UNIVERSITI TEKNIKAL MALAYSIA MELAKA

THE INFLUENCE OF CU-REINFORCED ALUMINUM METAL MATRIX COMPOSITE TO THE MECHANICAL PROPERTIES, CORROSION RESISTANCE AND MICROSTRUCTURE

Thesis submitted in accordance with the requirements of the Universiti Teknikal Malaysia Melaka (UTeM) for the Degree of Bachelor of Engineering Manufacturing (Engineering Material) with Honours.

By

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I hereby declare that this report entitled **"THE INFLUENCE OF CU-REINFORCED ALUMINUM METAL MATRIX COMPOSITE TO THE MECHANICAL PROPERTIES, CORROSION RESISTANCE AND MICROSTRUCTURE"** is the result of my own research except as cited in the references.

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (*Engineering Material*). The members of the supervisory committee are as follow:

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ABSTRACT

The objective of this project is to the study the mechanical characteristic alteration, to investigate on corrosion rate and to carry out observation on the microstructure due to the different filler loading of reinforcement. The composition of reinforcement material which is cooper will be added to Aluminum 390. It will be in the verification into 0, 2, 5 and 8wt%. In addition, preparation of this sample is complete through casting process tag along with parameter of addition material specification as it's confirmed. Next, the cutting process is performing by following the standard size for remaining tests which is confirmed. Then, the metal block will going through with heat treatment process namely solution heat treatment and artificial ageing. Whilst the sample is produced, hardness test (ASTM E18-03), corrosion test (ASTM G61) and microstructure observation is perform. Based on the acquired data, the comparison will be performs between Aluminum 390 data and sample MMC data which is produced. The achieve result, for hardness test the value of HRB is increase together with expansion of copper and corrosion rate become higher with increases of copper percentage. If referred on theory, the achieve properties on this experiment has successfully fulfill objective of the project because theory authentication with experiment is parallel.

ABSTRAK

Objektif kajian ini adalah untuk mengkaji perubahan sifat mekanikal, mengkaji sifat pengaratan dan melihat kepada perubahan mikrostuktur melalui perbezaan penambahan bahan penguat. Komposisi bahan penguat iaitu kuprum yang akan dicampurkan kedalam Aluminum 390 divariasikan kepada 0, 2, 5, and 8 wt%. Penyediaan sample ini dilakukan melalui proses casting mengikut kepada parameter campuran bahan yang telah ditetapkan. Seterusnya bahan ini akan melalui proses rawatan haba iaitu 'solution heat treatment' dan 'Artifical ageing'. Kemudian blok ini akan dipotong mengikut kepada standard saiz bagi ujian-ujian yang telah ditetapkan. Apabila spesimen dihasilkan, ujian kekerasan (ASTM E18-03), ujian pengaratan (ASTM G61) dan pengkajian kepada perubahan mikrostruktur akan dijalankan. Berdasarkan data yang diperolehi akan dibuat perbandingan diantara data aluminium 390 dan data sample 'metal matrix composite' yang dihasilkan. Keputusan yang dicapai, untuk ujian kekerasan ia menunjukkan nilai kekerasan meningkat seiring dengan pertambahan peratusan kuprum dan peningkatan kadar pengaratan berlaku apabila nilai komposisi kumprum semakin meningkat. Jika dirujuk kepada teori, ia akan sifat-sifat yang dicapai ini telah berjaya menepati objektif projek ini kerana pembuktian teori dengan eksperiment adalah selari.

DEDICATION

This thesis is gratefully dedicated to my parents, my sisters, supervisor that is Pn. Intan Sharhida Bt Othman and the examiner that is Dr. Azizah Bt Shaaban towards the guidance and understanding given. Including lecturers, technicians and towards understanding, applications and accomplishing the test. Not to forget, to my closes friends that gave moral values and driven courage along the thesis process.

