Development of Composite Material for Automobile Disc Brake Pad

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***Abstract*- Disc brakes are widely used for reducing velocity with their characteristics of braking stability, controllability and their ability to provide a wide ranging torques. During braking both brake pad and disc surfaces worn thereby affecting the useful life of brake as well as its behavior. The literature survey suggests that the currently used material asbestos is dangerous because of its carcinogenic nature. The experimentation involves the use of three different samples of composite materials which is performed on pin on disc apparatus where friction reaction against load, speed, temperature and wear are studied.**

***Index terms*- disc brake, brake friction materials, wear rate**

I. INTRODUCTION

Generally asbestos is widely used as a fiction material for automobile disc brake pads. Brake pads are exposed to a lot of friction which generates a lot of heat. Asbestos is a better material for absorbing and dissipating heat. But when asbestos breaks down, it's creates dust that's dangerous to breathe. Furthermore its carcinogenic nature makes it more harmful to human beings. For these purpose some of the brake pads are made from safer organic materials. Organic brake pads, sometimes called non-asbestos organic brake pads, are made from natural materials liked glass and rubber, as well as resins that can withstand high heat. In fact, the high heat helps to bind the brake pad materials together. An advantage of organic brake pads, is that they're made of materials that don't pollute as they wear and they're easier to dispose of. They're also softer than brake pads made of other materials, which means that they make less noise.

A disc brake system consists of a brake disc, a brake caliper and brake pads as shown in Fig.1. When the brake pedal is applied, pressurized hydraulic fluid squeezes the brake pad friction material against the surface of the rotating brake disc. The result of this contact produces friction which enables the vehicle to slow down or stop.

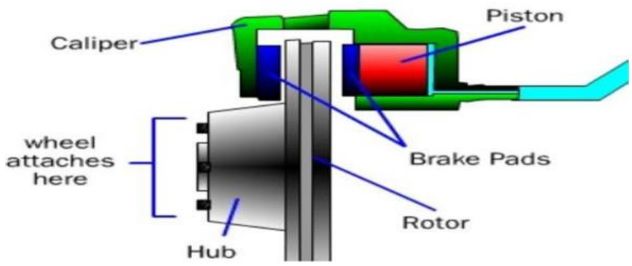

Fig.1 Components of Disc Brake

Disc brakes are fairly simple to work with. Typically, there are four main parts of a disc brake system as given below:

1. Mounting Bracket
Mounting Brackets are used to hold the caliper in place. Other than keeping the surface clean and free of rust road, there is very little to bed one with this part.

2. Rotor
Rotors are metal discs supported by the suspension. The calipers clamp onto them to slow their rotation, and then slow or stop the car. Vented rotors have fins in the spaces between their machined surfaces. These spaces allow air to pass through, which helps carry heat away. Non-vented rotors are used on smaller vehicles, and have no cooling fins.

3. Caliper
Calipers are the housings that contain the pistons and the brake pads. The calipers are connected to the hydraulic system, and hold the brake pads to the rotor.
There are two types of calipers as:
a) Fixed Caliper- Applies two pistons to opposite sides of rotor. Fixed calipers are as shown Fig. 2, are disc brakes that use a caliper, which is fixed in position and does not slide. They have pistons on both sides of the disc. There may be two or four pistons per caliper. Motorcycles and some import trucks and cars use this type.

b) Sliding Caliper- There are two pistons between which fluid under pressure is sent which passes one friction pad directly on to the disc whereas the other pad is passed in directly via caliper as shown in Fig. 3

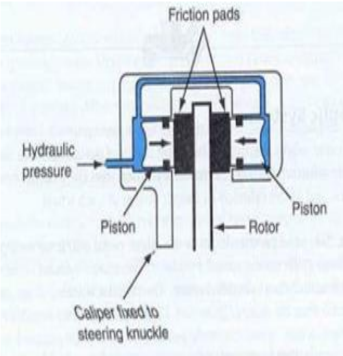

Fig.2 Fixed caliper

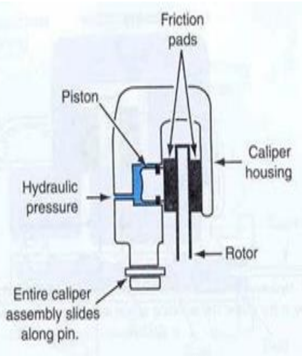

Fig.3 Sliding caliper

II. LITERATURE REVIEW

P. Thiyagarajan et al. [1] has introduced carbon fibers as reinforcement and graphite powder as friction modifier in the brake pad material, by his research he concluded that the brake pad material can play a vital role in this direction. The study reports the influence of these modifications on the thermal properties like coefficient of thermal expansion (CTE) and thermal conductivity along with the mechanical properties of non-asbestos brake pad composites samples developed in the laboratory. He also concluded that composition also helps in controlling the hardness of the brake pad to desired level. Reinforcement of carbon fibers at the present level does not influence the properties as much as the steel wool.

