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REVIEW OF AUTOMOTIVE BRAKE FRICTION MATERIALS

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Abstract- *The gradual phasing-out of asbestos in automotive brake friction materials in many parts of the world has sparked the onset of extensive research and development into safer alternatives. As a result, the brake friction industry has seen the birth of different brake pads and shoes in the past decade, each with their own unique composition, yet performing the very same task and claiming to be better than others. This suggests that the selection of brake friction materials is based more on tradition and experimental trial and error rather than fundamental understanding. This review strives to eliminate the cloud of uncertainty by providing an insight into the pros and cons of the common ingredients and make-up used in contemporary friction pads and shoes. In this paper typical brake materials are reviewed and their advantages and disadvantages in contemporary brake applications are discussed.*

Keywords- *automotive brake friction materials; brake pads; brake shoes; wet and dry braking; brake wearness*

I. INTRODUCTION

A vehicle brake is a brake used to slow down a vehicle by converting its kinetic energy into heat. Brake system constitutes an integral part of an automobile. Failure of the automobile brake system may lead to accidents, property damage, physical injuries or death of an individual.

The major components of brake system are calipers, drum brakes, master cylinder, and hydraulic boost units, rotors, brake pedal, cables pipes, hoses, sensors and electronic systems controlling the operation of brakes. Brake lining materials generally are asbestos, metals, non - asbestos organic (NAO) such as palm kernel shell (PKS), and ceramics. Asbestos during application releases the hazardous gases, which causes damage to the health [3].

The main element is used for brake lining from palm kernel shell (PKS) which is agro - waste. The average disk temperature and average stopping time for pass is increased and it has poor dimensional stability. Hence it has lost favour and several alternative materials are being replaced these days [1, 3].

This review paper will summarize the current components used in automotive brake friction material for braking.

II. BASIC INTRODUCTION TO BRAKE FRICTION MATERIAL

During braking the heat energy is first borne by the two contact surfaces of the brake namely the brake disc and the brake pad (or drum and shoe in the case of drum brakes) and is then transferred to the contacting components of the brake such as the calipers of the brake as well as surroundings.

The demand on brake pad are Maintain a sufficiently high friction co-efficient with the brake disc and no decompose with the brake disc is compromised, at high temperatures as well as exhibit a stable and consistent friction co-efficient with a disc brake.

Brake pad comprise the following subcomponents are;

A. Friction additives – which determine the frictional properties of brake pads and comprise a mixture of abrasives.
B. Fillers – which reduce the cost and improve the manufacturability of brake pads.
C. A binder – which holds components of a brake pad together.
D. Reinforcing fibers which provide mechanical strength.

Properties of good material for brake lining High frictional coefficient, Super thermal conductivity, High thermal diffusivity, Low mass, High wear resistance, Low noise susceptibility, No expensive, Easily available, Avoids damage to the braking surface, Eliminates cosmetic issues and Eliminates corrosion related judder.

Variation of wear and friction; The friction and wear behaviours of brake materials are very complex because of variable speeds and loads, dissipation of energy and temperature rise. The coefficient of friction decreases with the increase in temperature. Wear increases with the increase temperature.

III. DRY AND WET FRICTION MATERIALS

The materials used in formulating friction linings where the frictional contact surfaces are intended to be dry most of the time even though they may be unintentionally lubricated (such as braking a car in the rain). The four main components of a brake pad are reinforcing fibres, binders, fillers and frictional additives. It is important to note that certain substances perform multiple function and may be placed in more than one classification.

The friction materials that are designed specifically for use in a wet environment only, such as wet clutches and oil – immersed brakes. This is in contrast to the dry friction materials which are meant to be operating mostly under dry condition but also under wet conditions (such as braking a car in the rain). Wet friction materials generally comprise three different types.

The selection and production of composite brake pad with varied constituent's composition from Bashar dan asabe et al. [14]. Series of tests were conducted that involved tensile, compressive, hardness, impact, wear and corrosion to ascertain composition with the best property as compared to a commercial Honda brake pad (Enuco) model. The results shows that higher percentage of grounded coconut shell powder induces brittleness since compositions with lower percentage of it produced higher breaking strength and lower wear rate. It was also established from the tests results that compositions 4 and 5 have an overall better mechanical and corrosion resistance property than the model with composition 4 having the least wear rate effect.

The range and material for development of brake liner composition from Arun Bhuneriya et al. [16]. Range and material for development of brake liner composition has been taken as per IS code 2472 applicable on automotive brake liner. Present paper investigate that the selection of brake friction materials is based on as per regulation of Public Safety Standards of the Republic of India code IS 2472. A composite material with minimum wear rate and maximum coefficient of friction as compared with that of similar materials available for the same application. A reduction in wear and increase in coefficient of friction shall yield an increased life of brake liner together with good frictional resistance.