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LIST OF ABBREVIATIONS

Cr	-	Chromium
°C	-	Degree Celsius
Cu	-	Copper
g·cm-3	-	gram.centimeter-3
GPa	-	Giga Pascal
H_2O	-	Water (molecule)
HR	-	Rockwell hardness number
J/m	-	Joule/meter
Kg	-	Kilogram
kJ·mol-1	-	KiloJoule·mole- 1
Mn	-	Manganese
MPa	-	Mega Pascal
MMC	-	Metal matrix composite
Ni	-	Nickel
Nil	-	Zero
Psi	-	Pound per square inch
RC	-	Resistance/capacitance circuit
SUS	-	Steel use stainless
µm	-	Micrometer
%	-	Concentration
Ω.m	-	Ohm.meter

CHAPTER 1
INTRODUCTION

1.1 Introduction

Aluminum 390 has become a preferred materials for the automotive components because of its lightweight and good mechanical properties, hence offers the better strength-to-weight ratio material to these industries. The Aluminum 390 series alloy is one of the commercially important alloys. It is widely used for structural application such as cylinder head component. This is account on its excellent casting characteristics and good mechanical properties (Cerri, 1999). The Aluminum 390 becomes a preferred material in foundry application because of its excellent castability and mechanical properties. The alloy strength and ductility are optimised by heat treatment process comprising solution treatment and quenching followed by ageing. (Wang, 2003).

In this project Aluminum 390 will reinforced together with copper for several parameter 0, 2, 5, and 8 wt%. Expectation and prediction for this research hopefully will be given an excellent hardness property. The additional of copper particle in Aluminum 390 will increase mechanical properties. make the changes on the original properties. A series of microstructure observation, hardness tests, and corrosion tests will be conducted to study the properties of Aluminum 390 containing additional copper.

1.2 Problem Statement

Aluminum 390 is widely used as a casting material in manufacturing field. In this project aluminum 390 will reinforce with several parameter of copper to study the changes of the properties. The effect of copper on aluminum 390 is the main focusing in this project, because it will improve the mechanical properties based on the theoretical. Solution heat treatment and artificial ageing also be conduct to improve the properties. By the result in this project showed this material will have better properties than aluminum 309 or otherwise Hardness test, microstructure investigation and corrosion test is conducted in order to observe the sample on its physical changes instead use of Aluminum 390.

1.3 Objective

1. Investigate the changes of hardness properties Cu-reinforced Aluminum 390 at different filler loading of reinforcement.
2. Study the corrosion rate of Cu-reinforced Aluminum 390 at different filler loading of reinforcement.
3. Observe the microstructure of Cu-reinforced Aluminum 390 at different filler loading of reinforcement.

1.4 Scope of research including

The method for fabricate the specimen the starting point is to add both of the composite materials in the melting furnace. Hence, this molten melting material will dispense onto sand mold casting. This Block Metal metallic composite as shaped will get through the process of heat treatment using the conventional furnace. Next, the process of milling is to be executed. Next, the MMC block through the finishing process. Finally, the cutting process is carrying out to cutting the block to get the specimen shape as needed.

1. Mechanical test ASTM E18-03 – Rockwell hardness test.
2. Corrosion test of ASTM G61 – Corrosion rate of specimen.
3. Observation on microstructure to identify the chemical properties and microstructure

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This investigation studies the effects of various copper content and different heat treatment on the, mechanical, corrosion, and microstructure of Aluminum 390. Copper particle was added respectively to Aluminum 390 in proportions of 0, 2, 5, and 8 wt%. The combination of both materials is called as a metal matrix composite, which Aluminum 390 is a matrix and copper act as reinforcement. The induction furnace was used to melt the Aluminum 390 with various added of copper contents. These metal will be casting using sand casting and cut into test specimens and were through different parameter of heat treatments. A series of hardness test, corrosion tests, and microstructural observation were conducted to study the properties of Aluminum 390 reinforced with copper.

