PHYSICAL AND WEAR PROPERTIES OF ALUMINIUM MATRIX COMPOSITE REINFORCED WITH PSAC AND SLAG FABRICATED VIA POWDER METALLURGY

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Physical and Wear Properties of Aluminium Matrix Composite Reinforced with PSAC and Slag Fabricated via Powder Metallurgy

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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!

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LIST OF ABBREVIATIONS

MMC	Metal Matrix Composite
CMC	Ceramic Matrix Composite
PMC	Polymer Matrix Composite
AMC	Aluminium Matrix Composite
LM	Liquid Metallurgy
PM	Powder Metallurgy
MML	Mechanical Mixed layer
MIM	Metal Injection Moulding
ASTM	American Standard Testing Method
RPM	Revolution per Minute
UTM	Universal Testing machine
VHN	Vickers Hardness Number
SEM	Scanning Electron Microscope
TEM	Transmission Electron Microscope
EDX	Energy Dispersive X-Ray
XRD	X-Ray Diffraction
SPSS	Statistical Package of Social Science
ANOVA	Analysis of variance
PSAC	Palm Shell Activated Carbon

LIST OF SYMBOLS

^0C	Degree Celsius
%	Percent
wt. %	Weight percent
mg/m	milligram per metre
m^3/m	volume per metre
m^2	Metre square
nm	Nanometre
µm	Micrometre
g	Gram
ρ	Density
I_v	Independent variable
D_v	Dependent variable
MPa	Megapascal
H	Hardness

Sifat-Sifat Fizikal dan Haus Aluminium Matrix Komposit Bertetulang dengan PSAC dan Jermang Dihasilkan melalui Metalurgi Serbuk

ABSTRAK

Satu kajian sifat-sifat fizikal dan haus telah dijalankan pada aluminium tulen bertetulang dengan zarah produk terbuang biojisim seperti zarah karbon teraktif kelompang sawit (PSAC), zarah jermang dan zarah PSAC / jermang. Komposit aluminium hibrid dan bukan hibrid mengandungi 5-20% berat penguat telah dihasilkan melalui metalurgi serbuk. Sifat-sifat fizikal spesimen lepas sinter seperti ketumpatan, keliangan ketara dan kekerasan makro telah ditentukan. Kadar haus diukur dengan teknik pin-pada-cakera. Manakala puing, permukaan dan sub-permukaan haus telah dianalisis dengan menggunakan SEM dan EDX. Ujikaji gelonsor kering telah dijalankan dalam udara pada suhu bilik menggunakan pin-pada-cakera bina sendiri dipasangkan kepada mesin penggilap. Cakera yang bertindak sebagai bahan permukaan lawan dibuat daripada keluli lembut. Pengaruh beban kenaan telah dikaji di bawah halaju gelonsor malar adalah 150 rpm (0.58 m/s) dengan beban kenaan pada 3 N, 11 N dan 51 N. Keputusan menunjukkan bahawa ketumpatan pukal dan kekerasan makro komposit jermang/Al adalah tertinggi. Komposit hibrid PSAC/jermang/Al memberi nilai pertengahan dan komposit PSAC/Al memberi nilai terendah. Keliangan bagi komposit PSAC/Al adalah tertinggi, komposit jermang/Al adalah terendah dan komposit hibrid PSAC/jermang adalah pertengahan secara perbandingan. Gelongsor haus kering menunjukkan kehilangan jisim komposit berbanding aluminium telah menurun dengan ketara pada penambahan tetulang sehingga 20% berat jermang untuk komposit jermang/Al, sehingga 15% berat PSAC/jermang untuk komposit hibrid dan sehingga 10% berat PSAC untuk komposit PSAC/Al. Rintangan haus komposit PSAC/Al berbanding aluminium telah meningkat dengan ketara pada beban sehingga 11 N tetapi untuk jermang/Al dan PSAC/jermang/Al komposit berbanding dengan aluminium telah meningkat dengan ketara pada beban sehingga 51 N. Kadar haus kumulatif komposit PSAC/Al menurun apabila kandungan PSAC kurang daripada 10% berat PSAC dan meningkat apabila kandungan PSAC lebih daripada 10% berat. Didapati kandungan PSAC adalah 10% berat demi mencapai rintangan haus yang optimum. Kadar haus kumulatif komposit hibrid PSAC/jermang/Al menurun apabila kandungan PSAC/jermang kurang daripada 15% berat dan meningkat apabila kandungan PSAC / jermang lebih daripada 15% berat. Didapati kandungan PSAC/jermang adalah 15% berat untuk mencapai rintangan haus yang optimum. Kadar haus kumulatif komposit jermang/Al menurun secara drastik apabila jermang kurang daripada 10% berat. Mikrograf SEM bagi komposit 10% berat PSAC/Al menunjukkan lapisan berlumur karbon pada permukaan haus yang bertindak sebagai pelinciran diri dan memperbaiki rintangan haus. Walau bagaimanapun, mikrograf SEM bagi komposit 20% berat jermang/Al menunjukkan kehadiran puing halus sebagai jasad ketiga yang bertindak sebagai pemisah di antara spesimen dan permukaan lawan. Jasad ketiga ini mengurangkan interaksi langsung dan memperbaiki rintangan haus. Mikrograf SEM bagi komposit hibrid 7.5% berat PSAC/7.5% berat jermang/Al menunjukkan puing berlumur tak selanjar yang hadir pada permukaan haus memperbaiki rintangan haus yang lebih baik.

