

# 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.)

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FACULTY OF MANUFACTURING ENGINEERING 2022



# UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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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:



# **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. اونيومرسيتي تيكنيد

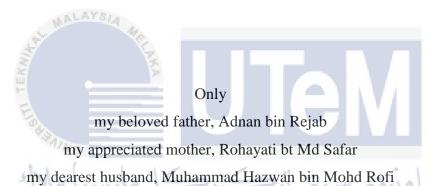
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## **ABSTRACT**

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.

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# **DEDICATION**



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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# TABLE OF CONTENTS

Abstı		i
Abstı	t	ii
Dedi	ion	iii
Ackn	vledgement	iv
Table	f Contents	v
List o	Γables	vii
List o	Figures	viii
List o	Abbreviations	X
List o	Symbols	xi
CHA 1.1 1.2 1.3 1.4 1.5 1.6 1.7	Background of study Problem Statement Objectives Scope Significant of study Thesis organizationSITI TEKNIKAL MALAYSIA MELAKA Summary	1 2 3 3 4 4 5
СНА	ΓER 2: LITERATURE REVIEW	
2.1	Aluminium alloy and metal matrix composite (MMC)	6
	2.1.1 Overview of A356 alloys	6
	2.1.2 Metal matrix composite (MMC)	7
2.2	Cooling slope casting	9
	2.2.1 Overview of cooling slope casting	9
	2.2.2 Parameters of cooling slope casting	11
	2.2.3 Advantages and disadvantages of cooling slope casting	12
2.3	Microstructure of aluminium metal matrix composite	13
	2.3.1 Comparison between conventional and cooling slope casting	13

	2.3.2	Effect of the pouring temperature variation on microstructure	15
	2.3.3	Effect of angle of inclined plate variation on microstructure	16
	2.3.4	Effect of the length of cooling slope variation on microstructure	17
2.4	Mecha	anical properties of aluminium metal matrix composite	19
	2.4.1	Tensile strength	19
	2.4.2	Hardness test	22
2.5	Summ	nary	23
CHA	PTER 3	3: METHODOLOGY	
3.1	Gantt	Chart	26
3.2	Flow	Chart	27
3.3	Relati	onship between objective and methodology	28
3.4	Exper	imental Procedure	28
	3.4.1	Materials preparation	28
	3.4.2	Feedstock production by using cooling slope casting	28
3.5	Micro	structural Analysis	30
	3.5.1	Sample preparation	30
	3.5.2	Optical microscopy	31
	3.5.3	Scanning Electron Microscope (SEM)	31
	3.5.4	X-Ray Diffraction Analysis (XRD)	31
3.6	Mecha	anical TestingSITI TEKNIKAL MALAYSIA MELAKA	32
	3.6.1	Hardness test	32
	3.6.2	Tensile Test	32
		3.6.2.1 Sample preparation	32
		3.6.2.1 Testing	34
3.7	Summ	nary	35
CHA	PTER 4	: RESULT AND DISCUSSION	
4.1	Mater	ial characterization	36
	4.1.1	Optical microscopy analysis	36
	4.1.2	Scanning electron microscope (SEM) analysis	38
	4.1.3	X-ray diffraction (XRD) analysis	40
4.2	Mecha	anical testing	41
	4.2.1	Hardness test	41

	4.2.2 Tensile test	43
4.3	Summary	45
CHAI	PTER 5: CONCLUSION AND RECOMMENDATIONS	
5.1	Conclusion	46
5.2	Recommendation	47
5.3	Sustainability development	48
5.4	Complexity	48
5.5	Life-long learning	49
REFE	ERENCES	50
APPE	ENDICES	
A	Gantt chart of FYP 1	58
В	Gantt chart of FYP 2	59
	(h) ( ) ( ; ; ; ; ; )	
	اويونر سيتي بيكتيكل مليسيا ملات	
	UNIVERSITI TEKNIKAL MALAYSIA MELAKA	

# LIST OF TABLE

1.1	Example of A356 chemical composition	7
2.2	Tensile Strength Values of test samples	8
3.1	Relationship between objectives and methodology	28
3.2	Chemical composition of A356 alloy (wt. %)	28
3.3	Tensile test dimensions – ASTM E8M	33
4.1	Hardness testing result	42
4.2	Tensile testing result  Linux Tensile testing result	43
	LINIVERSITI TEKNIKAL MALAYSIA MELAKA	

