STUDY OF A PALM SLAG-FILLED FRICTION COMPOSITE FOR BRAKE PAD

CHE MOHD RUZAIDI BIN GHAZALI

SCHOOL OF MATERIALS ENGINEERING
UNIVERSITI MALAYSIA PERLIS
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by

Che Mohd Ruzaidi bin Ghazali
540410065

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- C. M. Ruzaidi -

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LIST OF ABBREVIATIONS, SYMBOLS, SPECIALIZED NOMENCLATURES

ASTM	American Society for Testing and Materials
COPNA	Condensed Poly-nuclear Aromatic
DIN	Deutsches Institut für Normung (German Institute for Standardization)
DTA	Differential Thermal Analyzer
EDS	Energy Dispersion Spectroscopy
ED XRF	Energy Dispersive X- Ray Fluorescence
EFBs	Empty Fruit Bunches
EPA	Environmental Protection Agency
EPMA	Electron Probe Micro Analyzer
FRCPs	Fibre Reinforced Polymer Composites
MMCs	Metal Matrix Composites
MOR	Modulus of Rupture
NAO	Non Asbestos Organics
OSHA	Occupational Safety and Health Administration
SEM	Scanning electron microscope

TGA-DTA	Thermogravimetric Analyses- Differential Thermal Analyzer
TGA	Thermogravimetric Analyses
TG-MS	Thermogravimetric- Mass Spectroscopy
XRF	X-Ray Fluorescence
UTM	Universal Testing Machine

Kajian Komposit Geseran Berpengisi Sanga Kelapa Sawit sebagai Pad Brek

ABSTRAK

Semenjak penggunaan asbestos diharamkan dalam semua jenis produk dan aplikasi kerana sifatnya yang karsinogenik, penyelidik di seluruh dunia telah menjalankan aktiviti-aktiviti penyelidikan dan pembangunan dengan matlamat untuk mengenalpasti bahan gantian dan selamat. Kerja-kerja penyelidikan tersebut telah dijalankan dengan objektif utama menentukan potensi dan keupayaan penggunaan sanga kelapa sawit yang merupakan bahan buangan pepejal industi yang banyak terdapat di Malaysia, sebagai bahan pengisi gantian dalam komposit geseran bagi digunakan sebagai pad brek. Bahan-bahan ramuan utama lain yang digunakan untuk membangunkan komposit geseran dalam kajian ini adalah resin fenolik sebagai pengikat, grafit sebagai pelincir, alumina sebagai abrasif dan serat keluli untuk memberi pengukuhan. Campuran ini dipadatkan dengan alat penekan tangan bagi mendapatkan sampel berbentuk silinder 'green body' 10 mm diameter sebelum dipadatkan sekali lagi sambil dimatangkan dalam penekan panas pada suhu 160 ^{o}C selama lima (5) minit. Kemudian sampel tersebut dipanaskan sekali lagi dalam oven pada 160 ^{o}C selama empat (4) jam untuk proses lepas matang sebelum diuji dengan pengujian kekerasan, ketumpatan, kekuatan mampatan dan kerintangan haus. Pencirian bahan mentah, terutamanya sifat terma sanga kelapa sawit, menunjukkan bahawa ia adalah stabil terhadap haba dan sesuai untuk digunakan sebagai bahan pengisi dalam pad brek. Parameter pemprosesan dengan tekanan pengacuanannya yang lebih tinggi memberi kesan yang besar ke atas sifat akhir seperti ketumpatan, kekerasan dan kekuatan mampatan produk komposit pad brek tersebut. Hasil kajian ini juga menunjukkan bahawa sifat-sifat mekanik komposit adalah berkadar songsang dengan saiz zarah pengisi sanga sawit yang digunakan. Kadar haus

bahan komposit adalah dipengaruhi oleh jenis pengisi, tekanan pegacuanan dan saiz zarah pengisi. Sebagai kesimpulan, kajian ini telah mendapati bahawa sanga kelapa sawit boleh dijadikan bahan gentian kepada pengisi yang digunakan dalam pad brek dengan sifat haus yang standing dengan pad brek komersil di pasaran. Ia juga telah mendapati bahawa selepas tempoh penggunaan yang tertentu, trend kadar haus untuk pelbagai jarak gelongsor pada dasarnya tetap dan linear. Akhirnya pengujian brek di atas jalan dicadangkan untuk dilakukan bagi kajian selanjutnya di masa akan datang untuk pengesahan formulasi dalam penggunaan sebenar pada kenderaan.