R. B. Mathur et al. [2] has formulated material with CNSL and studied tribological properties. In spite of unparalleled combination of essential material properties for brake linings and clutch facings, replacement for asbestos is seriously called for since it is a health hazard. If once asbestos is replaced with other material then composition and properties of brake pad changes. In certain cases hardness of the material may be high enough to affect the rotor material. In this study, hardness of the brake pad has been controlled using suitable reinforcement materials like glass, carbon and Kevlar pulp. Brake pad formulations were made using CNSL (cashew net shell liquid) modified phenolic resin as a binder, graphite or cashew dust as a friction modifier and barium sulphate, talc and wollastonite as fillers.

A.Saffar et al. [3] studied deeply the role of rubber component on the tribological characteristics of composite friction materials. They prepared a series of friction materials with various amounts of rubber component, ranging from completely pure resin-based material, i.e. with no rubber component, to completely rubber-based material, i.e. with no resin binder. Then the influence of rubber component on the mechanical, physical, frictional, wear and fade characteristics was explored. The COF of rubber-based materials became bigger compared to resin-based materials at higher sliding velocities. The wear resistance of resin-based materials was higher than that of rubber-based composites. This behavior was attributed to coverage of friction surface with strongly adhered multilayer secondary plateaus which plays the protective role to the underlying surface.

S.G. Amaren et al. [4] investigated the effect of periwinkle shell particle size on the wear behavior of asbestos free brake pad. The asbestos free brake pad was produced by varying the periwinkle shell particles was from +125 to+710 um with phenolic resin as the binder. The wear test was performed using pin on disk machine by varying the sliding speed, applied load, temperatures and periwinkle shell particle size.

K.W. Liew et al. [5] studied the tribological properties difference of potentially new designed non-commercial brake pad materials with and without asbestos under various speed and nominal contact pressure. The two fabricated non-commercial asbestos brake pad (ABP) and non-asbestos brake pad (NABP) materials were tested and compared with a selected commercial brake pad (CMBP) material using a pin-on-disc tribotest rig under dry contact condition. Results showed that friction coefficients for all materials were insensitive to increasing speed and pressure.

U.D. Idris et al. [6] has produced new brake pad using banana peels. 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 banana peels waste to replaced asbestos and Phenolic resin (phenol formaldehyde), as a binder was investigated. The resin was varying from 5 to 30 wt% with interval of 5 wt%. Morphology, physical, mechanical and wear properties of the brake pad were studied. The results shown that compressive strength, hardness and specific gravity of the produced samples were seen to be increasing with increased in wt% resin addition, while the oil soak, water soak, wear rate and percentage charred decreased as wt% resin increased. The samples, containing 25 wt% in uncarbonized banana peels and 30 wt% carbonized gave the better properties in all. The result of this research indicates that banana peels particles can be effectively used as a replacement for asbestos in brake pad manufacture.

T. Singh et al. [7] brake pad hybrid phenolic composites based on lapinus–aramid fibre combination are designed, fabricated and characterized for various physical, chemical, mechanical, thermo-mechanical and tribo-performance. The physical properties such as water absorption, compressibility, void and ash contents increased with increase in lapinus fibre, whereas mechanical (such as hardness, impact energy, tensile and flexural strengths) and thermo-mechanical (loss-tangent, storage and loss modulus) properties increase with increased in aramid fibre. The assessment of braking performance is done using a standard test protocol conforming to ECE R-90 regulation on the Krauss friction testing machine. Comprehensively, it was found that incorporation of higher metallic-silicate lapinus fibre in formulation relative to aramid enhanced the overall frictional

response.
R. Ertan et al. [8] investigated a brake lining composition was experimentally to investigate the effects of the manufacturing parameters on the tribological properties and to obtain optimal manufacturing parameters for improved tribological behaviour. The friction tests were performed using a Chase-type friction tester to find the relationship between the manufacturing parameters and tribological properties, such as the wear resistance and friction stability, depending on the test temperature and the number of braking. The density and roughness were also analyzed in relation to the manufacturing parameters. The results showed that manufacturing parameters can substantially improve the tribological behaviour and manufacturing cost of brake lining as long as optimum values are chosen. It was found that as the molding pressure or heat treatment temperature increases, the density increases. As the molding time increased, the tribological characteristics improved remarkably. Also as the molding pressure increased, the average COF of the brake lining increased, given constant heat treatment parameters, molding temperature and time.

