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EVALUATION OF NON-ASBESTOS BRAKE PADS USING YATES ANALYSIS

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ABSTRACT

Non-asbestos brake pads are a suitable alternative to asbestos-filled brake pads. The carcinogenic nature of asbestos necessitates this. Organic, non-asbestos brake pads were evaluated to attain their effectiveness at elevated temperatures of 250˚C, 260˚C and 270˚C. Using the Yates approach, asbestos-free (corn husk based) brake pads were subjected to a heating regime for 7s, 8s, and 9s. Microstructural examination, hardness and tensile tests were then carried out. The values obtained showed that approximately the overall hardness of the brake pad specimen did not change during use. This suggests that brake pads made using corn husks as filler for the given formulation maintain their microstructural and physical integrity at slightly elevated temperature.

KEYWORDS: Asbestos, Yates, Hardness, Microstructure, Brake pads, Fade.

INTRODUCTION

Brake pads are safety and performance components materials in automobiles. Brake systems decelerate a moving vehicle and must be designed, considering safety [1]. Modern automotive can generate extremely high temperatures under high but short duration braking loads or relatively light but continuous braking. The possibility of brake overheating is always present, especially in mountainous terrains and with overloaded vehicles [2].

One of the consequences is the temporary loss in braking ability known as brake fade. According to [3], 'fade' is the term used to indicate a loss of braking effectiveness at elevated temperatures because of a reduction in the kinetic friction coefficient (μ). The fade phenomenon in friction materials represents a deviation from amonton's friction law, and its occurrence reduces braking efficiency and reliability. The inverse temperature dependency of frictional shear loads at the interfacial zones brings out fade and reduces the braking efficiency.

Sherwood [4] characterised brake fade into three different types, including pad fade, green fade and fluid fade. At elevated temperature, friction material can disintegrate; therefore, they are designed to work at optimum temperature when the friction coefficient is highest. When the temperature is too high, friction linings change their surface characteristics; they begin to melt, inducing a lubricating effect adverse to the stoppage of a moving vehicle. Some materials change with time, and others lose friction so quickly. The result of this surface change is the glazing of the brake pads and rotors. Green fade is typical with new pads. This is caused by sudden braking on new pads, causing the polymer resin to outgas, leading to loss of braking function.

Green fade occurs at lower temperature and not bedding of the pad. Fluid fade is due to the overheating of the braking fluid. Elevated temperature caused by braking heats the brake fluid, which should be dispersed by the rotors, callipers, brake pads and fluid. The fluid boils at 400 ºF; more stable braking fluid can boil at 500 ºF or higher. The boiling fluid generates bubbles which are compressed when the pedals are pushed. This reduces the connection between the brake pads and the rotor because the brake pedal and master cylinder are used to compress air.

According to [5], the friction system of a brake pad against a cast-iron disc or drum has an enormous technical significance in the automotive industry. However, brakes have thermal limits. This limit depends on the amount of energy brake components must deal with and dissipate. Temperatures above the performance envelope of friction materials can lead to potentially fatal results [4]. Brake pads are made up of friction materials, which are composites formed by the compaction of coarse powders made of different components.

Usual formulations can consist of more than 10 ingredients with more than 300 materials. The materials used can be grouped into binders, fillers, frictional modifiers and reinforcement. The reinforcing fibre provides structural integrity; the friction modifiers stabilise the rate of wear and coefficient of friction; fillers fill the free volume, and the binders hold them all together. All perform specific functions within the composite but work in synergy [6].

Although asbestos has good engineering properties that make it suitable for inclusion in brake linings, its carcinogenic nature makes it undesirable, posing health risks such as lung cancer, asbestosis, mesothelioma, and other cancers. In this research, asbestos was replaced with corn husks as filler in brake pads. These non-asbestos brake pads were subjected to a temperature envelope above their theoretical safe value to evaluate their performance characteristics and test reliability in operation. According to [3], passenger cars operating temperature can go up to 200 - 370ºC, due to severe and repeated braking. This research aims to investigate and ascertain corn husks as a suitable alternative to asbestos by statistically analysing the effect of change in temperature on the physical properties of the brake pad at given composition and temperatures. This is significant in ensuring better reliability for passenger cars while encouraging the local automotive industry on the suitable alternative of agro-wastes in brake pad production.

