2017

Faculty of Mechanical Engineering

SELECTION AND OPTIMIZATION OF KENAF/ EPOXY COMPOSITE AS AN ALTERNATIVE FRICTION MATERIAL

Ashafi'e bin Mustafa

Master of Science in Mechanical Engineering

2017

DESIGN OPTIMIZATION OF KENAF/ EPOXY COMPOSITE AS AN ALTERNATIVE FRICTION MATERIAL

ASHAFI'E BIN MUSTAFA

A thesis submitted
in fulfillment of the requirements for the degree of Master of Science
in Mechanical Engineering

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2017

DECLARATION

I declare that this thesis entitled "Selection and Optimization of Kenaf/ Epoxy Composite as an Alternative Friction Material" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in the candidature of any other degree.

Signature	:	....
Name	:	....
Date	:	....

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Mechanical Engineering.

Signature : ....

Supervisor Name : ....

Date : ....

DEDICATION

To my beloved father, brothers, sisters, lecturers, friends and Allah S.W.T

ABSTRACT

This research consists of the selection and optimization of the alternate materials which represent asbestos, using the Cambridge Engineering Selector (CES). The design and selection of potential materials are according to the friction material‟s suggested specifications and performances. Comparative and verification studies were performed using the Pugh and Weighted Decision Matrix (WDM) methods in order to select the best material to represent asbestos from among all potential materials such as jute, ramie and kenaf. As for the result, kenaf (Hibiscus Cannabinus) was chosen as the best material that meets the criteria and design constrains. The tribological performances of the kenaf epoxy (KE) composite were conducted according to the L_{18} arrays design. A 10 mm diameter cylindrical pin of KE composite was fabricated using a hot-cold compression machine and tested on a pin-on-disk tribometer according to ASTM G99. The signal to noise (S/ N), analysis of variance (ANOVA) and correlation between factors were employed in order to determine the optimal combination between controlled factors and levels. The optimal combination parameters of the KE composite were verified upon the confirmation test, and then compared with conventional friction material. The confirmation test verified that an optimized KE composite result falls within confidence intervals of 95%; which sounds promising to be included in friction material formulations which also exhibit friction coefficient (0.4 - 0.44) within the range suggested. The predominant wear mechanisms from worn surfaces are studied using Scanning Electron Microscopy (SEM) images revealed signs of predominant wear mechanisms such as abrasive, adhesive and fatigue mechanisms and a profilometer to measure the surface roughness.

ABSTRAK

Kajian dijalankan merangkumi pemilihan dan pengoptimumkan bahan alternatif bagi mengantikan asbestos menggunakan "Cambridge Engineering Selector" (CES). Pemilihan bahan-bahan yang berpotensi adalah dengan mengikuti standard spesifikasi bahan geseran ("brake pads"). Untuk memilih alternatif terbaik, kajian perbandingan diantara bahan-bahan berpotensi seperti jute, ramie dan kenaf bersandarkan asbestos dilakukan melalui kaedah Pugh dan Matrik Keputusan Wajaran (WDM). Setelah dipertimbangkan secara terperinci, Kenaf dipilih sebagai alternatif terbaik serta memenuhi kriteria-kriteria yang digariskan. Kajian tribologi untuk kenaf/epoksi (KE) komposit dilakukan mengikut susunan L18 yang telah ditetapkan. KE komposit pin berdiameter 10mm dibentuk menggunakan mesin pemampat bersuhu sebelum diuji pada tribometer mengikut ASTM G99a. Kaedah – kaedah seperti Isyarat Gangguan (S/N), analisis terhadap variasi (ANOVA) dan hubungkait diantara faktor-faktor, digunakan bersama untuk menentukan kombinasi optimum. Melalui kombinasi optimom parameter KE komposit serta bahan geseran konvensional akan dibandingkan melalui ujian pengesahan. Keputusan dari ujian pengesahan menunjukkan kombinasi optimum parameter KE komposit berada didalam 95% selang keyakinan dan berpotensi jika digunapakai didalam formulasi bahan geseran. Permukaan yang haus akibat geseran dikaji menggunakan imbasan imej- imej daripada mikroskop imbasan elektron (SEM) bagi mengenalpasti mekanisma - mekanisma haus yang mendominasi sepanjang geseran dan profilometer digunakan untuk mengukur kekasaran permukaan.

ACKNOWLEDGEMENT

All praise is due to Allah, the Beneficent the Merciful. We bear witness that there is no god except Allah, and that Muhammad is the Messenger of Allah.

I would like to express my sincerest gratitude to my supervisor, Associate Professor Dr. Mohd Fadzli Bin Abdollah and Co-supervisor En. Hilmi Bin Amiruddin from faculty of Mechanical Engineering, Universiti Teknikal Malaysia, Melaka (UTeM) for their guidance, support and constant encouragement towards completing this research.

I also would like to thanks Mrs Nurhidayah binti Ismail, Mrs Sushela Edayu Binti Mat Kamal, and Mrs. Noryani binti Muhammad from the Faculty of Mechanical Engineering, Universiti Teknikal Malaysia (UTeM), as my grant (RAGS/2013/FKM/TK01/03/B00042) supervisors for financial support and their advices during this research activity.

I would like take this opportunity to thank En. Azrol Syafiq bin Mazlan from the Tribology laboratory of Universiti Teknikal Malaysia (UTeM), for his suggestions and advices regarding the apparatus, procedures and facility provided for this study.

Finally, the deepest and special thanks to my father, Mustafa bin Salul, my dear siblings and my fellow friends for their continuous prayers and moral have brought me here.