Study of a Palm Slag-Filled Friction Composite for Brake Pads

ABSTRACT

Since the use of asbestos was banned in all types of products and applications due to its carcinogenic nature, researchers worldwide has conducted extensive research and development activities with the goal of identifying alternative and safe materials. This research work was conducted with the main objective of determining the potential and capability of using palm slag, an industrial solid waste that is abundant in Malaysia, as an alternative filler material in friction composites for brake pad applications. The other main ingredient that were used to develop friction composites in this research were, phenolic resin as a binder, graphite as a lubricant, alumina as an abrasive and steel fibers to provide reinforcement. The mixture was hand press compacted to have the 10 mm diameter cylindrical green body before being further compacted and cured in a hot press at the 160 ^{o}C for five (5) minutes. Then the samples were post-cured in the oven at 160 ^{o}C for four (4) hours before being tested for hardness, density, compressive strength and resistance to wear. Characterization of the raw material, especially the thermal behaviour of the palm slag, showed that it was thermally stable and suitable for use as the filler material in brake pads. The processing parameters with higher molding pressures had significant effects on the brake pad's end properties, such as density, hardness and compressive strength of the friction composite. The result of this study also indicated that the mechanical properties of the composite material were inversely related to the size of the palm slag particles that comprise the composite. The wear rate of the friction composite was influenced by the type of filler, moulding pressures and particle size of the filler. As a conclusion, this study was determined that, palm slag could be one of the alternative fillers used in brake pad with a comparable

wear properties to the commercial brake pad products in the market. It was also found that, after a certain initial period of use, the trend of wear rate for various sliding distances was essentially constant and linear. Lastly, on road brake test was recommended to be performed for further study in the future to validate the formulation or a real application in the vehicle.

CHAPTER 1

INTRODUCTION

1.1 Background

Brake pads are a crucial component in automotive braking systems. Brake pads on a disc brake literally hug the wheel. The braking system is used to slow down or stop, moving motor vehicles and to hold them stationary when they are parked (Darius et al., 2007).

Since the pads, push against the rotor to slow down the vehicle, it is important to choose the best pad for specific functions and applications. When brake pads must be replaced, there are many pad materials to choose from. The choices include ceramic, semi-metallic, metallic, and organic brake pads. Over time, all brake pads wear out due to the fact that these components are friction parts. Wear has been defined as damage to a solid surface due to abrasion, especially during braking (Amar Patnaik et al., 2010). According to Darius (2007), the kinetic energy or the momentum of a moving vehicle is converted to heat during braking. This heat is generated due to the friction between the brake pads and disc brake.

Brake friction materials were originally made with organic ingredients such as asbestos and carbon, held together by a strong resin. When disc brakes were first used in cars in the 1950s, asbestos was used in the brake pads. Asbestos brake pads were popular because they dealt with high heat very well and the health effects of asbestos were not well known at that time (Shibata et al., 1993).

Asbestos is a mineral that is composed of a mixture silicates, mainly magnesium and iron silicates. So far no single material has been able to replace asbestos and provide the same beneficial properties, such as strength, rigidity, friction, resistance to wear and heat stability. Even at very high temperatures asbestos will not burn (Chand et al., 2001). However, asbestos pads caused health issues because the particles of abestos emitted during braking were found to be hazardous and carcinogenic. The major diseases associated with long term exposure to asbestos are asbestosis, lung cancer and mesothelioma. Most advanced countries have banned the use of asbestos based on its carcinogenicity. The government of the United States as reported in Environment Resources (2000) banned the use of asbestos in the automobile industry in 1993. Due to this health issue as well as the requirement for a quality replacement for asbestos, many asbestos free material formulations for use in brake pads have been developed.

It is necessary to use asbestos free materials in order to produce brake pads that do not create carcinogenic emissions. When the effects of asbestos became known and its use was banned, brake pads that included a different organic material (carbon) replaced asbestos pads. The organic brake pads were prone to fading, so they were replaced with semi-metallic pads. As mentioned on the webpage of Brake Pad Warehouse (http://www.brakepadwarehouse.com), asbestos has now been replaced by a mix of alternative fibres such as mineral fibres, cellulose, aramid, PAN, chopped glass, steel- and copper fibres. Non-asbestos brake pads can be either non-organic or organic. The non-organic types include metallic and semi metallic materials (Ma et al., 2007; Sutikno et al.,2010).