III. MATERIALS AND METHODS

In general, the main substances in friction materials consist of fibers, fillers and binder. The binder consists of various types of resins such as phenolic, epoxy, silicone and rubber. The resin serves to bind the various constituent substances in the friction material. Binder can form a matrix at relatively stable temperature.

A. Fibers

Reinforcing fibers are used to provide mechanical strength. Steel wool, also known as wire wool or wire sponge, is a bundle of strands of very fine soft steel filaments. It is used as an abrasive in finishing and repair work for polishing wood or metal objects, cleaning household cookware, cleaning windows, and sanding in light painting. Steel wool is made from low-carbon steel. Steel wool is a metallic material which has an excellent structural reinforcement property and high thermal stability which are indeed required to improve the performance of the brake pad.

B. Binders:

Binder holds components of a brake pad together. Thermosetting phenolic resins are commonly used, often with the addition of rubber for improved damping properties. Phenolic resin is invariably used as binder in friction materials due to good combination of mechanical properties such as high hardness, compressive strength, moderate thermal resistance, creep resistance and very good wetting capability with most of the ingredient. The high hardness of the phenolic resin is attributed to the increase in the hardness during curing process.

C. Frictional Modifiers:

Frictional additives determine the frictional properties of the brake pads and comprise a mixture of abrasives and lubricants. The literature shows that graphite powder when used as friction modifier helps in improving the thermal conductivity of the composite brake pad material. Zirconium silicate is also widely used material as friction modifiers in brake pads.

D. Fillers:

Fillers are used to reduce the cost and improve the manufacturability of brake pads. Different minerals such as mica and vermiculite are often employed. Barium sulphate is another commonly used fillers.

Sample Preparation-

The fabrication of composites containing seven ingredients is based on keeping parent composition of 5 ingredients (around 64 vol. %) constant and varying two ingredients, namely steel wool and barite (around 36 vol. %) in complementary manner as shown in table 4.1 based on a systematic increase in steel wool (4, 8, and 12 vol. %).

The three samples S_1, S_2, S_3 are prepared in the size having dimensions 8mm diameter and 32 mm length. The samples are manufactured by dry-mixing, pre-forming, hot press molding, post-curing and heat treatment. All the brake pad materials are cut into specimen size of 8 mm diameter and 32 mm length as shown in Fig. 4

Fig.4 Samples of Composite

The compositions of the developed composite samples are given in Table 1. The steel wool and barites are varied by keeping other materials fixed.

Table 1 Composition of the sample

Sr. No.	Ingredient (Vol. %)	S_1	S_2	S_3
1	Steel wool∗	4	8	12
2	Phenolic Resin	36.5	36.5	36.5
3	NBR rubber	8.5	8.5	8.5
4	Synthetic graphite	10	10	10

5	Zirconium silicate	2	2	2
6	Synthetic barites∗	32	28	24
7	Vermiculite	7	7	7
	Total	100	100	100

IV. EXPERIMENTATION AND SET-UP

The experimental set up includes all hardware and software needed to collection of all necessary data and analysis of obtained data. The Wear and Friction Monitor TR 20 LE-PHM-400 DUCOM is as shown in figure with following specifications.

Table 2 Specification of friction & wear machine

Sr. No.	Parameters	Values
1	Specimen Size	3 to 12mm diameter 25 to 30 mm length
2	Disc Size	165 mm × 8 mm thick
3	Wear Track Diameter	50 mm to 140 mm
4	Sliding Speed Range	0.5 m/s to 10 m/s
5	Normal Load	5N to 200N Max.
6	Disc Rotating Speed	200 to 2000 rpm
7	Friction Force	0 to 200 N
8	Wear Measurement Range	-2000 micrometer to 2000 micrometer
9	Temperature	Ambient to 400°C
10	Environmental & Lubrication Chamber	Top Portion Detachable for clamping the Specimen : Tests for Dry, Heated & Lubricated Conditions

Friction tests are performed on this test rig. It is fully computerized and is programmable to study friction reaction against speed, load, temperature, and wear. The test rig uses gray cast iron disc with give specification in chart and a brake pad sample in the form of pin of different diameter & length. Each test sample was mounted on load arm and pressed against the rotating disc. The sliding speed of rotating cast iron disc was varied from 191 to 955 rpm and the test duration was 10 minutes. The surface of the sample and disc was grounded with 320-grid sand paper before beginning the test. The normal load was varied from15 to 100 N to achieve a constant friction force. The frictional coefficient was calculated by measuring the normal and shear forces every 5 seconds over the entire duration of the test. The total wear of the samples was measured from digital readout on the display panel. The temperature sensors were used to record the temperature of the contact interface during the test and temperature was maintained with the help of controller.

