STUDY ON FABRICATION AND MECHANICAL PROPERTIES OF AL-SIC NANO-COMPOSITE MATERIALS

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Report submitted in partial fulfillment of the requirements
for the award of the degree of
Bachelor of Engineering (Hons.) in Manufacturing Engineering

Faculty of Manufacturing Engineering
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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

h	Height (thickness) of the nano-composite
m_{Al}	Mass of aluminium
m_{SiC}	Mass of silicon carbide
M_{Al}	Molecular mass of aluminium
M_{SiC}	Molecular mass of silicon carbide
r	Radius of the nano-composite
V	Volume
ρ	Density
μ	Micron

LIST OF ABBREVIATIONS

Al	Aluminium
Al_2O_3	Aluminium oxide
Al-SiC	Aluminium silicon carbide
Al-TiO_2	Aluminium titanium oxide
Alumix 231	Al-14Si-2.5Cu-0.5Mg
Alumix 321	Al-1.0Mg-0.5Si-0.2Cu
AMC	Aluminium metal matrix composite
CFAMC	Continuous fibre-reinforced Aluminium metal matrix composite
Cu	Copper
HRE	Rockwell E Hardness Number
HV	Vicker Pyramid Number
h-BN	Hexagonal boron nitride
Mg	Magnesium
MFAMC	Mono filament-reinforced aluminium metal matrix composite
MMC	Metal matrix composite
PAMC	Particulate-reinforced aluminium metal matrix composite
P/M	Powder metallurgy
SFAMC	Short fibre-reinforced aluminium metal matrix composite
SiC	Silicon carbide
TiB_2	Titanium diboride
TiO_2	Titanium oxide

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ABSTRACT

The development of metal matrix composite (MMC) has set the stage for a new revolution in materials. Aluminium Silicon Carbide (Al-SiC) nano-MMC has better mechanical properties than micro-MMC and has extremely high strength and hardness. The Al-SiC nano-composites were fabricated using powder metallurgy method to produce a more uniform distributed structure. Compactions of the nano-composites were performed using hydraulic press and a cylindrical shaped die. Two compaction loads, 15 Ton and 20 Ton, have been used to fabricate the nano-composite. The Al-SiC nano-composites have been sintered in two different temperatures. Green uniaxial press compacts in the different compaction load of 15 Ton and 20 Ton were sintered at the temperatures of 580 ℃ and 600 ℃. The heating rate of the sintering process was 5 ℃/min and the sintering time varied between at 4 hour and 5 hour. Hardness and density of the nano-composites were investigated. Besides that, the microstructure of sintered nano-composites has been examined and characterized. It was found that the compaction load and sintering temperatures have significantly affected the mechanical properties and microstructure of the nano-composites. Green and theoretical density increased with the increment of compaction pressure. Besides that, the nano-composites have a better hardness value with higher compaction load and higher sintering temperature. It is found in the research that the nano-composite with 20 Ton compaction load and 600 ℃ sintering temperature provided better hardness value and microstructure as compared to the samples fabricated by other compaction load and sintering temperature. However, residual porosities were present in all sintered nano-composites under each sintering condition. This research demonstrated that the higher compaction load and sintering temperature contributed better mechanical properties for the nano-composite.

ABSTRAK

Pembangunan komposit matriks logam (MMC) telah menyediakan pentas bagi revolusi baru dalam bahan. Aluminium Silicon Carbide (Al-SiC) nano-MMC mempunyai sifat mekanikal yang lebih baik daripada mikro-MMC dan mempunyai kekuatan dan kekerasan yang sangat tinggi. Al-SiC nano komposit telah direka menggunakan kaedah metalurgi serbuk untuk menghasilkan struktur yang lebih seragam. Pemadatan daripada nano-komposit telah dilakukan dengan menggunakan penekan hidraulik dan die berbentuk silinder. Dua beban pemadatan, 15 Ton dan 20 Ton, telah digunakan untuk menghasilkan nano komposit. Al-SiC nano komposit telah disinter dalam dua suhu yang berbeza. Kompak hijau akhbar ekapaksi dalam beban pemadatan yang berbeza 15 Ton dan 20 Ton telah disinter pada suhu 580 ℃ dan 600 ℃. Kadar pemanasan proses pensinteran adalah 5 ℃/min dan masa pembakaran yang berbeza antara 4 jam hingga 5 jam. Kekerasan dan ketumpatan nano komposit telah disiasat. Selain itu, mikrostruktur tersinter nano komposit telah diperiksa dan ciri-ciri. Ia telah mendapati bahawa beban pemadatan dan pensinteran suhu telah terjejas dengan ketara sifat-sifat mekanikal dan mikrostruktur nano komposit. Ketumpatan hijau dan teori meningkat dengan peningkatan tekanan pemadatan. Di samping itu, nano-komposit mempunyai nilai kekerasan yang lebih baik dengan beban pemadatan yang lebih tinggi dan suhu pembakaran yang lebih tinggi. Ia didapati dalam kajian bahawa nano-komposit dengan 20 Ton beban pemadatan dan 600 ℃ suhu pembakaran disediakan nilai kekerasan yang lebih baik dan mikrostruktur berbanding sampel dipalsukan oleh beban pemadatan lain dan suhu pembakaran. Walau bagaimanapun, sisa keporosan yang terdapat dalam semua nano komposit tersinter di bawah setiap keadaan pensinteran. Kajian ini menunjukkan bahawa beban pemadatan dan pensinteran suhu yang lebih tinggi menyumbang sifat-sifat mekanikal yang lebih baik untuk nano komposit.

