Effect of palm ash composition to the brake pad application

by

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DECLARATION

I declare that this thesis is, to the best of my knowledge, a presentation of my original research work. Wherever contributions of others are involved, every effort is made to indicate this clearly with due reference to the literature. I certify that I have complied with the rules, requirements, procedures and policy of the University. I therefore cede copyright of the thesis in favour of the Universiti Malaysia Perlis.

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KESAN KOMPOSISI ABU SAWIT KEPADA APLIKASI PAD BREK

ABSTRAK

Penggunaan bahan gentian asbestos sebagai bahan pengisi di dalam pad brek telah dielakkan kerana ia mempunyai sifat-sifat karsinogenik yang mungkin menyebabkan risiko kesihatan. Asbestos kini telah digantikan dengan campuran gentian alternatif seperti gentian mineral, selulosa, aramid, pan, kaca dicincang, keluli dan gentian logam lain. Kajian ini dijalankan bagi menghasilkan pad brek tanpa asbestos. Sampel komposit untuk penggunaan pad brek disediakan melalui pra-campuran abu kelapa sawit, $CaCO_3$, resin fenolik, Al_2O_3, grafit dan gentian logam. Kemudian, bahan-bahan ini dipadatkan dengan menggunakan pemampat sejuk/ mesin manual mampatan. Ujian sifat mekanik seperti seperti ujian mampatan dan kehausan telah dijalankan. Keputusan menunjukkan bahawa komposisi peratusan tinggi abu kelapa sawit mempunyai kekuatan mampatan yang lebih baik. Nilai tertinggi untuk untuk kekuatan mampatan adalah 14.93 MPa dan nilai yang paling rendah adalah 8.85 MPa. Keputusan bagi ujian kehausan menunjukkan bahawa kehilangan jisim yang tertinggi adalah 0.2803 m^3 untuk peratusan rendah abu kelapa sawit manakala kehilangan jisim yang terendah adalah 0.00969 m^3 bagi peratusan tinggi abu kelapa sawit. Komposisi tanpa asbestos menunjukkan sifat-sifat mekanik yang setanding dengan pad brek konvensional.

EFFECT OF PALM ASH COMPOSITION TO THE BRAKE PAD APPLICATION

ABSTRACT

The asbestos fibre as a filler material in brake pad has been avoided due to its carcinogenic nature that might cause health risks. Asbestos has now been replaced by a mix of alternative fibres such as mineral fibres, cellulose, aramid, PAN, chopped glass, steel and other metal fibre. This research was conducted to produce a non-asbestos brake pad. In this research, palm ash was used to replace asbestos. The composite samples for brake pad application were developed by pre-mix the palm ash, $CaCO_3$, phenolic resins, Al_2O_3, graphite and steel fibre mill. Then, the material was compacted by using cold press/manual press machine. The physical and mechanical testing such as compression and wear test was carried out in this research. Results indicated that the higher percentage composition of palm ash has better compressive strength. The highest value for compressive strength is 14.93 MPa and the lowest value is 8.85 MPa. Wear test result indicated that the highest mass loss value is 0.2083 m^3 for the lowest percentage palm ash whereas the lowest mass loss is 0.00969 m^3 for the highest percentage of palm ash. The composition of non-asbestos showed comparable mechanical properties with conventional brake pads

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LIST OF ABBREVIATIONS

Al_2O_3	Aluminum Oxide
ASTM	America Society for Testing and Material
$BaSO_4$	Barium Sulfate
Ca	Come after
$CaCO_3$	Calcium Carbonate
CNSL	Cashew Nut Shell Liquid
EPA	Environmental Potential Agency
FASi	Fly Ash silica
Fe_2O_3	Hematite
Fe_2O_4	Magnetite
MPa	Mega Pascal
MPOB	Malaysia Palm Oil Board
NAO	Non Asbestos Organic
OPC	Ordinary Portland cement
OPA	Oil Palm Ash
P/M	Powder Metallurgy
Psi	Precipitated silica
RPM	Rotational Per Minute
S/S	Solidification/Stabilization
SEM	Scanning Electron Microscopy
SEM-EDX	Energy-dispersive X-ray spectroscopy
SiO_2	Silica Oxide

TGA	Thermogravimetric Analysis
UCS	Unconfined Compressive Strength
US	United State
UTM	Universal Testing Machine
XRF	X-ray fluorescence
ZnO	Zinc Oxide
$ZrSiO_4$	Zirconium silicate

CHAPTER 1

INTRODUCTION

1.1 Research Background

Brake pad is one of the important components in automotive application. Brake pads are steel backing plate with friction materials bound to the surface that faces the disc brake rotor. Brake pad works to slow the speed or stop the vehicle. Brake pad materials are generally considered as composites. Most of the automotive industries have used a variety of materials and processes to produce the high performance of brake pad. An improvement of grip, noise reduction, hardness, heat resistance and last longer is a major role in producing brake pad. In additional, improvements in term of material used are important to reduce the cost. Numbers of different materials are used and almost more than 10 types of raw materials are involved in producing the brake pad (EL-Tayeb & Liew, 2009). Most material used for the production of brake pad is asbestos, ceramic, calcium carbonate, metals, graphite, phenolic, fibre and more. Each material has a special and important role in the production of brake pad. The types of materials for developing brake pad can generally be classified into five types of materials, depending on the specific functional requirement. These include fibres (Jie Fei et al. 2010), fillers (Kumar & Bijwe, 2011), binders (Ingo et al. 2004), friction modifier (Gurunath & Bijwe, 2007) and solid lubricants (Seong & Ho Jang, 2000).

