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A Review paper on alternate materials for Asbestos brake pads and its characterization

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Abstract -***Studying about alternate materials for brake pads is necessary as the asbestos brake pads causing the carcinogenic effects and these are phased out. There are so many alternatives for asbestos are investigated from different journals. In this review paper some of the most suitable environment friendly and best performed compositions are presented. Fibers made up of agricultural wastes like banana peels, palm kernel shells, palm wastes, rock wool, aramid fibers, flax fibers etc are studied. Different alternatives for filler materials, Different binders like phenolic resin, epoxy resin are also studied and it effect on the performance of brake pads are presented. Formulations that are made by varying compositions of filler, fiber, binder etc and possibility of replacing the existing formulations and its effect on the physical and tribological properties of the brake pad are studied.***

Key Words: *Asbestos, fiber, filler, binder, phenolic, epoxy etc.*

1. INTRODUCTION

A brake plays a vital role in any automotive vehicle so as to slow down the vehicle or to stop the vehicle completely. During the application of brake, friction between brake pads and rotating disc causes to stop the vehicle by converting kinetic energy of the vehicle into heat energy. Therefore the brake pads should quickly absorb heat, should withstand for higher temperatures and should not wear. The brake pad material should maintain a sufficiently high friction coefficient with the brake disc, not decompose or break down in such a way that the friction coefficient with the brake disc is compromised at high temperatures and exhibit a stable and consistent friction coefficient with the brake disc. In past years asbestos is used in brake pads. But asbestos causes carcinogenic effects on human health. It leads to the investigation on new materials particularly agricultural residues or wastes are now emerging as new and inexpensive materials in the brake pads development with commercial viability and environmental acceptability for brake pad which possesses all the required properties. There are metallic, semi metallic and organic brake pad materials.

Generally brake pad consists of a composition of reinforced fibers ,binder, fillers, friction additives. All these constituents are mixed or blended in varying composition and brake pad material is obtained using different manufacturing techniques. Reinforced fibers increase mechanical strength to the friction material. The purpose of a binder is to maintain the brake pads structural integrity under mechanical and thermal stresses. It holds the components of a brake pad together and to prevent its constituents from crumbling apart. Fillers in a brake pad are present for the purpose of improving its manufacturability as well as to reduce the overall cost of the brake pad. Abrasives and lubricants are considered as friction additives, abrasives in a friction material increase the friction cofficient. They remove iron oxides from the counter friction material as well as other undesirable surface films formed during braking. Lubricant stabilizes developed friction coefficient at high temperature.

In the present review paper different environment and healthy friendly alternative materials for asbestos brake pads are provided and their preparation, properties etc are studied. The materials varied are the filler materials like dolomite, $CaCO_3$ etc, some agricultural wastes are studied to provide them as a fibers and binder also changed like phenolic or epoxy resin.

2. LITERATURE REVIEW

K.K. Ikpambese et-al[1] prepared brake pad material using natural fiber called palm kernel fibers (PKFs) for its eco friendly nature with $CaCO_3$, graphite and Al_2O_3 as other constituents. Epoxy resin is used as binder. Composition of 40% epoxy-resin, 10% palm wastes, 6% Al_2O_3, 29% graphite, and 15% calcium carbonate gave better properties than other composition. The results were compared with commercial asbestos, palm kernel shells.Results shown that PKF can be suitable for replacement of asbestos brake pads with epoxy resin as a binder.

C.M.Ruzaidi et-al[2] incorporated the waste material, palm slag as filler material along with $CaCO_3$ and dolomite in brake pad material to increase the performance to cost ratio. The final composition is made using steel fibres, phenolic resin and other friction additives. Results shown that even though the dolomite brake pad composite had the highest strength, it showed poor wear behavior compared to calcium carbonate and palm slag. Thermal stability of the palm slag material shown the better performance compared to other two filler material in the range of 50°C to 1000°C. It is proven that phenolic resin cannot be used at high temperatures since curing of binder starts at a temperature of 150°C caused for the weight loss.

C.M.Ruzaidi et-al[3] has studied mechanical properties and wear behavior of brake pads produced from palm slag. In this paper the composite formed after the hand hydraulic pressing is further compacted and cured using a hot press at 150°C with different processing pressures: 10, 20, 40, and 60 tons of compression molding pressure for 5 minutes. Results shown that hardness and compressive strength is higher for the composite which is pressed under 60 tons of compression and wear rate is low for the same. Based on the mechanical and wear properties, this research indicated that palm slag can be used effectively as an alternative to other fillers in brake pad composites. The compactness of the palm slag brake pad composite, a result of the processing compression load, plays an important role in enhancing the mechanical and wear properties of the product.