According to the ANOVA technique the three important factors load, speed & temperature were considered as experimental constant variables. The variation of parameters is shown in table.

Table 3 Operating variable factors and their levels

Sr.No.	Parameter	Unit	Levels		
			Level 1	Level 2	Level 3
1.	Load	N	15	50	100
2.	Speed	RPM	191	477	955
3.	Temperature	^oC	150	200	250

The values of these parameters are varied from minimum, average to maximum limits as shown in above table. By considering different combinations of these parameters and limits $(3)^3 = 27$ experiments were conducted. The experiments were conducted to determine coefficient of friction and wear rate at different working environment.

Fig.5 Friction Wear Monitor with Computer & Display Panel

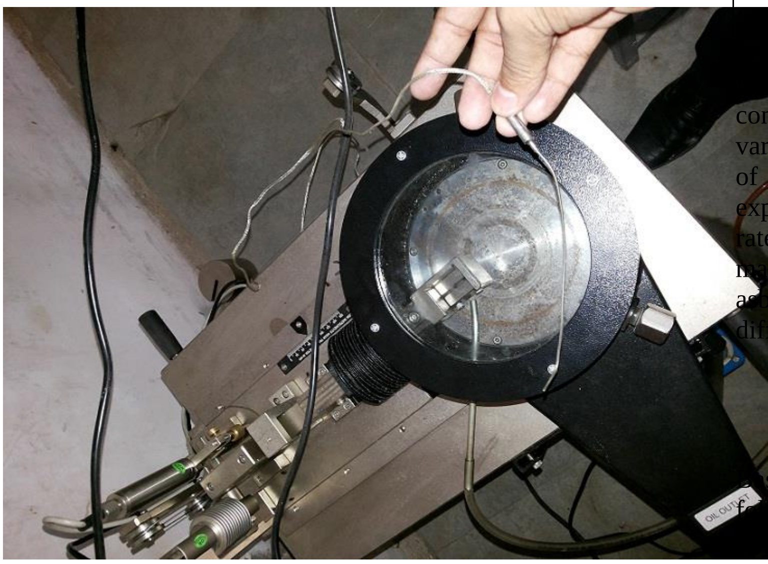

Fig.6 Friction & Wear Monitor With Temperature Probe

V. RESULTS

After conducting ANOVA analysis for optimization of parameters for four samples it was found that the parameter load has more contribution as compared to other factors for significant change in COF but less for change in wear rate. The range for COF is noted 0.3- 0.7 and wear rate is 0.001 - 0.005 mm^3/km. The results of ANOVA analysis for all samples are as shown in following table.

Table 4 Percentage contribution of parameters to wear rate

Parameter	SW1	SW2	SW3
Load	25.62	28.47	37.30
Sliding speed	35.54	40.47	27.54
Temperature	41.52	45.96	49.42

Table 5 Percentage contribution of parameters to COF

Parameter	SW1	SW2	SW3
Load	25.62	28.47	37.30
Sliding speed	35.54	40.47	27.54
Temperature	41.52	45.96	49.42

From this table we can see that for sample 1 has the contribution of load for variation of COF is maximum and for variation of wear rate it is minimum. Thus we get large value of COF & smaller wear rate in sample 1. From the experimentation it is observed that the range of COF & wear rate is showing equivalency with the other conventional materials which are previously used as friction materials like asbestos, banana pills, fibers of metal, carbon, glass, Kevlar different mineral and ceramic fibres etc.

VI. CONCLUSION

Based on the exhaustive experimentation analysis, the following conclusions are drawn.

1. The results shown that wear rate increases with increasing the sliding speed, load, temperatures.
2. The ANOVA analysis has shown that the variable speed is most significant factor affecting wear followed by load and temperature.
3. The variable speed and temperature are found to be most significant parameter affecting coefficient of friction.
4. Sample 1 is optimum as compared to other samples as we know that for disc brake application the COF should be as maximum as possible and wear rate should be as minimum as possible.

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