Physical and Wear Properties of Aluminium Matrix Composite Reinforced with PSAC and Slag Fabricated via Powder Metallurgy

ABSTRACT

A study of physical and wear properties were carried out on pure aluminium reinforced with biomass by product such as palm shell activated carbon (PSAC), slag and PSAC/slag particles. Hybrid and unhybrid aluminium composites containing 5-20 wt.% of reinforcements were fabricated via powder metallurgy. Physical properties of as-sintered specimen such as density, apparent porosity and macro-hardness are determined. The wear rate was measured by pin-on-disc technique while debris, worn and sub-surfaces have been analysed by using SEM and EDX. Dry sliding experiments were conducted in air at room temperature using a pin-on-disc self-built attached to polisher machine. The disc which acted as the mating surface material was made of mild steel. The influence of the applied load was investigated under a constant sliding velocity of 0.58 m/s with the applied loads at 3 N, 11 N and 51 N. Result appears that the slag/Al unhybrid composite had the highest values of bulk density and macrohardness. The PSAC/slag/Al hybrid composite gave intermediate values and the PSAC/Al unhybrid composite gave the lowest values. Porosity of PSAC/Al unhybrid composite was the highest, slag/Al unhybrid composite was lowest and PSAC/slag hybrid composite was the intermediate comparatively. Dry wear sliding showed the mass loss of composites relative to the aluminium was reduced significantly when the addition of reinforcement up to 20 wt.% slag for Al/slag composite, up to 15 wt.% PSAC/slag for hybrid composite and up to 10 wt.% PSAC for Al/PSAC composite. The wear resistance of Al/PSAC composites relative to the aluminium was improved significantly at a load up to 11 N but for Al/slag and Al/PSAC/slag composites relative to the aluminium was improved significantly at load up to 51 N. The cumulative wear rate of the PSAC/Al unhybrid composite decreased when the PSAC content less than 10 wt.% PSAC and increased when PSAC content more than 10 wt.%. The optimum content of PSAC was found to be 10 wt.% in order to achieve optimum wear resistance. The cumulative wear rate of the PSAC/slag/Al hybrid composite decreased when the PSAC/slag content less than 15 wt.% and increased when PSAC/slag content more than 15 wt.%. The optimum content of PSAC/slag was found to be 15 wt.% in order to achieve optimum wear resistance. The cumulative wear rate of the slag/Al unhybrid composite decreased drastically when the slag content less than 10 wt.%. SEM micrograph of 10 wt.% PSAC/Al composite showed carbon film smeared on the worn surface acting as self lubrication and improved wear resistance. However, SEM micrograph of 20 wt.% slag/Al composite showed the presence of fine debris as third body that acting as separator between specimen and mating surface. This third body reduced direct interaction and improved wear resistance. SEM micrograph of 7.5 wt.% PSAC/7.5 wt.% slag/Al hybrid composite showed discontinuous smear debris particles present at contact of wear surface and improved wear resistance.