1.2 Problem Statements

Asbestos is popular and widely used in fabrication of brake pads due to low price, excellent thermal stability, miscibility, tribological properties and its heat resistance (Gopal et al. 1996). However, it is well known that asbestos can degrade to airborne fibres (diameter less than 2 μm) and result in a long term health problem to human and environment which it can contribute to lung disease (Ho et al. 2005). Due to health issues as well as requirement for better quality, many countries have taken safety to stop using it for brake pad. Many material formulations of free asbestos brake pad were introduced such as in the U.S in the late end of the year 1960. Regarding these changes, there is still no clear explanation on this material consumerism. Beginning in mid-1970, three important new requirements were imposed on the automotive industry by the Federal Braking Regulations. One of them is the need to eliminate asbestos from friction materials (Mustafa Boz & Adem Kurt, 2007).

In this study, the asbestos in brake pad formulation is replaced with waste materials, which are palm ash. It is expected that recycle material can reduce the cost of the brake pad. In addition, it can recycle the palm ash that has a bigger amount waste in Malaysia. It was reported that palm ash has been used as cement replacement material and as an absorbent for the removal of zinc from aqueous solution (Chu & Hashim, 2003). Malaysia is the largest produced palm oil and it is a contributor to the economy of Malaysia and also palm oil in this country has contributed half of the world's palm oil production to increase global demand for vegetable oil (Basri et al. 1998). Therefore, all wastes produced from palm oil production become an alternative agent in the internal combustion chamber to replace the fuel for electric power generation. After burning, the palm ash is produced and this ash cannot be used for other processes. The problem is to dispose the palm ash because it requires a relatively large area to collect the ashes and affecting the surrounding environment (Singh et al. 2010). In 2007, the Malaysian Palm Oil Board (MPOB) estimated the amount of Palm ash produced in Malaysia to be approximately 3 million tons (Chea Handara et al. 2010). To solve this problem, use of palm ash as a filler in a brake pad is a potential alternative to reduce the palm ash waste and reduce the costing of raw materials. From the literature, the utilization of palm ash as filler into brake pad material has not been investigated extensively. This project proposes to use palm ash as filler materials in brake pad.

1.3 Objectives

This research is carried out to study the brake pad formulation without using asbestos fibres. The relationship of the percentage composition of raw materials, different applied load and sliding distance are the main concern in this study.

The interest of the study includes:

i. To formulate brake pad formulation using the palm ash as filler materials.
ii. To study the physical and mechanical properties of the samples fabricated.
iii. To investigate microstructure and to study the effect of palm ash addition on wear characteristic.

1.4 Scope of the Project

In this research, there are 3 major processes involve to produce the brake pad composites. In the usual production sequence first process (raw material characterization), analyse the raw material. The second process is sampling process; the sample formulation consists of phenolic powder as a binder, steel fibres as reinforcement, alumina (Al_2O_3) as abrasive, graphite as a lubricant and, calcium carbonate ($CaCO_3$) and palm ash as filler in the composition. The mixtures are compressed into the desired shape and followed by curing in a hot press machine to cause bonding of the particles into a hard rigid product. After that, samples were being post-cured again in the oven in several hours to fully cure. The third process is physical and mechanical testing. The wear loss behaviour has been tested on the samples. The ideal brake pad materials should have a constant of wear under various operating conditions such as applied load, sliding distance, time, temperature and speed.

CHAPTER 2

LITERATURE REVIEW

2.1 Brake pad

Brake pad is an important component of all vehicles. It works to slow and to stop the vehicle. Brake pads in the brake callipers with their friction surfaces was contacting each other with the disc surface. In this situation, the contact will be producing heat and transfer a small amount of friction on the surface of the disc.

There are three broad classifications of friction material that have been used as brake pad materials which are organic, metallic and carbon.

1. Organic friction materials were exclusively composites of one or more binder resins, chrysotile asbestos fibre, and a blend of additives that modified friction, improved wear, reduced cost, and aided processing, change colour, and so on. Currently, there are 3 subclasses of these resin-bonded friction materials:
    - Asbestos, also called organic brake lining
    - Non-asbestos organic (NAO), using a variety of fibres
    - Semi metallic, or resin-bonded metallic

2. Metallic brake lining can be based on either copper or iron. Most are solid state sintered, often with inorganic additives to improve performance. Another metallic friction material is cast iron. Although this venerable material is used on some old railroad tread brakes, no new automotive applications are known to use cast iron as the brake lining. However, it remains a friction element, although not a brake lining (Arnold, 1992).