A.O.A. Ibhadode et-al[4] used palm kernel shells (PKSs), an agro waste material as friction lining material for the application of brake pads. Among other agro wastes like hyphaene thebaica kernel shell (HTKS); and deleb palm kernel shell (DPKS) PKS shown better performance after a series of tests. The mechanical and physical properties compare well with commercial asbestos-based friction lining material. Its performance under static and dynamic conditions compare well with the asbestos-based lining material. However, further refinement of the PKS lining formulation is recommended in order to have a comparable wear rate at higher vehicular speeds.

IDris et-al [5] produced a new brake pad using banana peels waste to replaced asbestos and phenolic resin 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 (BUNCp) and 30 wt% carbonized (BCp) 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.

Poh Wah lee et-al[6] studied the friction and wear performance of Cu-free and Sb-free environmentally friendly automotive brake friction materials with natural hamp fibers and geo polymers as a fraction replacement of synthetic kevlon fibers and phenol resins respectively. Using geopolymer in the brake materials reduced the amount of phenol resin, which will release volatile organic compounds (VOCs) when pads are subjected to temperatures higher than 300°C. The Dynamometer results shown that the modified samples had better performance when compared to the T-baseline(Cu, Sb based). However, the modified samples exhibit higher wear rate than the T-baseline.

Yun Cheol Kim et-al[7] investigated the tribological properties of phenolic resin, potassium titanate whiskers, and cashew nut shell liquid (CNSL) cured by aldehide using a pad-on-disk type friction tester. Mixture of aramid pulp, rock wool, potassium titanate is used as fiber. But in this study, only the effects of phenolic resin, potassium titanate, and CNSL on the physical properties of the friction material were investigated. The average coefficient of friction is decreased when the amount of potassium titanate is increased. Phenolic resin increased coefficient of friction but causes for the high noise propensity. While noise occurrence reduced by increasing the CNSL and potassium titanate as friction material.

C.M.Ruzaidi et-al[8] investigated the development of asbestos free brake pad composites using different fillers (palm slag, calcium carbonate and dolomite) with phenolic as binder, metal fiber as reinforcement, graphite as lubricant and alumina as abrasive. Three types of composites were prepared by compression molding of mixture of three separate fillers. The result showed that palm slag has significant potential to use as filler material in brake pad composite. The wear rate of palm slag composite was comparable with the conventional asbestos based brake pad. The result also supported by SEM micrograph. Palm slag and calcium carbonate ($CaCO_3$) brake pad composite shown better wear properties than dolomite and comparable with the conventional asbestos based brake pads.

M.A.Maleque et-al [9] used natural fiber reinforced aluminum composite, coconut fibers as filler or fiber along with aluminum composite with phenolic resin as binder. Composite is made using powder metallurgy technique. The better properties in terms of higher density, lower porosity and higher compressive strength were obtained from 5 and 10% coconut fiber composites. The compressive strength showed the 10% coconut fiber exhibited higher strength to withstand the load application and higher ability to hold the compressive force. From the morphological study of the materials, it was found that the coconut fibre well distributed to the matrix and acts as filler in the friction materials.

Zhezhen fu et-al[10] developed Eco-friendly brake friction composites which are composed of plant flax fiber, mineral basalt fiber, and wollastonite as reinforcements, natural graphite as solid lubricant, zircon as abrasive, vermiculite and baryte as functional and space fillers, and cardanol based benzoxazine toughened phenolic resin as binder. Vermiculite acts as noise reduction agent. The friction sample without flax fibers shows slightly higher friction coefficient than the samples containing flax fibers at lower temperature. Also the effect of temperature on friction coefficient indicates that the fade phenomenon appears at higher temperature and higher content of flax fibers. Therefore, the optimal amount of flax fibers led to the stable and suitable friction coefficient. It is evident that at higher temperature, the wear resistance of friction samples containing flax fibers was enhanced significantly due to ductile fracture and char formation of the natural fibers at elevated temperature.

T. Singh et al [11] designed, fabricated and characterized the hybrid phenolic friction composites based on lapinus–aramid combination. Even though aramid pulp has peculiar characteristics like better fibrillation with most of the ingredients; ease processing aids by imparting better pre-form green strength it loses its strength at elevated temperatures. Lapinus/volcanic rock fibre inherently comprises of metallic-silicates(viz. mixture of SiO_2 ,CaO + MgO ,Fe_2O_3,Al_2O_3). It possesses good dispersion property, reduces sensitivity to cracking and blistering during molding/post-curing, possess heat resistant up to 1000°C. It uses phenolic resins of NOVLAC type as binder, barites and graphite as other compositions. The results also shown that the increased lapinus content with corresponding decrease in aramid content were observed to be effective to enhance the friction -performance, fade performance and stability coefficient of the friction composites, however wear performance, recovery performance, friction fluctuations and variability in friction coefficient get deteriorates.