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Metal Matrix Composite (MMC) is a composite consisting of two kinds of material where the matrix is metal. The Al-SiC MMC is composite with Al matrix and SiC reinforcement. SiC reinforced Al alloy composite is widely used in automotive, aerospace and other engineering applications. This is because they have better mechanical properties compared to the metal alone. Al-SiC has higher strength, modulus, excellent wear resistance, high hardness, high compressive strength and attractive thermal and electrical characteristics (El-Kady and Fathy; Rana et al.; Thakur, Tun, and Gupta). There are many kinds of method can be used to fabricate this kind of composite such as stir casting, squeeze casting, diffusion bonding and powder metallurgy method. Each of the method has its own advantage and also disadvantages. For example, casting method is normally used for economic purpose since it is the least expensive method (Saravanani et al.). However, in this thesis, the powder metallurgy method will be used to fabricate the MMC. This method has a great advantage of better uniformity distribution of SiC reinforcement in the Al matrix can be achieved. The uniformity distribution of the reinforcement is important in the composite because it can prevent the MMC to crack at the earlier stage. Other manufacturing methods fail to satisfy this (Venkatesh and Harish; Moazami-Goudarzi and Akhlaghi).

The compaction process and sintering process in the powder metallurgy method will affects the mechanical properties of the MMC. The particle arrangement of the MMC depends on the compaction load during the cold compaction process (Moazami-Goudarzi and Akhlaghi). And the porosity variation of the MMC can be controlled by the sintering temperature in the sintering process (Dutta and Bose). The optimal compaction load and sintering temperature will yield the better mechanical properties like density and hardness.

It is commonly recognized that the particle size of the reinforcement will affect the mechanical properties of the MMC. Hardness, compression strength and wear resistance of the composite is improved when proper SiC reinforcement is added to the matrix (El-Kady and Fathy). It can be seen obviously the difference in the mechanical properties using the micro-sized SiC particle reinforcement compared to the nano-sized SiC particle reinforcement. By using the nano-sized SiC particle reinforcement, the hardness, strength and the yield strength of the composite is increased (Thakur, Tun, and Gupta).

1.2 PROBLEM STATEMENTS

Al-SiC MMC (Metal Matrix Composite) is one type of composite that can enhance the mechanical properties such as the hardness, tensile strength and yield strength of the aluminium when the reinforcement, SiC is added to it. The plastic incompatibility modulus between the Al (matrix) and SiC (reinforcement) will cause the formation of dislocation tangles and the formation of dislocation cell structure. These formations of dislocation will affect the mechanical properties of the composite (Williams et al.). Literature review showed that due to the presence of micro-size SiC particles, fracture initial early in the MMC as the crack breaks the particle and propagate. Therefore, the overall mechanical properties of the MMC reduced. So reduction of the size of particle can be a solution to increase the life of MMC. This is because when it is below the critical level, particles will no longer fracture.

The uniformity or homogeneous distribution of particle is also very important to get a good mechanical response of the composite (Kung et al.). There are many types of method that can be used to manufacture the Al-SiC MMC. Most of the methods have a nearly uniform distribution of the reinforcement particle within the matrix. However, there are still some small agglomerations between it (Saravanani et al.). To reduce the agglomerations, the powder metallurgy method is used. This method can help to have a uniform and homogeneous distribution by length of the mixing time of the powders in the mixing procedure (Wozniak et al.).

1.3 OBJECTIVES

The objectives of this thesis are:

- To fabricate the Al-SiC nano-composite using powder metallurgy technique.
- To determine the effect of compaction load on the mechanical properties of nano-MMC.
- To determine the effect of sintering temperature on the mechanical properties of nano-MMC.

1.4 SCOPE OF RESEARCH

- To fabricate the Al-SiC nano-MMC.
- To determine the mechanical properties of the nano-MMC.

1.5 THESIS ORGANIZATION

This thesis consists of five chapters. The first chapter is organized about introduction, problem statement, objectives, research scope and the organization of the thesis. Then, in Chapter 2, it is explained about the literature review of some other researches about the method and mechanical testing on the nano-composite. In Chapter 3 is described about the process of the powder metallurgy method that will be used in this research to fabricate the nano-composite. The result of microstructure and mechanical properties of the nano-composites will be discussed in the Chapter 4. Finally, Chapter 5 presents the concluding remarks of the nano-composite.

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