3. Carbon based brake linings, such as carbon-carbon, were developed for military and commercial aircraft disk brakes. Some are now used on racing cars where weight is critical, performance is demanding, and cost is secondary. Carbon-carbon friction materials are made from carbon fibre (also called graphite fibre) that bonds with amorphous carbon (Arnold, 1992). Table 2.1 shown Historical Composition of Automotive Friction Brake Materials.

Table 2.1: Historical Composition of Automotive Friction Brake Materials (Peter, 2001)

Material Description	Application (s)	Approximate Year
Cast iron on steel	Railroad car brake blocks and tires	Prior to 1870's
Hair and cotton belting (limited by charring at about 300ºF)	Wagon wheels and early automobile	Ca. 1897
Woven asbestos with brass and other wires for increased strength and performance	Automobile and trucks	Ca. 1908
Moulded linings with shorter chrysotile	Automobile and trucks	Ca. 1926

fibre, brass particles, and low-ash bituminous coal		
Dry mix moulded material to replace cast iron brake blocks that produced metallic duct that shorted electric train rails	London underground	Ca. 1930
Flexible resin binders developed along with more complex formulations	Brake drum lining	1930's
Resin-bonded metallic brake linings	Industrial and aircraft applications	1950's
Glass fibres, mineral fibre, metal fibre carbon and synthetic fibre to provide semi-metallic with higher performance than asbestos (beginning of safety issue with asbestos)	Automotive and trucks	1960's
Non-asbestos (fibreglass) materials	Brake drums on original equipment cars	1980's
Suggested use of carbon fibre	Automotive brakes	1991
Palm ash, PCB, Phenolic and Aluminium	Brake pad	2011

Note: Ca. – come after

The effective performance of the brake pad friction at different levels of braking conditions in a wet environment is the main concerns of car drivers. Brake pad friction in the automotive brake system is always the key role of effective and safe braking performance, and blames always go to it when a brake-related problem arises. This is because brake pads are more vulnerable to various braking parameters. Therefore, frictional brake pad material should be designed to maintain a relatively high and stable friction coefficient irrespective of temperature, age, degree of wear, the presence of dirt, humidity, and water spraying from the road (Darius et al. 2007)

Over the past few years, many researchers have done research to reduce or replace the asbestos in the brake pad. Before it was banned by the United State in 1989 (Chan & Stachowiak, 2004). Asbestos is very important in manufacturing brake pad where it helps to structure the brake pad in the mechanical properties brake pad and gives more resistant to heat when it applied load to the friction. The asbestos can harm people and the environment. It occurs when the load applied to brake pad, the asbestos structure will disintegrate and it becomes light impurities and easily carried by air.

Asbestos is known to have toxicity. The inhalation of toxic asbestos fibres can cause serious illnesses, including malignant mesothelioma, lung cancer, and asbestosis (also called pneumoconiosis). Since the mid-1980s, many uses of asbestos have been banned in several countries. Asbestos that is used in previous brake pad had contained a carcinogen and are able to reach the alveolar area of the lung. In the safety profile, it confirmed human carcinogen producing lung tumours. Experimental neoplastigenic and tumorigenic data has been produced. Human pulmonary system effects by inhalation. Usually at least 4 to 7 years of exposure are required before serious lung damage (fibrous) results (Richard, 1991).

Asbestos exposure becomes a health concern when high concentrations of asbestos fibres are inhaled over a long time period. People who become ill from asbestos are almost always those who are exposed on a day-to-day basis in a job where they work directly with the material. As a person's exposure to fibre increases, either by breathing more fibres or by breathing fibre for a longer time, that person's risk of disease also increases. The disease is very unlikely to result from a single, high-level exposure or from a short period of exposure to lower levels.

In the past decade, many automotive industries has phasing out the asbestos in brake pad. Each company has developed their own unique composition into safer alternative use, yet performing the very same task and claiming to better than others. The manufacture of brake pads must follow the demands such as (Chan & Stachowiak, 2004):

1. Not decompose or break down in such a way at high temperature.
2. Maintain a sufficiently high friction coefficient with the brake disc.
3. Exhibit a stable and consistent friction coefficient with the brake disc.

The percentage composition material control is very important to avoid significant impact on the mechanical properties of the brake pad (Peter, 2001). The ingredients in brake pad comprise fibre reinforcement, binder, friction modifiers, solid lubricant, abrasive, and filler. Fibre is usually used because of their friction properties, heat resistance, and their thermal conductivity. Besides that fibre can impart toughness and strength to the binder. Filler materials are added to improve or optimize the properties. Table 2.2 shows some of the previous study of the composition of the brake pad which contains fibre, filler, binder, friction modifier and lubricants.