Kunal singha [12] reviewed on basalt fiber as it is now being a popular choice for the material scientist for the replacement of steel and carbon fiber. Industrial production of basal fibers on basis of their new technologies made its cost equal or even less than the glass fiber. Basalt originates from volcanic magma and flood volcanoes, a very hot fluid or semi fluid material under the earth's crust, solidified in the open air. Chemical composition of basalt rock contains oxides of Si, Mg, Al, Fe, Na, K, Ti, Mn, Cr etc. Due to its high temperature resistance it can be used as substitute for asbestos in brake pads. If acidity modulus M_s >1.5 then it is called rock wool fiber. Basalt fiber possesses low weight to strength ratio, better abrasion resistance, hardness, thermal properties but poor bending property. Comopsites can be made by using basalt fiber.

Arnab Ganguly et al [13] prepared new composite material consists of phenolic resin along with epoxy resin as tougheners to overcome the brittle nature which is caused by phenolic resin. Graphite and silica flour are added to act as anti-wear additives and the addition of silicone resins acts as a fire retardant. The cashew nut resin is added to improve the temperature resistance of the composite. The composite synthesized was characterized using SEM (scanning electron microscopy) technique. The samples were subjected to a number of tests including a wear test, 'thermo gravimetric analysis'. It was also found to exhibit exemplary friction and anti-wear characteristics along with providing high temperature stability. The constituents used in the composite are extremely economical and are hence appropriate for industrial applications.

P.V.Gurunath et al[14] used newly developed resin in brake pad materials due to phenolics suffer from serious drawbacks and limitations such as evolution of noxious volatiles (viz. NH_3(ammonia), HCHO(formaldehyde), etc.) during ambient temperature curing, very short shelf life. Results are compared with the resin that is capable of heat induced ring opening polymerization is made in the laboratory with the traditional Novalc phenolici resin., it was concluded that the composites based on newly developed resin showed superior performance to the composite based on traditional phenolic resin. These features, however, reflect the performance of materials in severe operating conditions where surface temperature of pads may exceed 400°C. It indicated large potential to replace the commercially used phenolic resins. The laboratory scale preparation studies also indicated the cost of synthesis of the new resin is comparatively lower than the phenolics. During the experiment they noted that there is no correlation between strength properties of resins, composites and their wear behavior.

3. EXPERIMENTAL PROCEDURE

3.1Preparation of the raw materials:

Agricultural wastes that are available cannot be directly used for final application in brake pad formulation. So some chemical and mechanical treatments are necessary before using them in brake pad composition. Here are some treatments presented for natural fibers based up on the literature.

1.Palm kernel fibers[1]: Palm kernel fibers (PKFs) were collected and suspended in a solution of caustic soda (sodium hydroxide) for twenty four hours to remove the remnant of red oil left after extraction. The fibres were then washed with water to remove the caustic soda and sun dried for one week. The dried PKFs was grounded into powder form using a Hammer mill and was thereafter sieved using sieve size <100 μm aperture.

2. Banana peels[5]: The banana peels was dried and ball mill at 250 rpm to form banana powder (uncarbonized, BUNCP). The powder was packed in a graphite crucible and fired in electric resistance furnace at temperature of 1200°C to form banana peels ash (carbonized, BCp).

3.Coconut fibers[9]: Four different combinations (such as BP1, BP2, BP3 and BP4) were prepared with varying coconut fibre contents from 0, 5, 10 and 15 volume fraction along with binder, friction modifiers, abrasive material and solid lubricant using powder metallurgy technique for the development of natural fibre reinforced aluminium automotive brake pad materials. The coconut fibre was used as a filler material. This was collected from waste coconut fruit and cleaned thoroughly using ethanol to remove impurities. It was crushed and ground to a fine powder (with a range of 100-200 μm), and sieved using crusher machine.

4. Flax fibers[10]:Flax fibers were treated by drying at 80C for 30 min, 12% NaOH solution at room temperature for 1 h, and 1M HCl steam for 30 min.

Aramid fibers, lapinous fibers[11], basalt fibers[12] etc can be directly used for formulating the brake pad composite without any chemical treatment.