2.2 Metal Matrix Composite (MMC)

2.2.1 Introduction

As the name implies, for metal matrix composite (MMC), the matrix is ductile metal. These materials may be utilized at higher service temperature than their base metal counterparts; furthermore, the reinforcement may improve the specific stiffness, specific strength, abrasion resistance, creep resistance, thermal conductivity, and dimensional stability. (Callister 2005). The matrix alloy, the reinforcement material, the volume and shape of the reinforcement, the location of the reinforcement, and the fabrication method can all be varied to achieve required properties. Aluminum MMC is produced by casting, powder metallurgy, in situ development of reinforcements, and foil-and-fiber pressing techniques. Consistently high-quality products are now available in large quantities, with major producers scaling up production and reducing prices.

Compared to monolithic metals, MMC have higher strength-to-density ratios, higher stiffness-to-density ratios, better fatigue resistance and better elevated temperature properties. Aluminum 390 also has lower coefficients of thermal expansion and lastly better wear resistance. Several advantages of MMC over polymer matrix composites are higher temperature capability, fire resistance, higher transverse stiffness and strength. No moisture absorption, higher electrical and thermal conductivities, better radiation resistance, no out gassing, fabric ability of whisker and particulate-reinforced MMC with conventional Metalworking equipment. Some of the disadvantages of MMC compared to monolithic metals and polymer matrix composites are higher cost of some material systems, relatively immature technology, complex fabrication methods for fiber-reinforced systems (except for casting) and lastly limited service experience. Categories of MMC for this project is particulate reinforced MMC wish mean the metal matrix composite with a particulate reinforcement occupying a volume fraction greater than 5% in the material (otherwise, the particulates are generally considered to be inclusions). (A.Mortensen *et al.* 2000). The MMC produce in this project will through several basic stages such as pre-processing, composite production, shaping and forming and lastly is final component or specimen by referring to figure 2.1.