Most brake pads that are sold today are considered semi-metallic. Semi-metallic brake pads usually use chopped steel wool mixed with resin. It is easy to tell the quality of a semi-metallic brake pad, i.e., smooth is good. The more finely chopped the metal that is used in a semi-metallic brake pad, the better the pad will be at dispersing heat and resisting fade. A cheap semi-metallic brake pad will be rough to the touch and could even leave metal splinters in your hand. A good quality semi-metallic brake pad will be smooth to the touch.

Ceramic brake pads have replaced semi-metallic pads in many applications. Ceramic brake pads were first used on production cars in the mid-1980s, and they used copper instead of steel to conduct heat away from the rotor (Nicholson, 1995). This allowed the ceramic pads to handle high braking temperatures with less heat fade, provide faster recovery after the stop, and generate less dust and wear on both the pads and disc. Ceramic brake pads provide better stopping power and less brake fade than semi-metallic pads. The brake dust from ceramic pads is light colored and doesn't stick to the wheels, which means no more of that unattractive black dust covering the wheels. Consequently, wheels and tires maintain a cleaner appearance for a longer period of time and, from a comfort standpoint, ceramic compounds provide much quieter braking because the ceramic compound helps dampen noise by generating a frequency beyond the range that people can hear.

1.2 Problem Statement

A large variety of commercial brake pad materials exist in the market place. They all have one thing in common; i.e., their compositions are complicated, and nobody knows exactly why so many different ingredients are needed. Brake pad formulations are based on experience, such as that compiled by Blau (2001). Substitution of critical ingredients is a major problem from the standpoint of their environmental friendliness. A closer look at the environmental aspects of brake dust will manifest the need for "green" pad materials in the future (Kukutschová et al., 2009). To my knowledge the use of industrial waste material in brake pads, such as palm slag has not been studied.

In this study, an industrial waste material, palm slag was used to replace the filler in non-asbestos brake pads. Malaysia is the largest producer of palm oil in the world, and as a result, large quantities of palm slag waste are produced. The use of low cost recycled materials, such as palm slag, can reduce the cost of brake pads, and such non- asbestos pads are safer than asbestos-based brake pads.

1.3 Research Objectives

This research was conducted to study the production of brake pads without using asbestos fibres as the filler materials. The main focus of this study was to determine the relationship of the composition of palm slag as filler materials with different applied loads and different filler sizes.

The specific aims of the study were:

i. to characterize and confirm the suitability of palm slag for use as a filler material in brake pads by assessing morphology, particle size, and thermal properties.
ii. to study and understand the effect of the compression load during processing of the samples on the mechanical and wear properties of the composite materials that contain palm slag.
iii. to investigate and understand the effect of different filler sizes of palm slag filler on the mechanical and wear properties of the composite.
iv. to study the correlation between the properties and wear rate of brake pads that contain palm slag.

1.4 Scope of Research

This research is presented in five major chapters, including then Introduction, Literature Review, Methodology, Result and Discussion and Conclusions.

In this research, there were five major steps involved in preparing the brake pad composite samples. The first step was to prepare and characterize the raw materials, i. e., phenolic powder as binder, palm slag, calcium carbonate or dolomite as filler, alumina powder as an abrasive, graphite powder as a lubricant, and steel fibres as reinforcement. The second step was to weigh all of the raw materials according to the fixed ratios. In this research, only one fixed ratio was evaluated.

In step three these raw materials were mixed in a mechanical ball mill mixer in order to get a homogeneous mixing of the brake pad composite materials. The fourth step was the preparation of 'pre-forms', also called as 'green body' using a hand press. The fifth step was to cure the brake pad composites under certain pressure by using the hot-press machine. Then the mechanical properties, physical properties, and morphology of the brake pad composite products were studied.

Three types of fillers are compared in the first part of the discussion in Chapter 4, i. e., palm slag, $CaCO_3$, and dolomite. Also the performances of these three fillers, especially their wear properties, were compared with the performance of asbestos based on the available literature data in order to confirm the feasibility of using palm slag as an alternative filler material in non-organic brake pads.

After that, the focus turned to the influence of the processing parameters on brake pads with the palm slag filler. The pressures used in the composite moulding process ranged from 1 to 60 tons. The resulting effects on density, hardness, compressive strength, wear properties and morphology are discussed further.

Three different sizes of filler, i. e., < 300 μm; 300 – 600 μm; and > 600 μm – 2 mm, were compared. The physical and mechanical properties of the brake pads using these fillers were evaluated.