3.2Preparation of the Brake pad composite:

Once the chemical treatment and mechanical treatment for raw materials is over, the final composition is made with other ingredients like filler, fiber, binder, frictional additives etc in different formulations. A sample formulation for palm slag wastes is shown in Table 1. Each formulation is mixed to obtain a homogeneous mixture of ingredients. Then, the mixtures are compacted at a pressure of 15-17 MPa using a unaxial, hydraulic hand-press machine for the green body of the brake pad composite Then, the green body was compacted further and cured using a hot press at 150 °C with 60 tons of compressive molding pressure for five minutes. At the end of the hot-pressing process, samples were taken out of the molds, allowed to cool to room temperature, and cured further at a constant temperature of 150 °C in air oven for four hours [13]. Final brake pads are as shown in Figure 1.

3.3 Testing and Analysis:

The mechanical properties of phenolic resin based brake pad composites were determined by a universal testing machine (UTM) at room temperature. Each sample, consisting of an initial cross-sectional area of 86.6 mm^2, was placed between the lower cross member and lower cross head of the UTM, and the load was applied at a cross-head speed of 5 mm/min. The load at which failure occurred was used to calculate the compressive strength of the sample. The Rockwell type E hardness values of the

Table -1: Material content (% wt) in the brake pad composite [13]

Materials	Formulation 1	Formulation 2	Formulation 3
Phenolic Resin	20	20	20
Palm slag	40	--	--
$CaCO_3$	--	40	--
Dolamite	--	--	40
Graphite	10	10	10
Steel fiber	20	20	20
Alumina	10	10	10

Figure 1 Sample brake pad after final finishing

friction composite samples were obtained using a digital Rockwell hardness tester. A sample with a diameter of 10 mm was used to carry out the test at different filler. The test was conducted using a 1/8-inch-diameter steel ball indenter with a load of 100 kgf[13]. Brake pad test rig was used to determine the pads wear, disk temperature rise and disk stopping time. Figure 2 shows the schematic diagram of the brake pad test rig. It has a 2.2kW motor with a provision for speed variation by using a stepped pulley. The motor provides the energy required to set the flywheel weights and the brake disc in angular motion. When a set of brake pad is fixed into the brake caliper assembly of the test rig, the system is switch-on and the drive shaft begins to rotate, it is then allowed to attain a desired speed. Thereafter, a manual force is applied on the brake pedal which is similar to that of a motor car. Subsequently the stopping time, temperature of the disc and brake pad material lost are recorded. The speed and brake line pressure ranges were: 6.66 m/s to 13.82 m/s and 0.2 – 0.6 MPa respectively for the test conditions [4].

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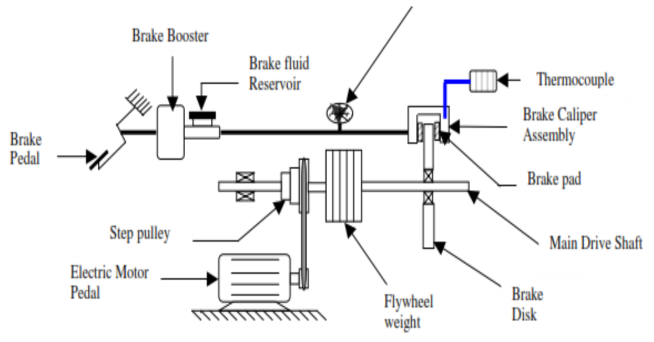

Figure 2: Schematic representation of the Brake pad test rig [4]

4. RESULTS AND DISCUSSIONS

4.1 Density and porosity of brake pad composite with coconut fibers [9]:

A density measurement test has been carried out on a laboratory scale to examine the density of the material after sintering. Density is depends upon the ingredients in the pad material. A metallic element will have a higher density than an organic element. Friction elements often exist in combination of various elements. The results shown in Figure 3 are the average density of three readings for each formulation. It is seen from Figure 3 that the density of the 15 % coconut fibre(BP4) composite shows lower than 0% coconut fibre(BP1) which have more coconut fibre. However, formulation BP1 has better properties because of having higher density with the value of 2.176 g/cm^3. This formulation has no coconut fibre in its constituents, hence, shows higher density of this composite material. The formulation, BP2 shows the second highest density with the value of 2.099 g/cm^3.