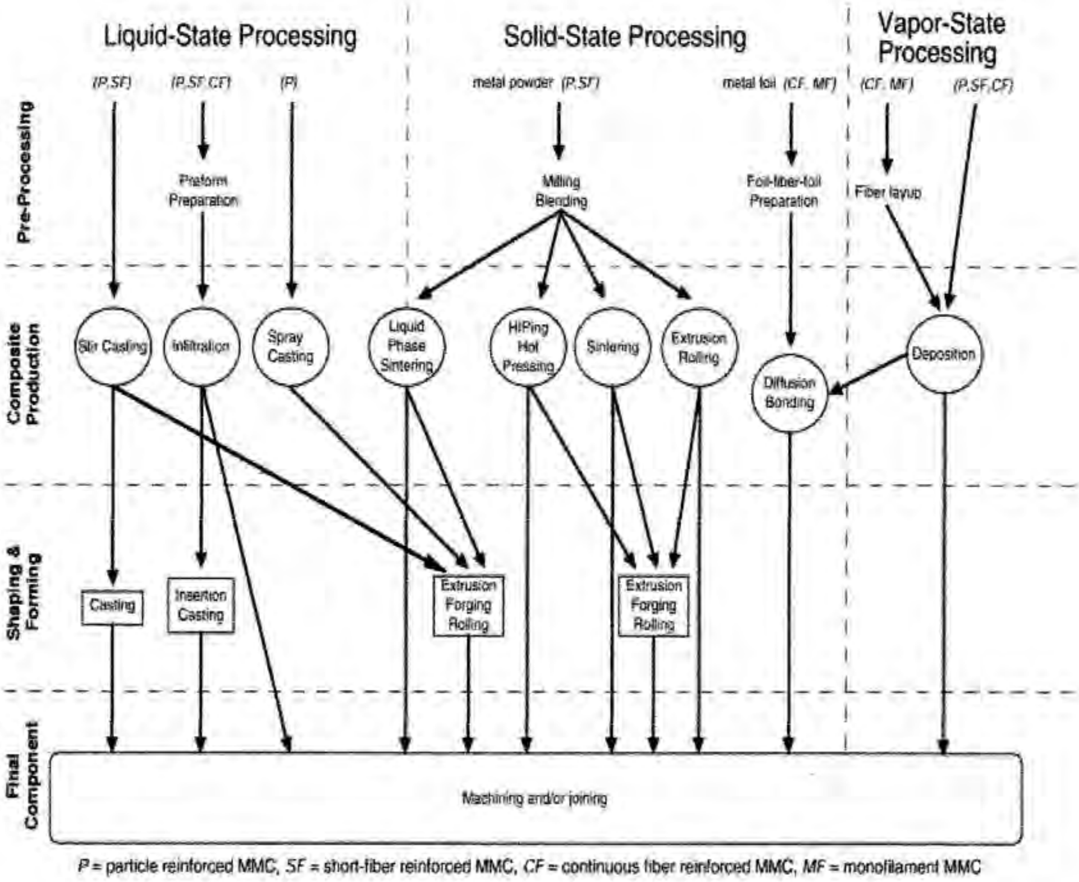


Figure 2.1: Metal Matrix Composite Processing. (A.Mortensen, 2000)

2.2.2 Matrix

The matrix is the monolithic material phase in the composite or two-phase alloy microstructure that is continuous or completely surrounds the other (or dispersed) phase. (Callister 2005). This means that there is a path through the matrix to any point in the material, unlike two materials sandwiched together. In structural applications, the matrix is usually a lighter metal such as aluminum, magnesium, or titanium, and provides a compliant support for the reinforcement. In high temperature applications, cobalt and cobalt-nickel alloy matrices are common. Metal matrix used for this project is a Aluminum 390.

2.2.3 Reinforcement

Metal matrix composite reinforcements can be divided into five major categories: continuous fibers, discontinuous fibers, whiskers, particulates, and wires. With the exception of wires, which are metals, reinforcements generally are ceramics. The reinforcement material is embedded into the matrix. The reinforcement does not always serve a purely structural task (reinforcing the compound), but is also used to change physical properties such as wear resistance, friction coefficient, or thermal conductivity. The reinforcement can be either continuous, or discontinuous. (Callister 2005). The copper which is use in this project functioned as reinforcement and attributes as large particle composites. Particulates roughly equated reinforcement or composite ingredient, usually of aspect ratio (ratio of largest to smallest diameter) less than about 5 %. (MMCICA, 2000). Copper size using in this metal matrix composite is 50μm ~ 100μm. Amount of copper for this project is divided into several parameters 0, 2, 5, and 8 wt%.

2.2.3.1 Particle – reinforced composite

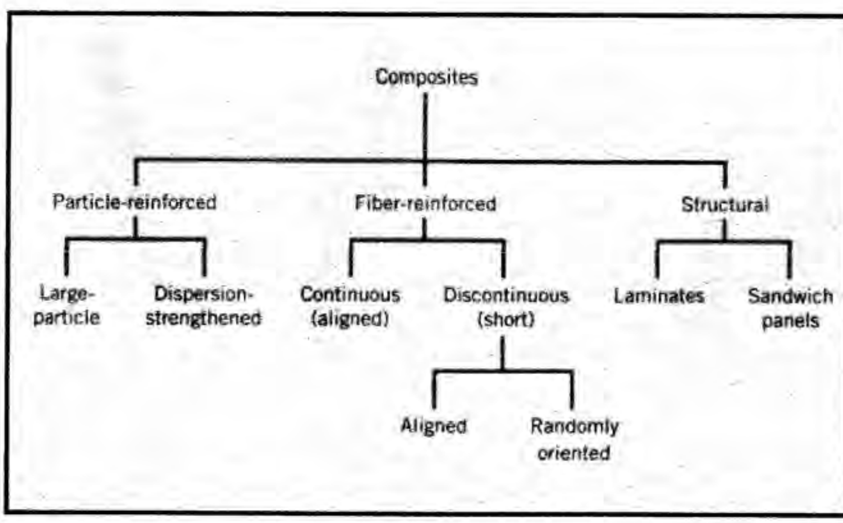


Figure 2.2: A classification scheme for the various composite types. (Callister 2005)

Simple scheme for the classification of composite material is shown in figure 2.2. Large particle and dispersion strengthened composites is the two sub classifications of particle reinforced composites. The distinction between these is based upon reinforcement strengthening mechanism. In this project type of dispersion strengthened large particle is selected. The properties of composites are a function of the properties of the constituent, phases their relative amounts, and the geometry of the dispersed phase. Dispersed phase geometry in this context means the shape of the particle and the particle size, distribution, and orientation; these characteristic are represented in figure 2.4.