Yates Analysis

The Yates analysis, named after the English Statistician, Frank Yates, was used to test for the effect of elevated braking temperature at different time intervals. The Yates analysis approach is useful in experimental designs to examine many factors under laboratory conditions. The analysis of these factors involves a randomised combination to test for the various factors simultaneously. The complexity of the approach involves that many possible factor combinations in a multi-factor experiment is a product of the levels of the single factors [7].

In this research, three factors, representing various hypothetical braking times of (7s, 8s and 9s) on three levels (low, intermediate and high), were used to test the impact of elevated temperature on the physical properties of the produced brake pad. These factors are above the average braking time for automobile depending on the velocity and rate of deacceleration as posited [8].

MATERIALS AND METHOD

Fabrication of Brake Pads

Frictional material is a heterogeneous material composed of few elements; each element has its function. Changes in the element types or weight percentage of the elements in the formulation may change the physical, chemical and mechanical properties of the friction material [1]. In this work, a friction material formulation was composed of five different ingredients –corn husks: the filler, graphite and silicon carbide, acting as friction modifiers; steel dust which is the reinforcing material and phenolic resin, the binder. The composite was developed using the powder metallurgy technique. The filler (corn husk) was collected from a farm, sun-dried, milled to pass through a sieve aperture of 100μm. The sieving was done using a set of sieves and formulation prepared (40% fillers, 31% friction modifiers, 15% reinforcement, and 14% binder). The binder consisting of the resin – hardener (64.3% to 35.7%) were poured into a container and mixed before pouring in the powdered friction ingredients and mixed homogenously to give a paste-like mixture. The paste was poured into a mould lubricated with talc to ease removal. The produced specimen was allowed to cure for 90mins [9], then kept in an aerated environment for 21 days to attain full strength due before carrying out the analytical tests. [10] and [11] kept specimens for 7days strengthening before mechanical tests.

Yates Approach

This experimental research aims to present corn husks as an alternative material to asbestos in brake pads production, showing its ability to retain its physical properties at a temperature above its theoretical performance envelope. Following Yates approach, specimens were subjected to elevated temperatures of 250ºC, 260ºC, 270ºC by heating in a Fisher Scientific 725F isotemp forced air convection laboratory oven for 7s, 8s and 9s (hypothetical braking time). The Yates procedure table using the 32 full factorial designs is shown in Fig 1. In a controlled approach, temperatures were allowed to rise to the desired temperature and then held steady for the given time interval before been taken out and allowed to cool under atmospheric conditions. The specimens were collected, classified and subjected to tests to determine their response in microstructure, hardness and tensile strength to temperatures slightly above their theoretical safe limits.

[1]Table 1: Yates procedure using the 3^2 full factorial design

Tests	Temperature Variable (T)	Roasting Time (t)	Treatment Combination
1	0	0	00
2	0	1	01
3	0	2	02
4	1	0	10
5	1	1	11
6	1	2	12
7	2	0	20
8	2	1	21
9	2	2	22

Tests Procedure

Microstructural Analysis

The microstructural analyses of the samples will be carried out by grinding the samples using 300, 400, and 600 grit papers, respectively. Dry polishing will then be carried out on these samples and the internal structures viewed under the computerised Metallurgical microscope [12].

Brinell Hardness Test

The hardness of the composites was evaluated using a tensometer (M500-25KN, Gunt Hamburg Hardness Tester and WP300). Based on BS240, a 10 mm diameter steel ball will be used, and the load applied P will be kept stable at 3000 kg/f. The indentation d will be measured along with two perpendicular directions, using an optical micrometre screw gauge. The average value will be taken and inputted into Eqn. 1 [13].

$$BHN = 2P \div \pi D\,(D - \sqrt{(D^2 - d^2)}\,) \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

P is the load applied; D, the diameter of the steel ball and d, the average depth of indentation.

