INFLUENCE OF NANO-REINFORCED PARTICLES ON THE MECHANICAL PROPERTIES OF ALUMINIUM METAL MATRIX COMPOSITE FABRICATED BY COOLING SLOPE CASTING

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

by

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I hereby, declared this report entitled “Mechanical and Physical Analysis on “Influence of Nano-reinforcement Particles on the Mechanical Properties of Aluminium Metal Matrix Composite Fabricated by Cooling Slope Casting” is the result 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 Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Degree of Manufacturing Engineering (Hons). The member of the supervisory committee is as follow:

Shukor

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Professor Madya Ir. Ts. Dr. Mohd Shukor bin Salleh

ABSTRAK

Nano komposit dengan asas aluminium yang diperkuat dengan zarah nano, mempunyai aplikasi yang luas dalam pelbagai industri, contohnya aeroangkasa, marin, automotif, kerana bahan tersebut ringan, kekuatan tegangan tinggi dan mempunyai yang rintangan kehausan yang tinggi. Sifat mikrostruktur, mekanikal dan tribologi bahan nano komposit adalah penting untuk reka bentuk bahan dalam mencari nilai optimum. Pengukuhan zarah julat mikro atau nano dengan matriks aluminium menghasilkan sifat fizikal dan mekanikal yang lebih baik dalam bahan komposit. Pencirian struktur mikro dan ujian mekanikal matriks komposit A356 dan pelbagai peratusan graphene (0.1, 0.3, 0.5 % berat) yang dihasilkan melalui proses kacau mekanikal dibincangkan dalam kertas kerja ini. Aloi A356 akan digunakan sebagai bahan matriks dan hasil nano graphene melalui kaedah pengurangan grafit oksida akan ditambah. Selepas itu, sampel akan dibuat menggunakan teknik tuangan cerun penyejukan. Parameter optimum untuk mendapatkan dan struktur mikro spesimen adalah berdasarkann skop yang telah ditetapkan. Ujian kekerasan Vickers dan kekuatan tegangan akan digunakan untuk menentukan sifat mekanikal spesimen. Ujian kekuatan tegangan akan dilakukan mengikut piawaian ASTM E8M.

ABSTRACT

Nanocomposites with aluminium base reinforced with nanoparticles, have wide applications in many industries, for example aerospace, marine, automotive, due to its lightweight, high tensile strength and wear resistance. Microstructure, mechanical, and tribological properties of nanocomposite materials are critical for the reliable and optimal design of novel materials. The reinforcement of micro or nano-sized range particle with aluminium matrix yields improved physical and mechanical properties in composite materials. The microstructure characterisation and mechanical testing of an A356 metal matrix composite with various percentages of graphene (0.1, 0.3, 0.5 % wt) generated by mechanical stirring process are presented in this paper. A356 alloy will be used as the matrix material and nano graphene produce by reduction of graphite oxide method will be added as reinforcement. Following that, the sample will be constructed utilising the cooling slope casting technique. The optimal parameters to get and the globular microstructure of the specimen are stated in the scope. Vickers hardness and tensile strength tests will be used to determine the specimen's mechanical properties. Tensile strength testing will be performed in accordance with ASTM E8M standards.

DEDICATION

Only
my beloved father, Adnan bin Rejab
my appreciated mother, Rohayati bt Md Safar
my dearest husband, Muhammad Hazwan bin Mohd Rofi
my adored sisters, Nur Hanani binti Adnan and Nur Athirah binti Adnan
for giving me moral support, money, cooperation, encouragement and also understandings
Thank You So Much & Love You All Forever

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In the name of ALLAH, the most gracious, the most merciful, with the highest praise to Allah that I manage to complete this final year project 1 successfully without facing difficulty. Without, His grace, this final year project 1 could not become reality.

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LIST OF ABBREVIATIONS

CSC	-	Cooling slope casting
ASTM	-	American society for testing and materials
MMC	-	Metal matrix composite
SSP	-	Semi-solid processing
SSMP	-	Semi-solid metal processing
SSM	-	Semi-solid metal
SF	-	Shape factor
GF	-	Globule factor
UTM	-	Universal testing machine
OM	-	Optical microscope
UTS	-	Ultimate tensile strength
Al_2O_3	-	Aluminium Oxide
SiC	-	Silicon Carbide
Al	-	Aluminium
Mg	-	Magnesium
Cu	-	Copper
Ti	-	Titanium
Ni	-	Nickel
Si	-	Silicon
Fe	-	Iron
Mn	-	Manganese
Zn	-	Zinc
SEM	-	Scanning Electron Microscope
XRD	-	X-ray Diffraction
YS	-	Yield strength
Mg_2Si	-	Magnesium silicide
S/N	-	Signal-to-noise

