UNIVERSITI TEKNIKAL MALAYSIA MELAKA (UTeM)

EFFECT OF SINTERING PARAMETER IN COPPER BASED ALLOYS METAL MATRIX COMPOSITE

This report is submitted with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Engineering Materials) (Hons.)

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DECLARATION

I hereby, declared this report entitled ‘Effect of sintering parameter copper based alloy reinforced tungsten carbide, metal matrix composites’ is the results of my own research except as cited in references.

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment to the requirements for the degree of Bachelor of Manufacturing Engineering (Engineering Materials) (Hons.). The member of the supervisory is as follow:

……………………………………..

(**Puan Siti Rahmah Binti Shamsuri**)

ABSTRAK

Aloi tembaga mempunyai sifat kekuatan yang baik tetapi tembaga juga adalah bahan yang menpunyai sifat lembut dan tidak sesuai untuk aplikasi keras seperti alat memotong. Disebabkan had-had pada sifat aloi tembaga, ia adalah penting untuk menggabungkan aloi tembaga dengan bahan-bahan lain yang mempunyai sifat keras. Antara bahan-bahan yang mempunyai sifat keras termasuklah logam dan seramik, karbida tungsten (WC) mempunyai ciri-ciri yang menarik untuk digabungkan dengan aloi tembaga seperti kekerasan dan rintangan haus. Oleh itu, tujuan projek ini adalah untuk mengsintesis dan menententukan sifat-sifat sebatian komposit aloi tembaga dengan WC menggunakan kaedah metalurgi serbuk. Serbuk campuran Cu/WC disediakan dengan menggunakan proses pengilangan bola planet untuk menghasilkan komposit homogen serbuk. Kepekatan WC sebagai tetulang yang dicampurkan dengan serbuk Cu adalah masing-masing 10, 20 dan 30% dan disinter pada suhu dalam lingkungan 900°C-1050°C. Hasil menunjukkan bahawa kedua-dua kekerasan dan kepadatan meningkat dengan peningkatan suhu pensinteran untuk semua komposisi. Walau bagaimanapun pada suhu 1050°C kepadatan dan kekerasan untuk komposisi 70Cu/30WC sedikit berkurangan. Untuk imej SEM, diperhatikan bahawa keliangan berkurangan dengan meningkatkan suhu sinter daripada 900 ° C to1000 ° C.

ABSTRACT

Copper alloys have a good strength but the copper is soft and not suitable for hard application such as cutting tool. Due to the limitation on properties of copper alloy, it is vital to embed it with others hard materials. Among hard material which include metal and ceramic, tungsten carbide (WC) has attractive features to combine with copper alloys such as hardness and wear resistance. Thus the aim of this project is to synthesized and determined the properties of the composite compound of copper alloy with WC using powder metallurgy route. A mixture powder of Cu/WC powder has been conducted using planetary ball milling process to produce homogeneous composites powder. The concentration of WC as a reinforcement added to the Cu powder is 10, 20 and 30 wt% respectively and sintered at temperature in the range of 900°C-1050°C. The result shows that both hardness and density increased with the increase of sintering temperature for all compositions. However at 1050°C the density and hardness for 70Cu/30WC composition was slightly decreased. For SEM image, it was observed that the porosity decreased by increasing sintered temperature from 900°C to1000°C.

DEDICATION

To my beloved parents, family, and supervisor as well as all supporters

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First of all I would like to thank Allah for His blessing me good health and thinking during this project. I want to take this opportunity to record my utmost and since gratitude to my supervisor, PUAN SITI RAHMAH BINTI SHAMSURI. She has shown me guidance, important advice, and inspiration throughout my project. She also has given me knowledge essential in doing this project.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

Btu/lb	-	British Thermal Units per pounds
^{o}C	-	degree celcius
CMC	-	Ceramics Matrix Composite
Co	-	Cobalt
CuAl25	-	Copper Aluminium
CuCrZr	-	Copper Chromium Zirconium
Cr	-	Chromium
Cu	-	Copper
°F	-	Fahrenheit
FCC	-	Face Centered Cubic
FKP	-	Fakulti Kejuruteraan Pembuatan
g/cm^3	-	gram per cubic centimeter
GPa	-	Giga Pascal
HV	-	Hardness Vickers
J/g	-	Joule per gram
Ksi		Kilopound per square inch
Kg/dm^3	-	Kilogram per cubic decimeter
L	-	Lorents Number

lb/in^3	-	Pounds per cubic inch
MMC	-	Metal Matrix Composite
Mpa	-	Mega Pascal
OM	-	Optical Microscope
P/M	-	Powder Metallurgy
PSA	-	Particle Size Analyzer
Psi	-	Pound per square inch
PMC	-	Polymer Matrix Composite
rpm	-	revolution per minute
SEM	-	Scanning Electron Microscopy
SiC	-	Silicon Carbides
T	-	Absolute Temperature
Ti	-	Titanium
TEM	-	Transmission Electron Microscopy
µm	-	micrometer
UTeM	-	UniversitiTeknikal Malaysia Melaka
WC	-	Tungsten Carbides
Wt	-	Weight percent
%	-	Percent

CHAPTER 1

INTRODUCTION

This section basically provides introduction, problem statements, objectives and scope of this research.