IV. FRICTION MATERIALS

A. Asbestos

Asbestos become the major material for friction material composition over eight decade and become more wide spread during the industrial revolution in1866. Asbestos were from Greek word which mean "unquenchable" or "inextinguishable" is a set of six naturally occurring silicate minerals exploited commercially for their desirable physical properties.

B. Kevlar or Aramid

The use of non-metallic friction material seems to become the solution forth asbestos friction material. Friction material made from Kevlar or aramid fiber.

Aramid fiber (a generic expression denoting fiber made from the condensation product of isophthalic orterephthalic acids and morphenylene diamine such as Kelvar fibre sareal so widely used as reinforcing fiber ,but they are a deferent class of fiber in that the relatively so fiber. They are very light an excellent thermal stability, with a very good stiffness to weight ratio.

C. Fibertuff

Fibertuff is a product designed to give the wear of a ceramic facing, yet have the engagement and disengagement qualities of an organic material. Fibertuff intended to wear against its mating surfaces like organic material. Used primarily in the stamped steel and cast units, this product offers greater life than organic material with many of the same qualities that organic friction has traditionally offered. Around-town delivery trucks and mid-range applications find that this product works best.

D. Another materials-

- A non – asbestos friction material was developed using an agro – waste material base - palm kernel shell (PKS) along with other constituents from A.O. A. Ibhadode et al. and K. Deepika et al. respectively [1, 3]. Taguchi optimization technique was used to achieve optimal friction material formulation and manufacturing parameters. 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 [1, 3].

From both results suggest that palm kernel shell could be a possible replacement for asbestos in friction lining materials. We can improve the properties further by changing the composition of a brake pad material (PKS).

- Bronze-based powders and Al_2O_3 reinforced break linings material by Mustafa Boz et al. [2]. The highest friction coefficient was obtained in the samples containing Al_2O_3 in the range of 4% due to an increase in the temperature during friction. The addition of 2% Al_2O_3 to the samples showed stable friction coefficient.

- Friction layer with the presence of potassium titanate from P. Filip et al. [4]. By determined using the Friction Assessment and Screening Test (FAST) and a full-scale single-ended inertial type disc brake automotive dynamometer test results show that the friction layer, with the presence of potassium titanate, significantly improved the overall performance.

- Iron oxide and graphite materials from W. Osterle et al. [6]. Solid lubricants like graphite affected the friction and wear behaviour of Fe_3O_4 powders considerably whereas further addition of hard nanoparticles induced only minor effects. The latter could be explained, after nanoscopic characterization, by oxidation and destruction of the wear-protecting tribofilm.

- Carbonized coconut char powder-based friction materials By M. Sutikno et al. [5]. carbon made from coconut char powders can replace the role of graphite or coal powders as fillers for brake friction materials. This is also an interesting new finding and a starting point to develop furthermore carbonized coconut char powder based-brake friction materials. To improve the tensile strength of fabricated brake friction materials, the fiber orientation and binder modification are necessary made.

- Palm kernel fibers with epoxy-resin binder by K.K. Ikpambese et al. [12]. Resins varied in formulations and properties such as friction coefficient, wear rate, hardness test, porosity, noise level, temperature, specific gravity, stopping time, moisture effects, surface roughness, oil and water absorptions rates, and microstructure examination were investigated.

  The conclusions are summarized as follows:

  1. That values of the necessary parameters obtained from PKFs are within (and even better) the standard requirement for commercial brake performance pad.
  2. Palm kernel fibre (PKFs) can be a suitable replacement to asbestos for brake pad production.

- kenaf fibres from Ashafi'e Mustafa et al. [13]. It performed using the Weighted Decision Matrix (WDM) method based on a formulated design and its requirements. Through all of the criteria and the constraints kenaf fibres are identified as being the most suitable material, which pass all the design requirements. The results show promising potential for kenaf fibres by capability on eco-aware with lower impact to the environment, is the lightest and the cheapest compared to other. . The results show promising potential for kenaf fibres by capability on eco-aware with lower impact to the environment, is the lightest and the cheapest compared to other.

- Al-Si (ADC12 & LM30) alloys from Sourav Das et al. [19]. The braking performance of the ADC12 and LM30 alloys is evaluated on the basis of experimental parameters such as coefficient of friction, rise in temperature, braking torque, rotational speed etc.

  The main outcomes are summarized as follows:

  1. Al-Si ADC12 and LM30 alloys are used to make brake drums and are tested in a dynamometer for their braking performance. The coefficient of friction between the liner and drum materials, rise in temperature in at the inner and outer surface, stopping distance and braking efficiency were found out at speeds of 700, 1000 and 1300 RPM at various applied loads.
  2. The coefficient of friction is found in the range of 0.35 to 0.45 under the present experimental domain.
  3. It is observed that higher the brake force lower is the stopping distance. The relation for speed is just reverse i.e., at higher speed the stopping distance is more. It may be mentioned that at a speed of 700 RPM and at a brake force of 20 N, the stopping distance is 8 m whereas, at 1300 RPM speed and 20 N brake forces, the stopping distance is 36 m which is approximately 4 times.

