# OPTIMUM PARAMETERS OF GRAPHENE REINFORCED MAGNESIUM ALLOY AND ITS INFLUENCE ON THE MECHANICAL PROPERTIES

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

by


**MOHAMMAD NA'AIM BIN ABD RAHIM**

**B051810116**

**971023-02-5975**

FACULTY OF MANUFACTURING ENGINEERING


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## UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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Tajuk: **Optimum Parameters of Graphene Reinforced Magnesium Alloy and Its Influences on The Mechanical Properties**

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Alamat Tetap:
Kampung Banggol Wan Mat A, Jalan Hospital, 09100, Baling, Kedah

Cop Rasmi: ASSOC. PROF. IR. TS. DR. MOHD SHUKOR BIN SAL
Deputy Dean ( Research & Postgraduate Studi
Faculty of Manufacturing Engineering
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Author's Name : MOHAMMAD NA'AIM BIN ABD RAHIM

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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:

…………………….................................

**(PROFESOR MADYA IR. TS. DR. MOHD SHUKOR BIN SALLEH)**

ASSOC. PROF. IR. TS. DR. MOHD SHUKOR BIN SALLEH
*Deputy Dean ( Research & Postgraduate Studies)*
Faculty of Manufacturing Engineering
Universiti Teknikal Malaysia Melaka

# ABSTRAK

Graphene ialah alotrop karbon yang terdiri daripada satu lapisan (monolayer) atom yang terikat bersama dalam corak berulang heksagon. Ia digunakan sebagai pengisi nano dalam komposit bahan untuk meningkatkan sifat fizikal dan mekanikalnya. Aloi magnesium tidak mempunyai sifat mekanikal yang mengehadkannya untuk digunakan untuk aplikasi tertentu. Kelemahan ini dianggap sebagai kerugian yang ketara kerana sifat aloi magnesium menjanjikan untuk pelbagai kegunaan kerana sifat fizikal dan mekanikalnya yang sangat baik, termasuk ketumpatan rendah, nisbah kekuatan kepada berat yang tinggi, nisbah kekakuan kepada berat yang tinggi. Projek ini memfokuskan kepada kesan kandungan graphene nanoplatelets (GNPs) pada aloi magnesium AM50 menggunakan salah satu pemprosesan separa pepejal, penyinaran. Parameter yang ditetapkan untuk projek ini menggunakan Kaedah Taguchi dengan memanipulasi masa dan kuantiti kacau kandungan graphene. Kualiti tuangan yang terhasil akan ditentukan oleh ujian mekanikal (ujian kekerasan dan tegangan). Daripada penyelidikan ini, taburan mikrostruktur dijangka mempunyai saiz butiran yang lebih kecil yang akan mempengaruhi sifat peningkatan kekuatan dan kekerasan bahan.

# ABSTRACT

Graphene is an allotrope of carbon consisting of a single layer (monolayer) of atoms bonded together in the repeating pattern of the hexagon. It is used as a nanofiller in the material composite to enhance its physical and mechanical properties. Magnesium alloy lacks mechanical properties that limit them to being used for specific applications. These drawbacks are considered as significant loss as the magnesium alloy properties are promising for various usages due to their excellent physical and mechanical properties, including low density, high strength to weight ratio, high stiffness to weight ratio. This project focuses on the effect of graphene nanoplatelets (GNPs) contents on magnesium alloy AM50 using one of semi-solid processing, rheocasting. The parameters set for this project using the Taguchi Method by manipulating graphene content's stirring time and quantity. The resulting quality of the cast will be determined by mechanical testing (hardness and tensile test). From this research, the microstructural distributions are expected to have a smaller grain size which will influence the increasing property of the strength and the hardness of the material.