1.1 Introduction

Powder metallurgy processing sequences consist of three major steps which are blending and mixing the powder, compaction and sintering. The component powders are mixed together with lubricant until a homogeneous powder mix is obtained. The mix is then loaded into a die and compacted under pressure before proceed to sintering process. This mixing process is to provide the homogenous mixture and also to mix with the lubricant and for compaction, the mixture powders are press into required shape in a die under pressure of 150 – 900 MPa to produce green compact. For sintering process the green compact was heating below melting temperature to increasing its strength by bonding together particle (Sontea Sever*et al*, 2002).

Powder metallurgy techniques are used for making large number of components such as friction material, refractory material, magnet material and also cemented carbide. Cemented carbide are very important product made by using powder metallurgy such as cutting tools, wire and deep drawing dies. These applications consist of tungsten carbide, tantalum, titanium and molybdenum. The actual proportions of various carbides depend upon its applications, either cobalt, nickel or also can used another ductile material such as copper as a matrix that can avoided the brittle fracture and mostly suitable for hard application such as cutting tools (Naiqin Zhou *et al*,.2004). The copper as a matrix and tungsten carbide as the reinforcement will be study in this research.

More over this copper have good properties like excellent electrical conductivity, high mechanical strength and with other properties ensure a wide application use copper. Many research work were published on the diverse processing and forming techniques of these composite materials especially on the development of highly reinforced copper alloys (D. Bozic *et al*,. 2009).

Other than that temperature is one of the important parameter in producing the material based on powder metallurgy because generally almost material is brittle at low temperature. Tube furnace is the preferred equipment to heating the sample of copper mix with tungsten carbides (green compact) at 900°c to 1050°c. Sintering will be under argon gas for 5 hours (A. Gokce *et al*., 2008). The effect of parameter sintering temperature on mechanical properties of this combination also will be study.

1.2 Problem Statement

The copper material has a good strength but the copper is soft and not suitable for hard application such as cutting tool, other than that copper is a ductile material because the crystal structure is face centered cubic (FCC) (Li M. *et al*,.2012). To make copper better in term of hardness, another hard material must be added to copper to produce a metal matrix composite (MMC) with good mechanical properties such as very hard, high strength and ductile. In this research,copper will be reinforced with tungsten carbides material. Even though this material is brittle but it has higher hardness compares other material such as nickel, zirconia and etc.The brittle fracture can be avoid by mixing the tungsten carbides with copper. Thus this composite will than make a very good combination of mechanical properties intern of hardness and brittleness (Naiqin Zhou *et al*,.2004) . Consequently, this research aims to prepare the copper reinforced with tungsten carbide, sintered at various temperature to enhance the bonding by using tube furnace and also to see the eefect of sintering temperature to certain temperature. The characterizations techniques such as Optical Microscope (OM) and Scanning Electron Microscopy (SEM), is to analyze the surface-interface structure, chemical elements and phase present. Surface hardness of Cu/WC composite reinforcedwill be analyzed by Vickers Microhardness.

1.3 Objective of Project

I. To produce 90, 80, 70 wt% of copper alloy matrix composite reinforced with 10, 20, 30 wt% of tungsten carbide respectively.

II. To studt the effect os sintering temperature on the mechanical properties of MMC.

III. To study the effect of sintering temperature on copper reinforced tungsten carbide microstructure using Optical Microscope (OM), Scanning Electron Microscopy (SEM).

1.4 Scope of Research

This research is focusing on the effect of sintering temperature on the copper metal matrix composite with composition of (90 wt% Cu, 10 wt% WC), (80 wt% Cu, 20 wt% WC) and (70 wt% Cu, 30 wt% WC). Powder particle of Cu and WC were used in this study as the main material. In order to produce the composites, an average particle size of powder with 2 μm copper powder and tungsten carbides powder were used. The Cu and WC powder were mechanically blended and mixed using planetary ball milling with ceramic balls for 48 hours. The purpose of the blending and mixing process is to mix the two different powder homogeneously as much as possible and to reduce the initial particle size up to 75 μm and also to reduce the internal stress within the powder samples. A single floating die was used to compact the powder in a manual hydraulic press to produce a green compact of Cu/WC powder. The green compact of Cu/WC was sintered in a tube furnace at a temperature of 900°C, 950°C, 1000°C and 1050°C for 3 hourssoaaking time with heating rates of 15 °C $min^{-}1$.