Tensile Strength Test

The strength in tension was determined from the conversion tables of BHN values. The equation is shown below[12]:

$$HV = 1.854P \div d^{12} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Where: $$TS\,(Mpa) = 3.45 \times HB$$

$$TS\,(Psi) = 500 \times HB$$

HB is the Brinell Hardness value; P is the load applied, and d is the diameter of indentation.

RESULTS AND DISCUSSION

Tests were carried out on the specimens and the results obtained are discussed below:

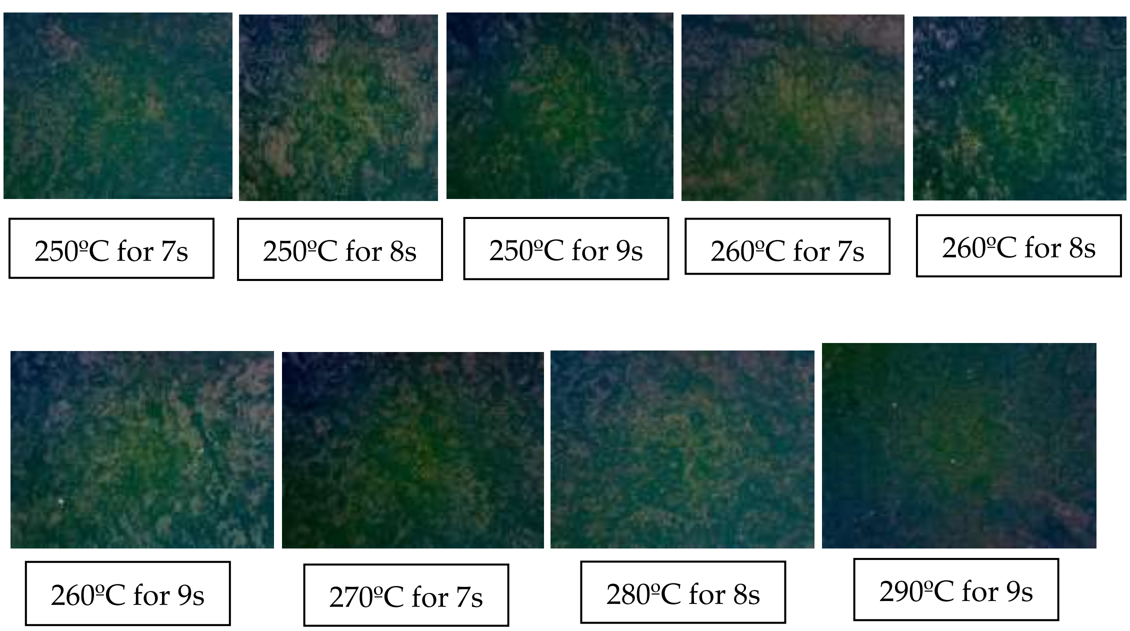

Plate 1: Micrograph of Samples

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Microstructural examination of the specimens shows little or no difference in the microstructure of the specimens. The increase in breaking temperature above the normal driving temperature of 200 ˚C - 250 ˚C, for passenger cars, according to [3], had little or no difference in the microstructure of the brake pads. This is a reflection of the structure, properties, processing connection. Silicon Carbide (SiC), a constituent material and steel dust, is a high-temperature resistant material. This helps to give good thermal stability to the brake pads, hence reducing the effect of brake fades on the pads. Plate 1 shows the various micrographs of the brake pads specimen of 100 µm sieve grade.