# DEDICATION

Only

my beloved father, Abd Rahim Bin Abdullah

my appreciated mother, Siti Fatimah Binti Mat Piah

my adored sister and brother, Sakinah and Khairi

for giving me moral support, money, cooperation, encouragement and also understandings

Thank You So Much & Love You All Forever

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Alhamdulillah, throughout the 14 weeks of this semester, I managed to complete my Final Year Project with bare along the name of Universiti Teknikal Malaysia Melaka. I would like to sincerely thank my supervisor

Alhamdulillah, throughout the 14 weeks of this semester, I managed to complete my Final Year Project with bare along the name of Universiti Teknikal Malaysia Melaka. I would like to sincerely thank my project's supervisor Profesor Madya Ir. Ts. Dr. Mohd Shukor Bin Salleh for his patient and guidance.

Thanks to Allah S.W.T for his blessing and guidance that give me strength to complete my report. I would like to express my special thanks and gratitude to my fellow friends especially my partner, Philip Patrick who help me the most.

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| | |
|---|---|
| 2D | Two Dimensional |
| UTS | Ultimate Tensile Strength |
| CNTs | Carbon Nanotubes |
| CVD | Chemical Vapor Deposition |
| DOE | Design of Experiment |
| GNPs | Graphene Nanoplatelets |
| HPDC | High Pressure Die Casting |
| HV | Hardness Vickers |
| OM | Optical Microscope |
| PECVD | Plasma Enhanced Chemical Vapor Deposition |
| RDC | Rheo Dies Casting |
| SEM | Scanning Electron Microscopy |
| UTS | Ultimate Tensile Strength |
| XRD | X-Ray Diffraction |
| YS | Yield Strength |

# CHAPTER 1

# INTRODUCTION

This chapter describes the overview of the study for the research. This chapter contains research background, problem statement, objectives, scopes of research, rational of research, research methodology, and project report organization.

## 1.1 Research Background

In recent years, the material known as graphene has emerged in advanced nanomaterial technology and is being explored deeply by scientists and engineers to utilize its advantages fully. It has contributed a lot to several applications like aerospace, building materials, mobile devices, and many others. Graphene is an allotrope of carbon consisting of a single layer (monolayer) of atoms bonded together in the repeating pattern of the hexagon. It had been arranged in a two-dimensional (2D) honeycomb lattice nanostructure. According to (Ameen et al., 2020) graphene happens to be the basic building block of other carbon allotropes such as graphite, single-walled/multi-walled carbon nanotubes, and fullerenes. The stack of monolayers on top of each other will form graphite.

The demand for innovative advanced materials has constantly been increasing due to the rapid growth of the current technologies and uses in many sectors. Graphene has attracted much attention to advance material technologies due to its unique properties. It has a remarkable combination of mechanical, thermal, chemical, and electrical properties. The study on graphene nanoplatelets (GNPs) by (Rashad et al., 2015a) states that GNPs have the potential reinforcement for strengthening metals such as Al, Cu, and Mg. It consists of several graphene layers with a thickness less than 100nm. By using graphene nanoplatelets (GNPs), various types of material can be reinforced by graphene to better enhance the material for a specific purpose. Graphene reinforced material will have higher stiffness, strength, thermal conductivity, and inert gas.

On the other hand, the usages of magnesium alloy AM50 are popular due to its lightweight property, excellent elasticity, superior energy absorbing properties, high strength, and castability. However, research has consistently shown that magnesium alloy AM50 has highly susceptible to corrosion and wear resistance. (Hussein and Northwood, 2014a) bold that magnesium alloy has low elastic modulus, limited cold workability and toughness, limited strength, and creep resistance at elevated temperature. To encounter its weaknesses, the idea of coating magnesium alloy with graphene can produce a much better new lightweight metal with high resistance corrosion.

## 1.2 Problem Statement

Much research on the rheocasting had been done and published to the education site. But the uncontrol parameters of the research resulted the variance size of grain in microstructural evaluations. Of cause individual decision on their research cannot be questioned, but the surface may not indicate a significant variance in grain size. The required grain size is determined by the material's intended use. (Baltzer and Copponnex, 2014) bold that the thinnest object dimension is at least 10 times larger than the grain size to achieve good mechanical stress of the material. The statement later had been supported by (Weng et al., 2015), with decreasing of grain size, the hardness value and corrosion resistance will be increased.

