Mechanical Properties and Wear Behavior of Brake Pads Produced from Palm Slag

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Abstract: Brake pads are important safety devices in vehicles. An effort to avoid the use of asbestos in brake pads has led to the development of asbestos-free brake pads that incorporate various organic and inorganic fillers. Palm slag as a filler in brake pads was investigated in this paper. Different processing pressures were employed during production of samples through compression molding. The properties examined included hardness, compressive strength, and wear behavior. The results showed that brake pad samples prepared with 60 tons of compression pressure resulted in the most desirable properties. Hence, palm slag has its own potential for use as a filler in asbestos-free brake pads.

Keywords: Brake pad, palm slag, wear characteristics, mechanical properties.

1. Introduction

Brake pads are important components in all types of vehicles. Brake pads are made from friction materials that are glued to the metal plate facing the metal brake disc. Friction materials are composites that mainly consist of a few types or classes of ingredients: binders, fibers, fillers, and friction modifiers [1]. Binders function to hold together all the components in the brake pad; fibers provide mechanical strength; fillers reduce costs and improve manufacturability and, in some cases, the properties of brake pads; and friction modifiers determine the frictional properties of the brake pads and comprise a mixture of abrasives and lubricants [2, 3].

Friction brakes decelerate a vehicle by transforming the kinetic energy of the vehicle into heat, via friction, and dissipating that heat into the surroundings [4]. Brake pads must have a sufficiently high friction coefficient with the brake disc to achieve braking effectiveness and should not decompose or break down in such a way that the friction coefficient with the brake disc is compromised at high temperatures. Brake pads should exhibit a stable and consistent friction coefficient with the brake disc [5].

Before the ban on using asbestos in brake linings was imposed by the United States Environmental Protection Agency in 1989, asbestos was the preferred filler material [6]. Asbestos had several engineering characteristics that made it desirable for inclusion in brake linings. Asbestos is thermally stable up to 500ºC, it helps regenerate friction surface during use, it insulates thermally, it is strong and flexible, and, mostly, it is inexpensive [1, 7, 8]. Since the ban on asbestos, researchers have struggled to come up with an equally efficient alternative to asbestos. Barites, mica, cashew dust, and fly ash are among the materials that have been considered for use as fillers [2, 9].

Palm Slag as Alternative Filler

Palm slag is a by-product left behind during palm oil production. Disposal of palm slag is an economic and environmental liability for oil palm industries all over the world. This paper presents a study of mechanical and wear properties of brake pads produced from a mixture of palm slag and other existing brake pad materials.

2. Materials and Experiment

Raw Materials: Five types of raw materials were used: palm slag, phenolic resin, steel fiber, graphite, and alumina. Palm slag was supplied by a local oil palm manufacturer (Seberang Perai) and used as filler in the brake pad mixtures. The amount (as a percentage) of each material in the composite brake pad mixture is shown in Table 1. Phenolic resin was selected as a binder, graphite as a lubricant, steel fiber as reinforcement, and, finally, alumina was used as an abrasive. Palm slag with a particle size lower than 600 µm was used.

Table 1 Materials composition of brake pad

Material	Percentage by weight
Phenolic resin	20
Palm slag	40
Graphite	10
Steel fiber	20
Alumina	10

All the ingredients were mixed together to obtain a homogeneous mixture. Each mixture was then compacted with a pressure of 15-17 MPa using a uniaxial hydraulic hand-press machine for the green body of the brake pad composite. The green body was then further compacted and cured using a hot press at 150oC with different processing pressures: 10, 20, 40, and 60 tons of compression molding pressure for 5 minutes. At the end of the hot-pressing process, samples were removed from the mold, allowed to cool to room temperature, and post-cured at a constant temperature of 150oC for 4 hours.

Hardness of the Composite Rockwell type E hardness values of the samples were obtained using a digital Rockwell hardness tester. A sample with a diameter of 10.5 mm was used to carry out the test at different processing pressures. The test was conducted using a 1/8-inch-diameter steel ball indenter with a load of 100 kgf.

Compressive Strength of the Composite Compressive strength of the brake pad composite was tested using the Instron Universal Testing Machine (UTM). Each sample using an initial cross-sectional area of 86.6 mm^2 was placed between the lower cross member and lower cross head and the load was applied to it with 5mm/min crosshead speed. The load at which failure occurred was then used to calculate the compressive strength of the sample. Five replications of the compressive tests were conducted on the sample using the different hot-press/processing pressures of 10, 20, 40, and 60 tons.

Wear Behavior of the Composite

Wear of brake pad composites was determined using a polisher machine with load. The setup was similar to the concept of the pin-on-disc test. The tested samples were in the form of cylindrical pins of 10 mm in diameter and 15 mm in height placed on the stainless steel wheel with a load of 10N and a wheel speed of 100 rpm. The test was run for the constant distance of 1 km. The samples were weighed before and after the testing with an accuracy of 0.0001 mg to determine weight loss. Wear volume and wear rate for the brake pad composites were determined using the following equations:

$$wear\ volume = \frac{Wg_{before} - W_{after}}{\rho}$$

$$wear\ rate = \frac{wear\ volume\ (m^3)}{sliding\ distance\ (m)}$$

3. Results and Discussion

Mechanical Properties of Palm Slag Brake Pads The hardness values of the composite are shown in Figure 1. One can see that as hot-press pressure increases, the hardness values of the samples also increases. The high hardness for the 60 tons of pressure example was a result of high compaction caused by the high pressure. Increasing the pressure will help the composite materials pack and eliminate voids. It is important to keep porosity to a minimum to obtain compact and dense composite materials that increase the mechanical properties [10, 11].

Figure 2 shows the compressive strength of the palm slag brake pad composite. One can see that compressive strength exhibits a similar trend to that of hardness. Compressive strength of the brake pad increases with increased processing pressure. Once again, the compactness of the composite material through the processing load can be seen clearly.

Wear Behavior of Palm Slag Brake Pad Composite

The wear behavior of the palm slag brake pad composite under 10N for 1 km sliding distance is shown in Table 2. Weight loss was measured after 1 km sliding on the stainless steel plate; then wear volume and wear rate of the palm slag brake pad composite were calculated and compared with the asbestos brake pad described in the literature. From the data shown in Table 2, one can see that the palm slag brake pad composite, especially with a processing pressure of 60 tons, possesses the same mechanical and wear properties as the conventional asbestos-based brake pad.

4. Conclusion

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.

Sample	Density g/cm^3	Wear volume cm^3×10^{-3}	Wear rate m^3/m×10^{-12}
Palm slag 10 %	1.93	2.02	2.02
Plam slag 20 %	1.98	1.77	1.77
Palm slag 40 %	2.01	1.09	1.09
Palm slag 60 %	2.02	0.89	0.89
Asbestos	2.22	0.72	0.72

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