LIST OF SYMBOLS

Wt% - Weight percent
% - Percent
℃ - Degree Celsius
mm - Millimetre
° - Degree
T - Temperature
L - Length
θ - Tilt angle
μm - Nanometre
m - Meter
Mpa - Mega Pascal
HV - Hardness value
J - Joules
N - Newton
kN - Kilo newton
GPa - Giga Pascal
nm - Nanometre

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Metal matrix composite (MMC) is a composite material which is a combination or a mixture from at least two or more constituent differing in form of metal or other material composition that are essentially insoluble with each other. The new material result with the better properties and the sum of their constituents are produced because both constituents maintain their identity as they are insoluble and melt with each other. Hybrid composition develop by the incorporation of several different types of ceramic particulates into a single matrix. The uses of hybrid composition that contain two or more types of particulates able to help others complement that lacking their own properties and it can increase the value added of the composition. Moreover, the mechanical behaviour of composites is determined by the matrix material composition, size, reinforcement weight percentage, and composite manufacturing technology. . The factor that influence of the distribution of the reinforcement particles are rheological behaviour of the matrix melt, interaction of particle and the matrix before during and after missing and lastly the particle incorporation method.

The combination of matrix phase of aluminium and reinforcements phase represent aluminium metal matrix composite. Aluminium matrix composites are a type of engineering material that is widely utilised in the automotive, aerospace, marine, and defence industries, among others. This is because there have high thermal resistance, low density, high corrosion resistance and better mechanical and physical properties. The overall weight of the vehicles able to be reduced by aluminium matrix composite while maintaining satisfactory structural strength.

Thixoforming and rhixocasting are two semi-solid processing (SSP) processes. SSP's capacity is to produce components that meet the stringent requirements of the automotive industry by combining die casting's near-net-shape capabilities and fogging's mechanical properties. From the studies has been made by Taghavi and Ghassemi, the part that produce from thixoforming technique have high sustainability quality compare to the die-casting and forging costs is lower. Nevertheless, it required special block of steel with thixotropic (non-dendritic) microstructure is required for thixoforming technique. The cooling slope casting method is one of the several SSP techniques. According to Sahini et al., (2014), cooling slope casting is a simple method that requires very little equipment to execute. The cooling slope casting technique can be used to manufacture feedstock materials for semi-solid processing. Reheating the feedstock to semi-solid temperatures produces nondendritic, spheroidal solid particles in a liquid matrix, which are perfect for thixoforming. This process involves depositing molten metal on top of an angled cooling plate, which causes gravity to accelerate and shear the metal. Following that, the semi-solid slurry is placed into a mould for solidification. It is then reheated at a temperature within the alloy's freezing range to form a globular structure. By adding ultrasonic or mechanical vibration to a solidifying melt, fine, non-dendritic, and spherical structures can be formed.

1.2 Problem Statement

The formation of non-dendritic microstructure usually difficult and need a lot of cost. Based on Kumar et al. (2014), thixoforming is one of the example technique in producing non-dendritic microstructure but due to the high production costs, restricted variety of sizes, and non-uniform microstructure of ingots that can be produced using this technology, thixoforming has not experienced the wide distributed utilisation that it deserves. One of the key contributors to the high cost of creating specialty ingots is the necessity of thixoforming with non-dendritic or globular microstructure.

Furthermore, based on Mabrouk, W.M *et al.* (2021) there is a difference between the formation of coarser α (Al) dendritic phase of non-uniform distribution without semi-solid and semi-solid. The application of semi-solid change the morphology of α (Al) phase from course structure to fine globular structure with homogeneous distribution. Moreover, the microstructure of A356 alloy without semi-solid show course of dendritic morphology of primary α (Al) phase has a high average size compare to the microstructure of A356 alloy with semi-solid. As the pouring temperature increase, the grain boundaries visible and the α (Al) phase become globular.

Next, the casting defect such as cold flakes and porosity will decrease the tensile strength of the aluminium alloy. The existing of the porosity inside the aluminium alloy casting, it will influence the mechanical properties and yield strength. Furthermore, based on the research has been made by Ahamed and Kato, (2008) the location of the cold flake where the crake started was linked to tensile strength. However, the total area of cold flakes occurring in the fracture surface is related to the strength, therefore the area of the oxide layer was approximated. The stress-strain curves for specimens with and without cold flakes show that the specimen with cold flakes has lower fracture strength and elongation. As a result, the goal of this study is to see how nano-reinforced particles affect the mechanical properties of an aluminium hybrid metal matrix composite formed via cooling slope casting.

1.3 Objective

The objective of this study are:

a) To determine the microstructural evaluation of the aluminium metal matrix composite.

b) To evaluate the mechanical properties of aluminium metal matrix composite.

1.4 Scope

The scope of the study are:

a) A356 with nano-graphene (0.1,0.3 and 0.5% wt) as the work piece material.

b) The parameters for the cooling slope casting are pouring temperature (T), cooling slope length (L) and tilt angle (θ) of the inclined plate.

i) Pouring temperature of 660℃.

ii) Cooling slope length of 300 mm.

iii) Tilt angle (θ) of the incline plate 60°.

c) The mechanical properties that is evaluated are hardness and tensile test.

d) Tensile test sample according to the ASTM: E8M standard.

