Counter Face Material (Disc Material)

One of the most important factors that influences tribological performance is the counter rotor disc. For this study, a grey cast iron rotor disc was used as a counter disc. Therefore, parameters related to it, such as composition, initial surface roughness, microstructure, and hardness, are discussed. Under testing temperature 24.5°C, elements present in the gray cast iron (Tables 6 and 7) with their weight percentage were analyzed by Optical Emission Spectrometry per ASTME 1999–99 (R-04) standard [8–10]. Figs. 1 and 2 give the microstructure of the brake liner.

Table 6: Composition of the Grey cast iron (Sample 1)

Element present	Observed values
Carbon	3.8800%
Chromium	0.0460%
Manganese	0.5010%
Molybdenum	0.0017%
Nickel	0.0690%
Phosphorous	0.0357%
Sulphur	0.0581%
Silicon	2.0300%
Iron	Balance

Note: This material conforms to IS 210 in respect of above tests.
Hardness test as per IS 1586 (2006).
Hardness in HRB: 85–85–86.

Gray cast iron is named for its gray appearance. Gray cast iron contains flake graphite in a matrix of ferrite and pearlite [11–16]. The flake structure is well-defined. SEM image shown in Figs. 1 and 2 indicates uniform spread of particle. The valleys and peek indicate the different sizes of particle.

Table 7: Composition of the Grey cast iron (Sample 2)

Element present	Observed values
Carbon	3.8800%
Chromium	0.0450%
Manganese	1.0000%
Molybdenum	0.0058%
Nickel	0.0580%
Phosphorous	0.0356%
Sulphur	0.0451%
Silicon	2.0200%
Iron	Balance

Note: This material conforms to IS 210 in respect of above tests.
Hardness test as per IS 1586 (2006).
Hardness in HRB: 84–84–84.