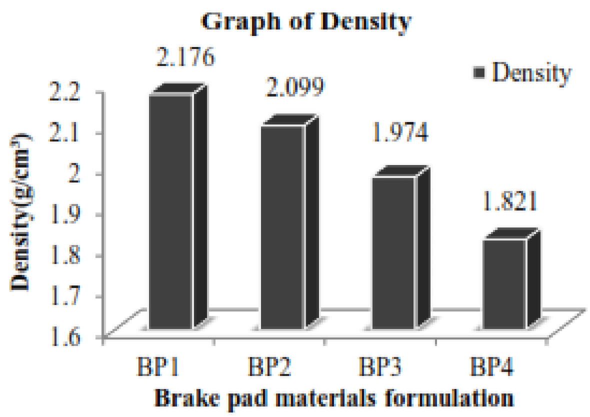

Figure 3: Density of materials

Figure 4 shows the porosity test results for all formulations of brake pad materials. Porosity plays an important role in automotive brake pad materials .The function of porosity is to absorb energy and heat. This is a very important for the effectiveness of the brake system. Theoretically, lower porosity will result in higher friction coefficient and wear rate due to higher contact areas between the mating surfaces. Brake pad should have a certain amount of porosity to minimize the effect of water and oil on the friction coefficient and increasing porosity by more than 10% could reduce the brake noise. Porosity, a gross measure of the pore structure, gives the fraction of total volume which is void. The pore structure should be preserved during specimen grinding and polishing. Distortion by excess working will smear material over the pores, giving the appearance of a low porosity (German, 1997). From the porosity results as shown in Figure 4 it can be seen that two brake pad formulations such as, 5 and 10 % of coconut fibre composite shows lower percentage of porosity compared to other two.

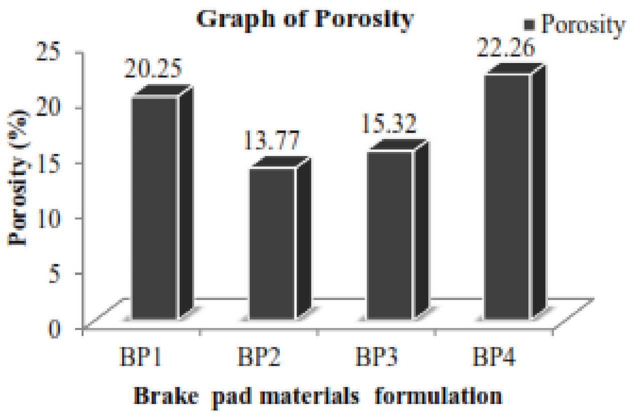

Figure 4: Porosity of materials

4.2 Effect of phenolic resin on properties of the brake pad with banana peels [5]:

As the weight fraction of resin increased wear rate decreases in the banana peels particles. This may be attributed to higher/ closer packing of the microstructure which has affected stronger bonding of banana peels with resin. Also due to high hardness values and compressive strength of the samples as the resin addition increased in the banana peels particles (Blau,2001; Aigbodion and Akadike, 2010). The coefficient of friction of the samples increases as the wt% of resin increased in the formulation. Again the effect of uncarbonized banana peels particles shows a marked effect as higher friction was recorded for brake pad composites as the wt% of resin increased. The friction co-efficient fall within the industrial standard ranges of 0.3– 0.45 for automotive brake pads system (Dagwa and Ibhadode, 2005). The results of this work indicates that sample containing 25 wt% in BUNCp and 30 wt%BCp gave better properties than other samples tested. Hence, the increase in wt% of resin in the banana peels particles, the better the properties. These grade of results were compared with that of commercial brake pad (asbestos based) and optimum formulation laboratory brake pad (Palm Kernel Shell based (PKS) and bagasse as shown in the Table 2 which were tested under similar conditions

Table 2 :Properties of different agricultural wastes fibers for brake pad composites [5]

Properties	Commercial Brake pad (asbestos based)	Laboratory Formulation (Palm Kernel Shell)	Laboratory Formulation (bagasse)	New Laboratory Formulation (banana peels uncarbonized at 25% resin)	New Laboratory Formulation (banana peels carbonized at 30% resin)
Specific gravity (g/cm^3)	1.89	1.65	1.43	1.26	1.20
Wear rate (mg/m)	3.80	4.40	4.20	4.15	4.67
Friction coefficient	0.3-0.4	0.440	0.420	0.40	0.35
Hardness values (HRB)	101	92	100.5	98.8	71.6
Compressive strength (N/mm^2)	110	103.5	105.6	95.6	61.20

5. CONCLUSIONS

In this review paper different agricultural wastes are studied as alternative for asbestos brake pads. The results are shown that the performance is almost equal to asbestos brake pads without any environment and health effects. Chemical and mechanical treatments of raw materials for using them in formulation are presented. For having better physical properties, brake pads with coconut fibers are studied and their composition percentage is optimized. Increasing the percentage of phenolic resin to the composition made up of banana peels increases tribological properties but excessive addition causes poor shelf life, evolution of noxious volatiles etc. Alternatives for phenolic resins like newly developed resin, epoxy resin etc are studied

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