STUDY ON THE MECHANICAL AND WEAR PROPERTIES OF Mg/SiC/Gr HYBRID METAL MATRIX COMPOSITE

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MASTER OF SCIENCE

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We hereby declare that we have checked this thesis, and in our opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Master of Science.

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I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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ABSTRAK

Reka bentuk yang ringan dengan ciri mekanikal yang sempurna pada masa kini merupakan sasaran utama dalam pelbagai industri, terutamanya dalam industri automotif dan aeroangkasa. Kebelakangan ini, magnesium (Mg) menjadi salah satu bahan yang sangat diperlukan untuk digunapakai bagi industri-industri tersebut kerana ketumpatan Mg yang rendah dan kebolehbentukan yang tinggi. Walau bagaimanapun, Mg menunjukkan ketahanan kepada kehausan yang rendah dalam keadaan kekurangan pelincir dan membataskan penggunaannya dalam aplikasi tribologi. Oleh itu, bahan pelincir grafit dipilih kerana pelincir pepejal yang terkandung di dalamnya boleh dikeluarkan secara automatik semasa proses penghausan untuk mengurangkan kehausan. Grafit (Gr) adalah salah satu bahan yang mempunyai ciri-ciri pelincir tinggi. Walau bagaimanapun, kekangan grafit dalam menambah matriks magnesium adalah ia mengurangkan kekuatan komposit dengan ketara. Oleh itu, satu penyelesaian yang dapat dilakukan adalah menambah bahan ketiga kepada komposit Mg-Gr untuk meningkatkan kekuatan komposit. SiC adalah salah satu bahan seramik yang digunakan secara umum yang boleh ditambah kepada magnesium agar dapat meningkatkan kekuatan mekanik. Isu utama dalam penghasilan komposit adalah untuk mengekalkan keseragaman zarah tetulang pada matriks metalik. Kekuatan mekanikal dipengaruhi oleh homogeniti zarah. Antara pelbagai teknik fabrikasi, metalurgi serbuk dianggap sebagai proses yang efektif kerana keseragaman dapat dicapai dengan cara ini. Oleh itu, dalam kajian ini, komposit hibrid terdiri daripada matriks magnesium dan SiC, juga Gr telah dihasilkan melalui teknik metalurgi serbuk; dan kesan kandungan SiC dan grafit pada ciri-ciri mekanikal dan tribologi komposit Hibrid Mg / SiC / Gr telah dikaji. Dalam kajian ini, fabrikasi telah dijalankan dalam dua fasa. Pada fasa pertama, komposit magnesium-grafit (Mg-Gr) dengan nilai peratusan berat yang berbeza dari grafit telah direka dan sifat mekanikal dan kehausan bahan tersebut dinilai dan nilai optimum grafit telah ditentukan. Seterusnya, MMC hibrid telah direka dengan menambah zarah tetulang SiC dan grafit kepada bahan asas magnesium komposit magnesium dan Mg-Gr tulen. Selain itu, kesan gabungan 10% SiC dan 5% Gr menunjukkan prestasi yang tinggi dalam kedua-dua sifat mekanikal dan tribologi. Pada peringkat ini, peratusan zarah grafit ditetapkan pada satu nilai (nilai yang memberikan ketahanan kepada kehausan yang tinggi) tetapi peratusan tetulang SiC dipelbagaikan untuk mendapatkan sifat mekanikal yang tinggi. Serbuk mentah dengan peratusan yang diingini dicampur, dipadatkan dan disinter untuk mendapatkan komposit hibrid. Sampel-sampel yang dibuat kemudian disediakan untuk pencirian struktur mikro, ujian mekanikal dan tribologi. Struktur mikro menunjukkan pengikatan ikatan dan keseragaman yang betul bagi tetulang dalam matrik Mg. Hasilnya menunjukkan bahawa semua sifat mekanikal, termasuk kekerasan, kekuatan tegangan dan kekuatan lenturan meningkat dengan ketara dan sifat-sifat tribologi bertambah baik dalam komposit hibrid berbanding dengan komposit magnesium dan Mg-Gr tulen. Selain itu, kesan gabungan 10% SiC dan 5% Gr menunjukkan prestasi yang tinggi dalam kedua-dua sifat mekanikal dan tribologyi.