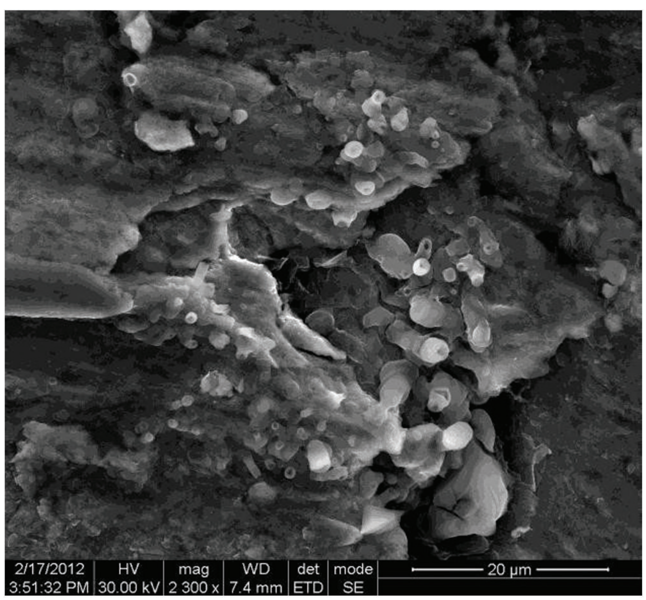

Figure 1: SEM image of grey cast iron–Couter disc

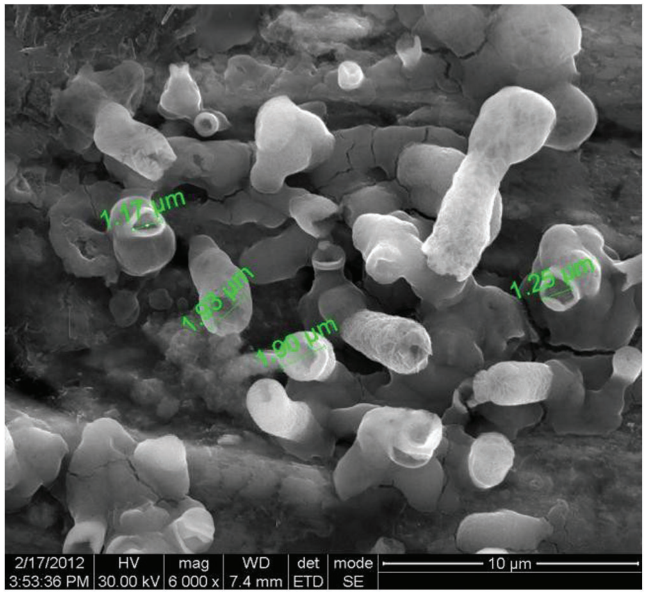

Figure 2: SEM image of grey cast iron with particle size

5 Wear Experiment

It is verified that the loading arm movement is free about its horizontal and vertical axis support, and the two pulleys rotate smoothly with an adjustment range of 10–60 mm. Loading pans (1.5 and 2 Kg) are suspended from the wire rope and run over the pulleys. Experiments are conducted in dry conditions without oil. Disc speed is adjusted to 500 rpm, running time is set to 5 min, and the pin is held in its holder refer the Fig. 3. An electronic weighing machine with an accuracy of 10–5 g is used to measure the weight of the pin before and after the experiment. Refer the Tables 8 and 9. Load is added to the iron rope and friction force is initially set to zero in the digital readout system. These two arrangements are important for each experiment.

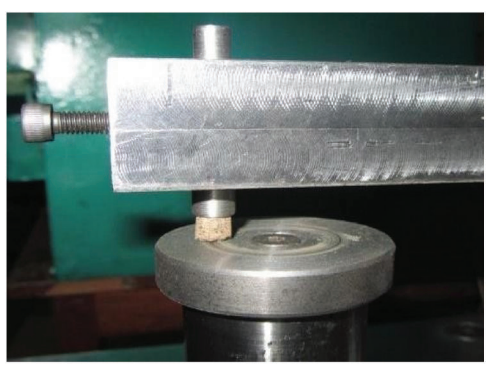

Figure 3: Testing process in Pin-on-disc testing rig

Table 8: Test parameters of counter disc

Selection of the sliding distance "S"		
1	Wear track radius	20 mm
2	Speed	500 rpm
3	Time	5 min
4	Normal load (FN)	1 Kg (9.81 N)
5	Hardness of gray cast iron	85 and 84 HRB
6	Pin diameter	8 mm
7	Pin length	15 mm
8	The sliding distance "S"	314000 mm
	$\pi \times D \times$ speed (rpm) $\times$ time $3.14 \times 40 \times 500 \times 5$ [13]	0.314 Km (approximately)

Table 9: Composition of the grey cast iron (Sample 2)

Specification of (counter face) disc material		
S. No.	Sample I	
1	Diameter	50 mm
2	Thickness	10 mm
3	Internal diameter	6 mm
4	Counter sunk	45°
5	Sample II	
6	Diameter	60 mm
7	Thickness	11 mm
8	Internal diameter	6 mm
9	Counter sunk	45°

5.1 Experiments Results

Friction coefficient is based on friction force and applied load. The direct measurement of efficiency of friction from the pin on disc machine for the duration of 5 min is depicted below for the pin counter to disc material under 1 and 1.5 Kg at wear track radius 15 and 20 mm which is shown in Tables 10 and 11.

Table 10: Wear of pin with varying load

Sample (pin)	Speed (rpm)	Wear track radius (mm)	Time (min)	Load (Kg)	Mass at initial (g)	Final at final (g)	Net mass (g)
I	500	20	5	1	1.855	1.830	0.025
				1.5	1.830	1.802	0.028
II				1	0.902	0.869	0.033
				1.5	0.869	0.832	0.037

Table 11: Wear of pin with varying wear track radius

Sample (pin)	Speed (rpm)	Load (Kg)	Time (min)	Wear track radius (mm)	Mass at initial (g)	Final at final (g)	Net mass (g)
I	500	1.5	5	20	1.802	1.775	0.027
				15	1.775	1.756	0.019
II				20	0.832	0.801	0.031
				15	0.801	0.782	0.019

6 Conclusion

The outcomes show that hybrid brake liner material fulfils the necessities of the manufacturing and automotive application. The Hybrid Composite for Brake Lining material formulations with varying fly ash, cashew shell powder and limestone powder content were developed and evaluated. The results of mechanical properties such as elements present in the disc material, hardness, and SEM image captured at different levels of magnification, physical property such as density, carried out showed significant improvement. The tribological evaluation was carried out using Pin-on-disc wear-testing machines (Fig. 3) for brake application, the coefficient of friction was in the range of 0.3 to 0.6 according to its application. In this case, the achieved average value of μ- is 0.38 on associating the varying loads and wear track radius categories and also, the developed composition has 20% improved efficiency than the current brake. Furthermore, the production cost of these developed materials is comparatively less than the commercial friction material.

Acknowledgement: We are very grateful to FDMP Managing Editor, Guest Editor and the reviewers for their suggestions, comments and language editing, which greatly improved the quality of our article.

Funding Statement: This work is self-supported one and not funded by any agency.

Conflicts of Interest: The authors declare that they have no conflicts of interest to report regarding the present study.

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