1.5 Significant of study

The significant of study are:

a) The wear qualities of a hybrid aluminium composite reinforced with graphite and silicon carbide particles were studied, and it was observed that the metal matrix composite had better mechanical and wear properties. The purpose of this study is to look at the mechanical properties of aluminium metal matrix composites.

b) The presence of metal matrix composite reinforcement has greatly improved the mechanical properties of the Al 356 alloy, such as tensile strength and hardness.

c) The cooling slope casting parameters have an impact on the microstructure of the aluminium metal matrix composite. This study is being conducted to determine the best settings for the cooling slope casting process for aluminium metal matrix composites.

1.6 Thesis Organization

The thesis is organised as follows. Chapter 1 introduces the research context, problem statement, aims, and scope of the study. The significance of the study is defined in order to more precisely characterise a particular aspect of aluminium metal matrix composite created by cooling slope casting in this thesis. Next in chapter 2, literature review comprises previous research or study about the mechanical properties and microstructures analysis of the aluminium metal matrix composite. Moreover, in this chapter it discuss about the optimum parameters for the cooling slope casting process and the testing method. Lastly, chapter 3 methodology describe all the raw materials, the method used to prepare the aluminium metal matrix composite, the cooling slope casting process and on how to conduct microstructural analysis, hardness and tensile test.

1.7 Summary

Overall in chapter 1, it consist of background of the study, problem statement, objectives, and scope of the study, significant of study. This chapter dedicated as an introduction to the aluminium metal matrix composite and the process of cooling slope casting. Moreover, chapter 1 also will discuss about the problems that are related to the study and based on the problems, the objective was created to solve the problems. At the end of this chapter, the objective of the study based on the scope will be understand.

CHAPTER 2

LITERATURE REVIEW

This chapter explains the content, steps and point that are related to the study. All data collected from articles, journals, and published literature pertaining to the cooling slope casting method, microstructure, and mechanical properties of aluminium metal matrix composite. Chapter 2 examines the effect of nano-reinforced particles on the mechanical characteristics of an aluminium metal matrix composite produced via cooling slope casting. Furthermore, this chapter discuss about the tensile strength, hardness and microstructural of aluminium metal matric composite.

2.1 Aluminium alloy and metal matrix composite (MMC)

2.1.1 Overview of A356 alloys

A356 alloys are composed primarily of aluminium (Al), with copper, magnesium, manganese, silicon, and zinc serving as distinguishing alloying components. A356 is typically utilised in engineering structures and components where light weight and resistance to corrosion are required. Since the debut of metal-skinned aircraft, alloys based mostly on aluminium have played a significant role in aerospace manufacturing. Aluminium-magnesium alloys are lighter and less combustible than other aluminium alloys. If anodizing and other corrosion-resistant coating processes are not used, A356 alloy surfaces will form a white, protective layer of corrosion-resistant aluminium oxide.

According to Dwivedi et al. (2014), galvanic corrosion can occur in a damp environment when an A356 alloy comes into electrical contact with other metals that have higher negative corrosion potentials than aluminium and there is an electrolyte present to facilitate ion exchange. Heat treatment of aluminium alloys can result in uncomfortably high temperatures. Internal element separation occurs as a result, and the metal corrodes from the inside out. A356 alloy corrosion is something that aircraft mechanics deal with on a regular basis. Additionally, experiments conducted on A356 indicate that the elastic modulus of A356 alloys is naturally about 70 GPa, which is approximately one-third of the elastic modulus of the bulk of steels and steel alloys. As a result, A356 alloy components flex more elastically than steel ones of the same size and form under the same load. There are A356 alloys with somewhat higher tensile strengths than commonly used steels.

Table 1.1: Example of A356 chemical composition

Element	Si	Mg	Fe	Ti	Cu	Mn	Zn	Ni	Al
Weight%	6.6	0.45	0.10	0.10	0.05	0.055	0.005	0.005	Bal.

2.1.2 Metal matrix composite

Metal matrix composites (MMCs) are a subset of engineering materials defined by the use of a light metal base reinforced with various types of reinforcement to enhance the material's qualities. Aluminum (Al), magnesium (Mg), copper (Cu), and titanium (Ti) are all examples of materials that are frequently utilised as the basis for composites. Additionally, metal matrix nanocomposites are a novel family of materials that incorporate nanoscale reinforcement (1-100 nm).

An experiment has been made by Velickovic *et al.*, (2019) prove that, The curves produced by nanoindentation of samples of A356 alloys and nanocomposites with reinforcement content of 0.2, 0.3, and 0.5 wt.% SiC show that the obtained values of the nanocomposite's hardness are greater than the base alloy. The difference in material hardness may be noticed in the indentation depths of the indenter into the test samples (figure 2.1), with