ABSTRACT

Nowadays, lightweight design with perfect mechanical properties is the major target in various industries, especially in the automotive and aerospace manufacturing. Therefore, magnesium (Mg) becomes one of the significantly demanding material for such industries in recent years due to its low density and high formability. However, Mg shows low wear resistance under insufficient lubricating conditions which limits its use in tribological applications. Therefore, self-lubricating materials are preferred because the solid lubricant contained in them can be automatically released during the wear process to reduce the wear. Graphite (Gr) is one of the materials which possess high lubricating characteristics. However, the limitation of graphite in adding magnesium matrix is that it significantly reduces the strength of the composite. Therefore, one solution could be to introduce a third material to the Mg-Gr composite to improve the strength of the composite. Silicon Carbide (SiC) is one of the popularly used ceramic materials whose introduction to the magnesium can increase the mechanical strength. The most important issue of composite fabrication is to maintain the uniformity of the reinforcement particles in the metallic matrix. The mechanical strength is significantly influenced by the particles homogeneity. Among the various fabrication techniques, powder metallurgy is considered to be an effective process as reinforcements uniformity can be achieved by this. Therefore, in this study, hybrid metal matrix composite (MMC) composed of magnesium matrix and SiC, Gr reinforcements has been developed by powder metallurgy technique and the effect of SiC and graphite content on the mechanical and the tribological behaviour of the Mg/SiC/Gr hybrid composite has been studied. The fabrication has been carried out in two phases. In the first phase, magnesium-graphite (Mg-Gr) composites with different weight percentage values of graphite were fabricated and their mechanical and wear properties were evaluated, and the optimum value of graphite was determined. After that, hybrid MMCs was fabricated by adding SiC and graphite reinforcement particles to the magnesium base material. At this stage, the percentage of the graphite particles kept constant (the value gave high wear resistance) but the percentage of SiC reinforcement varied in order to obtain the high mechanical properties. The raw powders with the desired percentage were mixed, compacted and sintered to produce the hybrid MMCs. The fabricated samples were then prepared for microstructural characterization, mechanical and tribological tests. The microstructure shows a proper bonding and uniform distribution of the reinforcement in the Mg matrix. The results revealed that all the mechanical properties, including hardness, tensile strength and flexural strength increases significantly and the tribological properties tremendously improved in the hybrid composite as compared to the pure magnesium and Mg-Gr composite. Moreover, the combined effect of 10% SiC and 5% Gr shows superior performance in both the mechanical and tribological properties.

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LIST OF SYMBOLS

Ag	Silver
Al	Aluminium
AlN	Aluminium nitride ceramic
Al_2O_3	Aluminium oxide
Al_4C_3	Aluminium carbide
B_4C	Boron carbide
C	Carbon
Ca	Calcium
CNT	Carbon nanotube
Cu	Copper
Fe	Iron
g	Gram unite
g/mol	Gram/mole
g/cm3	Gram per cubic centimetre
h	Height
KN	Kilonewton
L	Length
MoS_2	Molybdenum disulphide
mm	Millimetre
MPa	Megapascal
m/s	Metre per second
mm3 /N-m	Cubic millimetre per newton metre
N	Newton
Ni	Nickel
p	Applied load
Pb	Lead
PVA	Polyvinyl alcohol
S1	Sample one
S2	Sample two
Si	Silicon
SiO_2	Silicon dioxide

Sn	Tin
SiC	Silicon carbide
t	Thickness
Ti	Titanium
TiB_2	Titanium diboride
TiC	Titanium carbie
wt%	Weight percentage
WC	Tungsten arbide
Zn	Zinc
Ɵ	Diameter
σ_B	Bending stress

LIST OF ABBREVIATIONS

ASTM	American Society for Testing and Materials
CFMMCs	Continuous Fiber-Metal Matrix Composite
CIP	Cold Isostatic Pressing
CVD	Chemical Vapour Deposition
DMA	Disintegrated Melt Deposition
HIP	Hot Isostatic Pressing
HV	Vickers Hardness
MA	Mechanical Alloying
MMCs	Metal Matrix Composite
MFMMCs	Mono Filment Reinforced Metal Matrix Composite
PM	Powder Metallurgy
PRMMCs	Particle Reinforce Metal Matrix Composite
RSP	Rapid Solidification Process
SEM	Scanning Electron Microscope
SFMMCs	Wisker or Short Fiber Reinforced Metal Matrix Composite
XRD	X-ray Powder Diffraction

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