# LIST OF FIGURES

2.1	Mechanical properties (hardness) as a function of the impression depth	8
2.2	Microstructure of (a) Pure Al356 (b) $2\% Al_2O_3$ (c) $2.5\% Al_2O_3$	9
	(d) $3\% A l_2 O_3$	
2.3	The cooling slope casting apparatus (a) a photograph (b) schematic	10
	illustration	
2.4	Three zone of cross section	14
2.5	Boundary condition that set for simulation	14
2.6	Microstructure of the conventional cast A356 monolithic alloy	14
2.7	Microstructure of A356 monolithic alloy ingot produced using cooling	14
	slope casting	
2.8	Microstructure of semi-solid formed with the mold temperature of 25°C	16
	and the following pouring temperature of 650°C and 625°C: (a) 650°C at	
	the center zone, (b) 650°C at the middle zone, (c) 650°C at the wall zone,	
	(d) 625°C at the center zone, (e) 625°C at the middle zone, (f) 625°C at the	
	wall zone	
2.9	Different sloping angle cast specimen microstructure, scale 20µm 500 x	17
	magnificent. (a) Slope angle 15° (b) Slope angle 30° (c) Slope angle 45°	
	(d) Slope UNIVERSITI TEKNIKAL MALAYSIA MELAKA angle 60° (e) Slope angle 75°	
2.10	Microstructure of ingots cast over a cooling plate with a cooling length	18
	of 200 millimetres and pouring temperatures (a) 640°C, (b) 630°C,	
	(c) 620°C	
2.11	Microstructure of feedstock (a) cast over the cooling slope casting	18
	surface with pouring temperature of 640°C and slope length of 400	
	mm and isothermal holding at 580°C for (b) 5 minutes	
2.12	Microstructure of feedstock (c) 15 minutes (d) 30 minutes	18
2.13	(a) Tensile results of various conditions and (b) dimensions of tensile	19
	sample	
2.14	SEM micrographs of the fracture surfaces of the investigated A356 alloy	20
	(a) without semisolid casting and (b) with semisolid casting with optimum	1
	pouring temperature of 640°C	

2.15	(b) 30°	21
2.16	Fracture surface of tensile materials in various tilt angle (c) 45°, (d) 60° and (e) 75°	21
2.17	Vickers hardness of conventional cast alloy and cooling slope cast alloy at different pouring temperature and slope length	22
2.18	Hardness of aluminium-silicon alloy in various tilt angle of the cooling slope	23
2.19	The impact resistance of aluminium-silicon alloy in various tilt angle of cooling slope	23
3.1	Flow chart of the process	27
3.2	Schematic illustration of cooling slope casting	29
3.3	Weighing machine	29
3.4	Bandsaw machine (FKP,UTeM)	29
3.5	Portable melting furnace	30
3.6	Cooling slope casting	30
3.7	Stainless steel mold	30
3.8	Mechanical strirrer	30
3.9	SEM-EDX machine (FKP, UTeM)	31
3.10	Vikers hardness tester (FKM, UTeM)	32
3.11	EDM wire-cut machine   TEKNIKAL MALAYSIA MELAKA	33
3.12	Dog-bone Shape Specimen- ASTM E8M	33
3.13	Universal Testing Machine (FKP, UTeM)	34
3.17	Setup of tensile test sample (FKP, UTeM)	34
4.1	The microstructure of $A356 + 0.1$ wt% graphene (a) top, (b) center and (c) bottom	36
4.2	The microstructure of $A356 + 0.5$ wt% graphene (a) top, (b) center and (c) bottom	37
4.3	The microstructure of $A356 + 0.3$ wt% graphene (a) top, (b) center and (c) bottom	37
4.4	SEM image of A356 + 0.1 wt% graphene with magnification of (a) 200, (b) 500, (c) 1000	38
4.5	SEM image of A356 + 0.3 wt% graphene with magnification of (a) 200,	39

	(b) 500, (c) 1000	
4.6	SEM image of A356 + 0.5 wt% graphene with magnification of (a) 200,	39
	(b) 500, (c) 1000	
4.7	XRD pattern of sample 1 A356 + 0.1 wt% graphene	40
4.8	XRD pattern of sample 2 A356 + 0.3 wt% graphene	40
4.9	XRD pattern of sample 3 A356 + 0.5 wt% graphene	41
4.10	Vickers Hardness test for various graphene content	42
4.11	Tensile sample before fracture	43
4.10	Tensile sample after fracture	43
4.11	Ultimate tensile strength (MPa)	44
4.12	Yield Strength (MPa)	45
4.13	Percent of elongation	45



# LIST OF ABBREVIATIONS

CSC - Cooling slope casting

ASTM - American society for testing and materials

MMC - Metal matrix compositeSSP - 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 -UNIVERSITitaTium NIKAL MALAYSIA MELAKA

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

°C - Degree Celsius

mm - Millimetre

° - Degree

T - Temperature

L - Length

 $\theta$  - Tilt angle

μm - Nanometre

m - Meter

Mpa - Mega Pascal

HV - Hardness value

J - Joules

N - Newton

kN - Kilo newton

GPa - Giga Pascal

nm - UNIVERSINanometre IKAL MALAYSIA MELAKA

#### CHAPTER 1

# **INTRODUCTION**

#### 1.1 Background of Study

MALAYSIA

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.

Thix of orming and rhix ocasting 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 (nondendritic) 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.

# UNIVERSITI TEKNIKAL MALAYSIA MELAKA

#### 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  $\alpha$  (Al) dendritic phase of non-uniform distribution without semi-solid and semi-solid. The application of semi-solid change the morphology of  $\alpha$  (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  $\alpha$  (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  $\alpha$  (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 ( $\theta$ ) of the inclined plate.

- i) Pouring temperature of 660°C.
- ii) Cooling slope length of 300 mm.
- iii) Tilt angle ( $\theta$ ) 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.

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## 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.

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#### 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