Magnesium alloy has lack of mechanical properties that limited them to be used for specific applications. These drawbacks are considered as big loss as the magnesium alloy properties are very promising for various usages in term of weight strength ratio (Trang et al., 2018). In the recent decade, several R&D efforts have resulted in the development of various types of magnesium alloys with an excellent balance of strength and ductility. Magnesium alloys have poor formability due to numerous causes, including the development of a strong basal roughness during rolling (thermomechanical treatment) and a restricted number of possible deformation modes due to the hexagonal close packed (hcp) structure of magnesium. Even though Mg alloys may be easily formed at warm or high temperatures despite their poor formability at room temperature, forming at these temperatures is energy costly and inefficient.

Various of parameter had been applied to achieve the best result for graphene reinforced magnesium alloy in term of mechanical strength. All these casting techniques rely on precise control of all input parameters as well as correct metal solidification control to be successful. Because complex technologies are used in the casting process, even little changes in any of the input parameters might alter the process output and result in defective castings (Rao et al., 2014). It is very crucial to decide the parameters so that potential the defects and failure could be avoid during early stages.

## 1.3 Objectives

The objectives are as follows:

(a) To evaluate the microstructural evaluation during semisolid metal processing.

(b) To investigate the effect of the GNPs content on the mechanical properties of AM50 magnesium alloy.

(c) To study the optimum parameter for stirring time and the value of graphene content by rheocasting process.

## 1.4 Scopes of the Research

The scopes of research are as follows:

This study is focusing on the effect of graphene nanoplatelets (GNPs) content on magnesium alloy specified to AM50 using rheocasting process. The parameter used for the study are stirring time and quantity of graphene used for the reinforcement. The experiment will be conducting cylindrical samples with two different diameters of 6mm and 12mm to analyse the stirring time effect, and the stirring time will be executed in four separate units. The microstructure of the casting result will be analysed through optical microscope (OM) and scanning electron microscopy (SEM). The mechanical properties of the graphene reinforced magnesium alloy will be analyse using mechanical testing which are tensile test and hardness test to determine the material's properties. All the processes will be conducted in faculty of manufacturing's laboratory in UTeM.

## 1.5 Rational of Research

The rational of research as follows:

(a) Generate knowledge of the present of graphene as experiment constant to test the effect and characteristics of magnesium alloy that affected with and without it using casting process.

(b) Graphene reinforced magnesium alloy will archive the highest strength when the composition of graphene nanoplatelets (GNPs) and magnesium alloy AM50 are in the perfect ratio and using the proper mechanical stirring

(c) Generate scientific information and deep understanding of the study about the microstructure and its behaviour when responding to several aspects likes mechanical, thermal, chemical, and electrical.

(d) Reduce the dependency of finding and exploring the new material that are unknowingly present that fit all the characteristic that graphene reinforced magnesium alloy probably should had.

(e) Magnesium alloy AM50 is widely and commonly used in industry.



## 1.6 Project report Organization

This research is organized into several sub-topic and chapters. The introduction had begun as Chapter 1 that provides the background of the research, problem statement, objectives, scope of research, rational of research and thesis organization.

# CHAPTER 2

## LITERATURE REVIEW

In this chapter is mainly explains about the past research regarding the theory of experiment such as importance of tools and materials discussion, influence of parameters of casting, and microstructural characterization of the composite and mechanical testing such as hardness and tensile test.

### 2.1 Graphene nanoplatelets

Graphene nanoplatelets (GNPs) are a novel carbon species generated when graphite is exposed to circumstances. GNPs are two-dimensional carbon structure materials with a single or multilayer graphite plane that have several desirable properties such as high electrical conductivity, high modulus, high strength, high thermal conductivity, and high specific surface area. According to (Tiwari et al., 2020), these nanoparticles typically have a thickness of 1e15 mm and a lateral dimension of up to 100 mm. The synthesis of GNPs was carried out with the help of micromechanical graphite breaking, and it only allows for the formation of graphene nanocomposites with improved barrier properties. The conductivity percolation threshold for GNPs is 1.9 weight percent in the context of a thermoplastic matrix. Conductivity at densities of 2e5 weight percent is insufficient to provide electromagnetic shielding. After being mixed with glass fibers, polymers, or another matrix, GNPs can offer sufficient conductivity. GNPs can also improve the mechanical properties of various composites, such as stiffness and tensile strength, due to the solid interfacial interaction of nanoplates with the matrix.