For most for these composites, the particulates phase is harder and stiffer than the matrix. These reinforcing particles tend to restrain movement of the matrix phase in the vicinity of each particle. In essence, the matrix transfers some of the applied stress to the particles, which bear a fraction of the load. The degree of reinforcement or improvement of the mechanical behavior depends on strong bonding at the matrix-particle interface. (Callister 2005). The differential shape of particle will influence the microstructure of MMC. By referring to figure 2.3, it shown the type of particle dimensional.

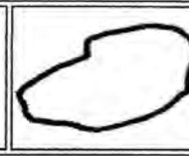
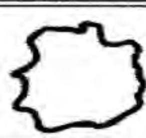
One-dimensional			
Acicular Chemical decompositions		Irregular Rod-like chemical decompositions mechanical comminution	
Two-dimensional			
Dendritic Electrolytic		Flake mechanical comminution	
Three-dimensional			
Spherical atomization cabonyl (Fe) precipitation from a liquid		Irregular Rod-like atomization chemical decomposition	
Irregular atomization chemical decompositions		Porous reduction of oxides	

Figure 2.3: Type of Particle Shapes (Metal Matrix Composites International Copper Association, 2002)

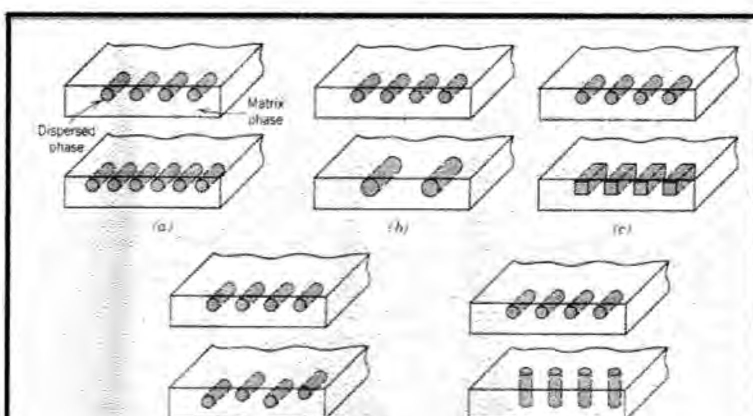


Figure 2.4: Schematics Representations Of The Various Geometrical And Spatial Characteristics Of Particles Of The Dispersed Phase That May Influence The Properties Of Composite : (A) Concentration, (B) Size, (C) Shape, (D) Distribution, (E) Orientation. (Callister 2005)

2.3 Aluminum 390

2.3.1 Overview

Aluminum 390 is a main material used for this project also known as a matrix. Castings are the main use of this material, although some sheet or wire is made for welding and brazing, and some of the piston alloys are extruded for forging stock. Often the brazing sheet has only a cladding of aluminum-silicon alloy and the core consists of some other high melting alloy. Silicon is the main alloying element; it imparts high fluidity and low shrinkage, which result in good castability and weldability. The low thermal expansion coefficient is exploited for pistons, the high hardness of the silicon particles for wear resistance. The maximum amount of silicon in cast alloys is of the order of 22-24% Si, but alloys made by powder metallurgy may go as high as 40-50% Si. (Totten, 1997)

2.3.2 Mechanical Properties

The mechanical properties of materials are of vital importance in determining their fabrication and practical application. For elongation test is initially as a load is applied on the material, the nominal stress is defined as the load divided by the original cross section area, and the nominal strain as the extension divided by the original length. (C. W. Lung, 1999). Table 2.1 showed the several grade of mechanical properties for Aluminum 390.