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LIST OF SYMBOLS

μ	Coefficient of friction
ρ	Density (g/ m^3)
Ws	Specific wear rate (mm^3/ Nm)
L	Distances (m)
M_{loss}	Mass loss (mg)
V_{loss}	Volume loss (mm^3)
F_n	Force (N)
F_f	Frictional force (N)
%.wt	Weight concentration (g)
E	Young‟s Modulus (N/ m^2)
σ	Yield Strength (N/ m^2)
M	Performance indices slope
S/N	Signal to Noise
SS_T	Total sums of squared deviations
SS_d	Sums of squared deviations
F_{value}	Fisher‟s ratio
Ra	Surface roughness
L	Distance

LIST OF ABBREVIATIONS

AISI	American Iron and Steel Institute
Al_2O_3	Aluminium Oxide
ANOVA	Analysis of Variance
ASTM	American Standard Testing Method
B	Bleached
BFC	Brass Fibre
CES	Cambridge Engineering Selector
CFP	Coir Fibre Polyester
CI	Confident Interval
CPC	Copper Powder
DOE	Design of Experiments
DOF	Degree of Freedom
EDX	Energy Dispersive X-ray
EPA	Environment Protection Agency
FMs	Friction Materials
HRC	Rockwell Hardness C Scale
JH	Jute Hazelnut Shells
JPP	Jute/ Polypropylene
KE	Kenaf Epoxy
LCA	Life Cycle Assessment
M	Metallic

MMC	Metal Matrix Composite
NAO	Non-Asbestos Organic
NaOH	Sodium Hydroxide
NP	Neat Polyester
NT	Non Treat
OPRP	Oil Palm Fibre Reinforced Polyester
PF	Phenol Formaldehyde
PLM	Polarized Light Microscope
PP	Polypropylene
PV	Pressure Velocity
RH	Rice Husk
RS	Rice Straw
SN	Signal to Noise Ratio
SAE	Society of Automotive Engineers
SEM	Scanning Electron Microscope
SiC	Silicon Carbide
SMFM	Semi-Metallic Friction Materials
SOPRP	Seed Oil Palm Reinforced Polyester
STDeV	Standard Deviations
SWC	Steel Wool
T	Treated
WDM	Weighted Decision Matrix
WGRP	Woven Glass Reinforced Polyester

LIST OF PUBLICATIONS

Journals

1. **<u>A. Mustafa</u>**, M.F.B. Abdollah, , H. Amiruddin, Shuhimi, F.F., and N. Ismail, 2016. Optimization Of Friction Properties of Kenaf Polymer Composite as an Alternative Friction Material. *Industrial Lubrication and Tribology,* Volume 69, Issue: 2, pp. 259-266, DOI: http://dx.doi.org/10.1108/ILT-05-2016-0118. (ISI Q4).
2. **<u>A. Mustafa</u>**, M.F.B. Abdollah, N. Ismail, H. Amiruddin, and N. Umehara, 2015. Selection and Verification of Kenaf Fibres as an Alternative Friction Material Using Weighted Decision Matrix Method, *Materials and Design*, Volume 67, pp. 577-582. DOI: http://dx.doi.org/10.1016/j.matdes.2014.10.091 (ISI Q1).
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Conferences attended

1. **<u>A. Mustafa</u>**, M.F.B. Abdollah, H. Amiruddin, F.F. Shuhimi, N.A.M. Tahir, N. Muhammad, S.E. Mat Kamal, and N. Ismail. *Optimization of Friction Coefficient of Kenaf/Epoxy Composites as an Alternative Friction Material Using Taguchi Method*. Proceedings of Mechanical Engineering Research Day 2016 (MERD'16), Melaka, 31 March 2016.

2. **A. Mustafa**, M.F.B. Abdollah, and H. Amiruddin. *Tribological Performances of Kenaf Polymer Composite as Potential Friction Material using ANOVA*, 1stMYTRIBOS Colloquium 2016 (MTC2016), School of Mechanical Engineering, Engineering Campus Universiti Sains Malaysia, 26 January 2016.
3. **A. Mustafa**, M.F.B. Abdollah, and H. Amiruddin. *Effect of Friction Coefficient and Wear on Different Types and Treatments of Kenaf/Epoxy Composites*. Postgraduate Research Symposium In Mechanical Engineering 2016 (PRISME), Melaka, 5-6 January 2016.
4. **A. Mustafa**, M.F.B. Abdollah, N. Ismail, and H. Amiruddin, *Pre-Materials Selection for Eco-Aware Lightweight Friction Material*, Proceedings of 9th International Materials Technology Conference and Exhibition (IMTCE2014), Kuala Lumpur, 13-16 May 2014.

CHAPTER 1

INTRODUCTION

1.1 Background

Friction materials (FMs) in automotive brake systems are known as complex composites that contain numerous ingredients or materials. The FMs are divided into 4 main important categories which are binders, fibres, fillers and friction modifiers. Asbestos fibre has been used as a traditional fibrous ingredient which is reinforced within the friction materials to provide essential mechanical strength, preventing the damaging of the friction material composite when operating.

However, due to its non-biodegradability, difficulty in processing, high cost, high density and potential risk of causing lung cancer when produced, asbestos FMs were banned by the Environment Protection Agency (EPA) (Rammazini, 1992). Thus, the search for safer and cheaper alternative sources is increasing. The alternative materials which can represent asbestos will be identified using the material engineering design approach according to the desired performances and characteristics using the systematics approach. A comparative study will be performed in order to justify and verify the new alternative materials found and compare them to other potential materials using a statistically comparative Pugh and Weighted Decision Matrix (WDM) method.

In order to evaluate and identify the tribological performance of the alternate FMs, the materials will be compressed into pin shaped polymer composites using a hot-cold compression machine. The samples being pin shaped is necessary to fit into a pin-on-disk tribometer sample holder mounting apparatus. The samples also have to perform several