4. Braking efficiency is found as a function of brake force. The braking efficiency of LM30 alloy is 36 % at 5 N force is increased to 95 % when the brake force is increased to 20 N. However, speed does not have any correlation with the braking efficiency. ADC12 alloy shows lesser braking efficiency than LM30 alloy.

- Titanium alloys by Peter J. Blau et al. [20]. A titanium alloy rotor can weigh approximately 37% less than a conventional cast iron rotor with the same dimensions, while offering good high-temperature strength and much better resistance to corrosion from road-deicing salts. The thermally spray-coated Ti disc exhibited the least wear and merits further attention as a lightweight, corrosion-resistant brake rotor material.

- Cryogenic processing of grey cast iron from R. Thornton et al. [8]. Cryogenic treatment affects the whole cross-section of the component and is inexpensive compared to other treatment processes. The results indicate an improvement in the wear rate of grey cast iron of 9.1–81.4% due to deep cryogenic treatment where significant wear has occurred, although there was no significant change in the bulk hardness, matrix hardness or in the microstructure of the material under optical observation.

- Semi metallic friction material from Ashish D. Dhangar et al. [18]. To determine its functionality a wear test was conducted on a commercial brake pad at various pressure speeds and inertia load. This prototype test rig can be used in testing the brake pad of different vehicle such as Maruti, Tata, Nissan, Toyota, Mitsubishi, Volvo, Peugeot, and other brands of interest. With little modification, this product can be commercialized. The main outcomes are summarized as follows: 1>As the pressure increases wear of semi metallic disc brake friction material is increases. 2>The speed increased with decreasing wear180 rpm to 300 rpm and then starts increasing to 450 rpm. 3> Variation inertia load on wear of semi metallic disc brake friction material at various combination levels of speed, pressure. Wear increasing with increasing in inertia load.

V. TRIBOLOGY

Tribology is the study of the friction, wear and lubrication of engineering surfaces with a view of understanding surface interactions in detail and then prescribing improvements in given applications. One of the important objectives in tribology is the regulation of the magnitude of frictional force according to whether we require a minimum or a maximum frictional force.

Quantitative values for friction and wear in the forms of coefficient of friction and wear rate depend on the following basic groups of parameters:

1. The structure of the system, i.e. its components and their relevant properties;

2. The operating variables, i.e. load (stress), kinematics, time and temperature; Mutual interaction of the system's components.

A. Friction

Friction is the resistance to motion, which occurs whenever one body slides over another. Whenever there is contact between two bodies under a normal load W, a friction force is required to initiate and maintain relative motion. This force is called frictional force, F. Three basic facts have been experimentally established:

1. The frictional force, F, always acts in a direction opposite to that of the relative displacement between the two contacting bodies;

2. The frictional force, F, is a function of the normal load on the contact,

$$\mathbf{F = \mu F_N}$$

Where μ = coefficient of friction,
F_N = Normal Load

B. Wear

Wear is commonly defined as the undesirable deterioration of a component by the removal of material from its surface. It occurs by displacement and detachment of particles from surface. The mechanical properties of steel are sharply reduced due to wear.

VI. COMPARISON BETWEEN METHODS FOR MEASURING WEAR IN BRAKE FRICTION MATERIALS

Comparison between methods for measuring wear in brake friction materials by P.D. Neis et al. [9]. Three different techniques for measuring wear in brake pads are compared: a gravimetric method (electronic balance), a linear measuring touch probe method, and a three-dimensional laser scanning method. Laboratory-scale wear tests were performed on two different types of brake friction materials: a semi-metallic (SM) and a non-asbestos organic (NAO).

The main outcomes are summarized as follows:

- Both gravimetric and linear measurement methods showed a wear rate about 4 times higher for the SM material (considering 920 brakings), which also presented a higher magnitude in the coefficient of friction.
- SM material is around 5 times more hygroscopic. However, the proportion between moisture absorption and mass loss due to wear is 3 times higher for NAO.
- The increase of the contact pressure resulted in wear rate rises for both SM and NAO materials.

VII. CONCLUSIONS

In this paper, the advantages of several alternative materials for use as brake lining material were reviewed. In the case of the brake pads, the alternative material— aramid, is suitable for the required function of a friction pad material. It showed similar traits to the common material in use, asbestos (which has hazardous health effects), and is thus an appropriate replacement for it as a friction material in brake pads. Overall finally, the aluminum metal matrix composite, the results also showed that it is a best suitable alternative. Though the conventionally used grey cast irons are no danger to the health and are affordable, AMC has a lower density and higher thermal conductivity as compared to GCI and it results in weight reduction of up to 50–60% in brake systems.

The objectives of improve vehicle fuel efficiency and lower emissions will mean that brakes will have to be lighter and not release any toxic and carcinogenic substances into the atmosphere during use. This means that the choice of brake friction materials will need to be more environmentally friendly and not include toxic substances such as asbestos.

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