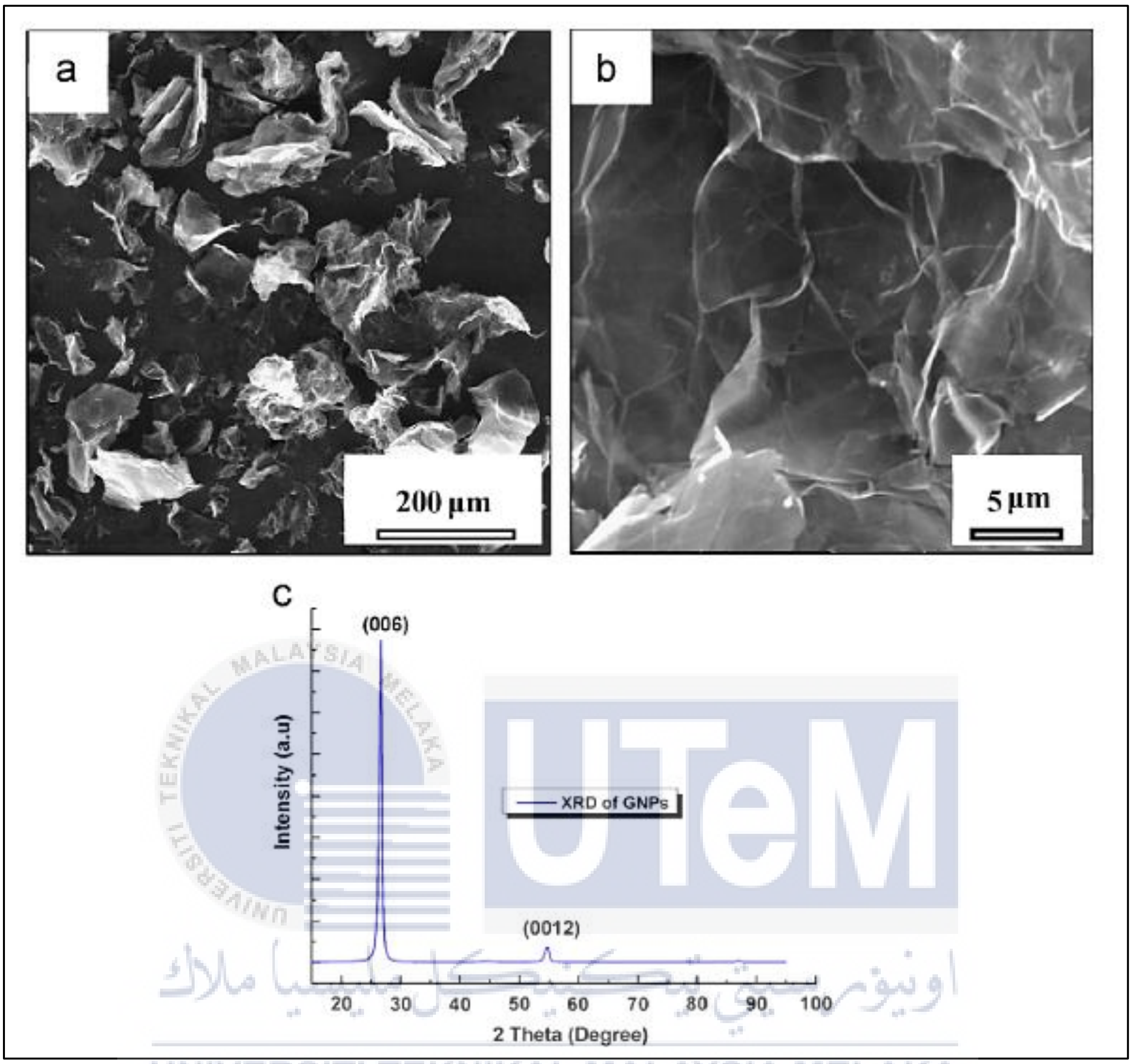

Figure 2.1: SEM micrographs of GNPs at (a) low magnification; (b) high magnification; (c) XRD graph of as received GNPs (Rashad et al., 2015)