The copper reinforced tungsten carbides was then characterized by using Optical Microscope (OM), Scanning Electron Microscopy (SEM) and Vickers microhardness. OM was used to characterize the microstructure of the copper metal matric composite while the SEM was used to characterize morphology of solid sample after sintering process as well as after grinding and polishing process. The hardness and compressive strength of Cu/WC was determined by Vickers Microhardness Tester due to evaluate the MMC mechanical properties produce at various condition.

1.5 Project Organization

This project is divided into five chapters comprising of introduction, literature review, methodology, result and discussion as well as conclusion and future work respectively. The introduction chapter elaborates about the research background, problem statement, objectives, scope of study and the organization of the project.

Chapter two is literature review that will present the published literatures that are relevant to particular topic of this research, demonstrating the knowledge of any work before and the related theories and debates. It also provides the background of the new research, link to the new research to what preceded it.

In chapter three, details review on the methodology of the research. It explains more about the method that has been used for the experimental process. The most appropriate method was chosen, allowing the sample to be further analyzed by suitable material characterization method.

Chapter four explained on the result and the discussion for the experiment.

The conclusion this study is discussed in chapter five. It is also include some of the recommendation in order to get more satisfactory outcome in the future work.

CHAPTER 2

LITERATURE REVIEW

This section provides literature review related to the project development. It reviews on basic alloy materials and reinforcement used and its properties and application.

2.1 Metal Alloys

Metal alloys, by virtue of composition, are often group into two classes; ferrous and monferrous. Ferrous alloys, those in which iron is the principal constituent, include steels and cast irons. Nonferrous alloys are any metal including alloys that does not contain iron in a significant amount such as copper and copper alloys. These following subtopics explain the detail purposely on the type of metal alloys is ferrous and nonferrous alloys.

2.1.1 Ferrous alloys.

Ferrous alloys are those which constituent are produced larger quantities than any other type of metal. Ferrous alloys especially are important as engineering construction material, their widespread use is accounted for by three factor;

1. Iron containing compound exist in abundant quantities within the earth's crust
2. Metallic iron and steel alloys may be produced using relatively economical extraction, refining, alloying, and fabrication technique.
3. Ferrous alloys are extremely versatile, in that they may be tailored to have a wide range of mechanical and physical properties.

The principal disadvantages of many ferrous alloys are their succeptibility to corrosion. There are several types of ferrous alloy namely is steels, low carbon steels, high carbon steels, stainless steel and etc.

2.1.2 Nonferrous alloys.

Nonferrous alloys is and alloys that does not intentionally contain iron which are the by product of nonferrous metal such as aluminum, cobalt, lead, magnesium, titanium and zinc. In general, nonferrous alloys are more expensive than ferrous metals state by (Thomas *et al*,.1998).Nonferrous alloys are invested with non-magnetic properties, higher conductivity, have higher melting points and better strength, lightweight and are resistant to chemical and atmospheric corrosion. These properties make them a favored choice for several commercial and non-commercial uses, such as automobile and aircraft parts, communication equipment, water valves and the manufacturing flammables and explosives. Some non-ferrous materials are also used in the iron and steel industries. Nonferrous metal consist of many material such as copper, aluminum, magnesium, and titanium alloys. This project only focuses on copper alloy as the main ingredient and tungsten carbide particle as their reinforcement.

2.2 Copper alloys

Thomas *et al*,.(1998) in his paper mentioned that copper is one of the most useful material and it was one the first to be utilized. Copper is a reddish yellow material and extremely ductile. Copper has a good electrical conductivity which is conductivity of 97% and the crystal structure of copper is face-centered-cubic (fcc).Other than that copper has very high of the thermal conductivity. Now depending on the commercial product almost 400 different product made from copper alloys such as rods, plates, sheets, strips, tubes, pipes, extrusions, foils, forgings, wires, and castings from foundries. Typical elastic modulus of copper alloys is about 117 GPa for (25°C) at room temperature. The typical of the density copper alloys ranges from 8.8 to 8.94 g/cm3. The typical tensile strength of copper alloys between 172 and 220 MPa. The wide range of ultimate tensile strength is largely due to different heat treatment conditions. Cast copper alloy and wrought copper alloy is type of copper alloys.

Cast copper alloys generally have a great range of alloying elements than wrought alloys because of the nature of the casting process.

Wrought copper alloys produced by several methods such as annealed, cold worked, hardened by heat treatments, or stress relieved.

2.2.1 Properties of copper alloys

There are four type properties of copper alloys that is physical, mechanical, electrical and thermal conductivity. This following subtopic is explained about properties of copper alloy.