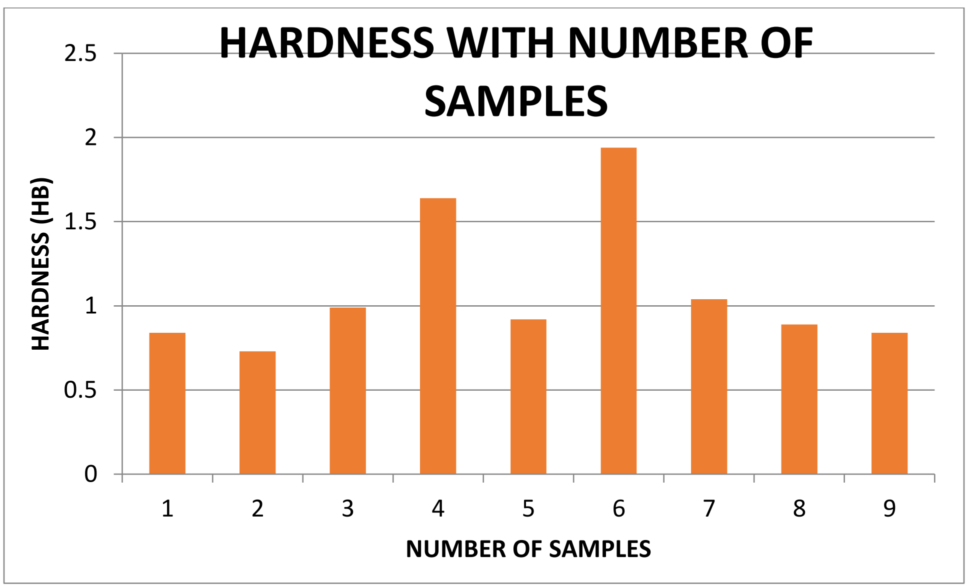

Figure 1: Hardness of Specimens

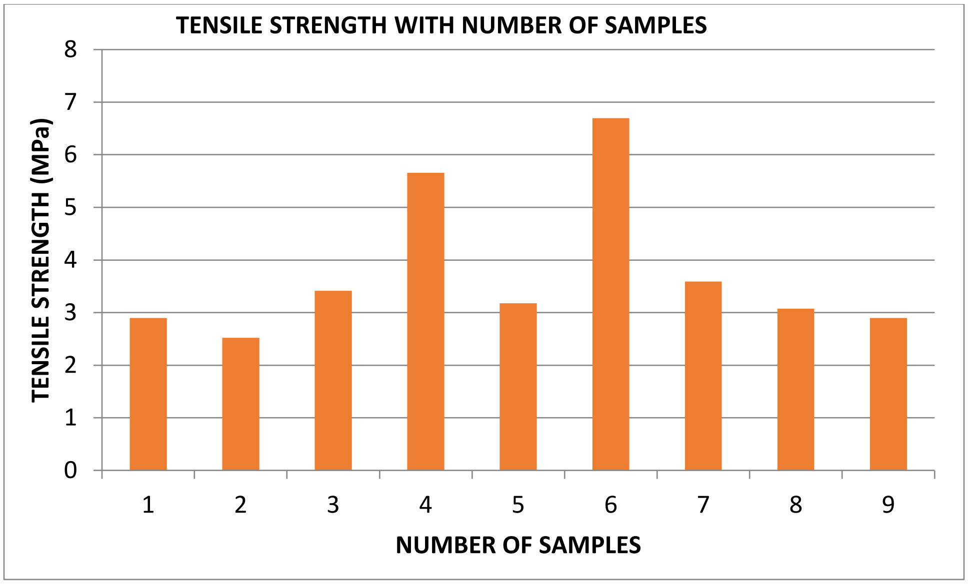

Figure 2: Tensile Strength of Specimens

From figure 1, the maximum hardness value was observed at specimen 6, followed by specimen 4 of the given formulation. A direct relationship is observed with Figure 1 and 2, where the higher the hardness value, the higher the tensile strength of the specimens. The observed variation in hardness value for specimens with fixed composition can be attributed to the heterogonous nature of the friction composite. According to the composite micrograph in plate 1, constituent materials are not homogeneously distributed, with the darker sections showing the resin. This applies to taking the hardness value; if the indenter strikes a resin region, the hardness value will be much lower than when the indenter strikes steel dust particles. However, the hardness values are observed within close range, with little or no difference.

CONCLUSION

The physical properties of asbestos-free brake pads (corn husks based) were evaluated to determine their reliability and performance at a temperature above its theoretical safe limits. It was observed from the study that the physical properties of the pads marginally changed at slightly elevated temperatures for the given formulation and composition. Although more tests and research would need to be done, this research suggests corn husks brake pads as an excellent alternative to asbestos in passenger cars.

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