### 2.1.1 Properties of Graphene Nanoplatelets

Lightweight, wide aspect ratio, electric and thermal conductivity, mechanical strength, cheap cost composition, and so on are all appealing characteristics of graphene nanoplatelets. They are viable physics and engineering possibilities for replacing a variety of nano-structured preservatives, such as other carbon allotropes, steel microparticles, or clay. GNPs have a nanometer-thickness and are hence less susceptible to faults. Although GNPs have a lower surface area than single-layer graphene, they have a large interfacial area, making them ideal for creating hybrid structures with other nanoparticles (Fatima et al., 2017). These are attractive to nanocomposites because of solvent and melt counteracting. It has the melting point of 3652-3697 °C. They could be quickly and effectively included within the polymer matrices.

Graphene nanoplatelets are safer than carbon nanofibers and nano-tubes and equivalent to tube-like nano-fillers in altering polymers' chemical properties. In contrast, the chemical reactivity for Graphene nanoplatelets is lower than that of graphene oxide. As a result, graphene nanoplatelets are already being used in various technical fields. In practice, items made with graphene nanoplatelets have better tribology, mechanical, biological, gas barrier, flame retardant, and heat convection capabilities. Graphene nanoplatelets can convert plastic into an electrical capacitor, making it an ideal electronic material. Graphene nanoplatelets can improve the heat capacity of polymer matrixes, making them suitable as thermal interface materials



### 2.1.2. Importance of Graphene

Graphene nanoplatelets are frequently used as nanofillers in various matrices, including polymers, concretes, and metals (Jiménez-Suárez and Prolongo, 2020). GNPs are often used to improve the mechanical properties of polymer matrices and their chemical resistance and hence their longevity (Arribas et al., 2019). GNPs in polymers lower the ability of the polymers to absorb water, making them more resistant to harsh humid environments. A precise amount of graphene nanoplatelets delivers the best behaviour due to this chronic propensity. It can also enhance the material's thermal conductivity, making these nanocomposites promising materials for solar energy conversion and storage.

Research from (Moosa et al., 2016) had proved that the success and remarkable synergetic effect between the GNPs and CNTs in improving the mechanical properties and electrical conductivity of epoxy composites.When squeezed into a polymer film or solid component, graphene nano-platelets drastically reduce a composite material's permeability and scattering coefficients. The particle size of the additive has a considerable impact on permeability, and large diameter particles often have smaller absorption reductions. According to test results from (Du and Pang, 2015), adding 2.5 wt% GNPs can reduce water penetration depth, chloride diffusion coefficient, and chloride migration coefficients by 64%, 70%, and 31%, respectively.

### 2.1.3 Applications of Graphene Nanoplatelets

Graphene nanoplatelets-based adaptable devices have been intensively investigated and appear to have already had a substantial impact. The free-standing of GPNs films and their usage in polymers are two outliers to the numerous various ways offered. Nonetheless, the most promising results have been produced by applying flexible plastic substrates with pure nano-flakes and conductive inks with polymer-Graphene nanoplatelets. Scientists gathered durable and high-performance equipment like antennas, compatible electrical electrodes for power applications, and lightweight electromagnetic resistance coatings with such approaches. Furthermore, the widespread usage of cellulose thin films, which are frequently mixed with biopolymers, has aided in the development of long-lasting, adaptable Graphene Nanoplatelets-based technologies and ecologically responsible electronic waste management. Intelligent sensors focused on Graphene nanoplatelets, on the other hand, have made promising progress. They preserve stretching ability and flexible electrical features that have made a significant impact as portable sensing technology of the future generation. Tactile apps and digital robotic skins might benefit from the growth of graphene nanoplatelets-based intelligent detectors. Strain sensing systems have evolved for various applications, ranging from structural and human health