CHAPTER 1

INTRODUCTION

1.1 Recent Scenario of Aluminium Matrix Composite

Aluminium Matrix Composite (AMC) is a kind of material having special function and structures. It is formed by spreading reinforcement in matrix of aluminium alloy. AMC has many advantages such as isotropic properties, better specific strength, high stiffness and hardness as well as good wear resistance. Therefore, AMC are applied to automotive industry such as cylinder liners, brake disc and drums, wear resistance materials (cemented carbides) and sporting equipment (bicycle frame, golf head and chain wheels). Technologically, almost all AMCs have difficulties in mixing or combining the reinforcing phase with the matrix. Many of the techniques were taken to overcome the processing problems have resulted in high material costs, leading to extremely limited use (Yeh et al., 1997). However, the emerging mixing techniques have improved the fabrication technique for particulate composite with differing reproducible structures and properties. Fabrication techniques like vortex technique under vacuum, compocasting, infiltration process, spray process and powder metallurgy have been developed in production of AMC. Currently, one of major driving forces for the technological development of aluminium matrix composite is a result of superior wear resistance and hence potential candidate for a number of tribological applications (Mazlee, 2006). Much effort has been given to produce more durable materials and techniques to reduce the wear of tools and engineering components. These include modification of bulk properties of the materials through fabrication of AMCs. Over 30 years, researches have been focused on understanding the behaviour of surfaces in sliding contact and the mechanism of AMCs, which leads to wear. It can be seen from the previous works, the main particulate reinforcements used in aluminium matrix composites are silicon carbide (Rao & Das, 2011), alumina (Wang et al., 2010) and graphite (Deaquino-Lara et al., 2011). In fact, many other possible reinforcements are readily available or naturally renewable at affordable cost such as coconut shell char, mica, palm-kernel shell char and zircon (Ejiofor & Reddy, 1997) as well as fly ash (Luong et al., 2011). Palm shell activated carbon (PSAC) and slag are also potential to be used as reinforcement in aluminium matrix composite due to the similarity with graphite that contain of carbon content. PSAC and slag are biomass by-products from palm oil factory and can be obtained locally. The idea proposed is to reduce the cost of starting material in fabrication of novel aluminium composite reinforced with local waste materials. From the practical perspective, the utilisation of PSAC as reinforcement in fabrication of metal composite is also important for the development of palm oil industry in Malaysia in order to reduce the waste materials. It can help the government to formulate the right and appropriate strategies to promote sustainable approaches in generating higher value-added products from palm biomass and adopting of zero waste strategy.

1.2 Problem Statements

Based on the current issues, there are three problems need to be solved in order to make aluminium matrix composites more competitive and environmental friendly.

The problems are:

(a) Aluminium is an important material for engineering application because of its low density and high thermal conductivity. However, aluminium by itself exhibits poor wear properties that lead to tribological problems during application (Venkatamaran and Sundarajan, 2000). Improving the wear properties of aluminium by using particulate reinforcement strengthening is necessary due to isotropic properties of particulate form in particular.

(b) Fabrication of aluminium composites had established by reinforced with silicon carbide, alumina and graphite. However, those materials are imported and highly cost that lead to the problems during fabrication. It is possible, to reduce the cost of reinforcement by using natural resources (Ejiofor and Reddy, 1997) such as biomass (PSAC) and by-product (slag) that can be obtained locally at affordable cost or no cost.

(c) In Malaysia, palm shell is one of the main agriculture wastes from the palm oil industries lead to abundant and environmental pollution problems due to hard clinker. Several studies have been initiated to utilise palm shell in order to reduce the abundant problems (Luo & Guo, 1998; Bizami et al., 2011). Therefore, to overcome the abundant and pollutions problem through sustainable engineering concept, the utilisation of the palm shell as reinforcement can be proposed to