EFFECT OF AL2O3/CNT IN DENDRITE REFINEMENT AND MECHANICAL PROPERTIES OF HYBRID NANOCOMPOSITE

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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EFFECT OF AL2O3 IN DENDRITE REFINEMENT AND MECHANICAL PROPERTIES OF HYBRID NANOCOMPOSITES

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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DECLARATION

I hereby, declared this report entitled "Effect of Al2O3/CNT in dendrit refinement and mechanical properties of hybrid nanocomposite" is the results of my own research except as cited in reference.

Signature : ……………………………………

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Date : 25 MARCH 2024

APPROVAL

This report is submitted to the Faculty of Industrial and Manufacturing Technology and Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Hons.). The members of supervisory committee are as follow:

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ABSTRACT

This research was carried out to investigate the microstructural characterization and mechanical properties of permanent mold casting processed carbon nanotube-aluminium composite. Using the casting to create carbon nanotube-aluminum composites, carbon nanotubes will be employed as reinforcing material and their amounts will vary between 0.2 and 1.0 weight percent. For complex designs and large scale manufacturing, the liquid metallurgical approach for the synthesis of the multiwalled carbon nanotube–A356 aluminium alloy (MWCNT–A356) composite was appropriate. Aluminium metal matrix composites, or AMMCs, have become more widely used in the aerospace, automotive, and defence industries due to their many uses. However, the transportation industry has benefited most from AMMCs because they reduce structural weight, which lowers fuel consumption,costs and airborne pollutants. The permanent mold casting process was used to prepare AMMC because it highly accurate and give better surface finish than other preparation methods. However, because aluminium has a low wet ability, the difficulty lies in achieving a homogenous combination of carbon nanoparticles as reinforcement and aluminium as the matrix. Therefore, employing a robust design of experiment (DOE), specifically, Taguchi technique, with two factorial levels, the optimisation and impact of variables such as quantity of carbon nanotube (CNT) and percentage alumina weight was explored. Field Emission Scanning Electron Microscopy (FESEM) was used to investigate the microstructure and fracture surface of the composites. At different percentages of CNT nanoparticles, evaluation of the mechanical characteristics such as elongation, yield strength, and ultimate tensile strength were successfully obtained. Since there was a noticeable improvement in the mechanical characteristics as the percentages of CNT nanoparticles grew, it was discovered that the concentrations of the reinforced CNT nanoparticle had a significant impact on AMMC's mechanical qualities. The uniform distribution of the reinforcing nanoparticles and the little porosity of the aluminium matrix's grain refinement were credited with this increase in the mechanical characteristics. The findings demonstrated that the A356's dendritic structure has been lost and replaced with a more refined structure. Results indicated that the mechanical properties of the aluminium (Al) matrix composites (AMCs) was significantly improved after the

reinforcement with alumina and CNT. This work demonstrated the enhanced mechanical properties achieved.

DEDICATION

This project is dedicated to my beloved parents, Mohd Sukri bin Maudin and Zuraini binti Mahusin,who have never failed to give motivation and moral support, and for teaching me that even the largest task can be accomplished if it is done one step as a time.

Thank you also to my supervisor,Profesor Madya Ir.Ts.Dr. Mohd Shukor bin Salleh who guided me in this process and kept me on track.

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LIST OF ABBREVIATIONS

CNT	-	Carbon Nanotube
Al	-	Aluminium
AL2O3	-	Alumina
AMCs	-	Aluminium Matrix Composites
MMC	-	Metal Matrix Composite
UTS	-	Ultimate Tensile Strength
PM	-	Powder Metallurgy
SEM	-	Scanning Electron Microscopy
EDX	-	Energy Dispersive X-ray
SWNTs	-	Single Walled Nanotubes
MWCNTs	-	Multi Walled Carbon Nanotubes
DWNTs	-	Double Walled Nanotubes
DoE	-	Design of Experiment
BM	-	Ball Milling
HPS	-	Hot Press Sintering
SPS	-	Sparkle Plasma Sintering
HIP	-	Hot Isostatic Pressing
CIP	-	Cold Isostatic Pressing
FSP	-	Friction Stir Processing
SP	-	Spread Dispersion
EPD	-	Electrophoretic affidavit
XRD	-	X-Ray Diffraction
OM	-	Optical Microscope
DIC	-	Differential Interference Contrast
EDS	-	Energy Dispersive Spectroscopy
TEM	-	Transmission Electron Microscope
SDD	-	Silicon Drift Detectors
FESEM	-	Field Emission Scanning Electron Microscopy
BEI	-	Backscattered Electron Imaging
SEI	-	Secondary Electron Imaging

LIST OF SYMBOLS

%	-	Percentage
kWh	-	Kilowatt Hours
g/cm3	-	Gram Per Cubic Centimetre
wt.%	-	Weight Percentage
N/mm^2	-	Newton Per millimeter square
MPa	-	Mega Pascal
W	-	Watt
mm	-	Millimetre
°C	-	Degree Celsius
nm	-	Nanometer
K	-	Kelvin
A	-	Ampere
V	-	Volts
µm	-	Micrometre
Rpm	-	Revolution Per Minute
L/min	-	Litres Per Minute

CHAPTER 1
INTRODUCTION

1.1 Background of Project

Nowadays, nanocomposites, the most common substance, have created new avenues for technological and innovative growth for all industrial sectors. When opposed to traditional monolithic materials like metals, ceramics, and polymers, which are primarily employed as the matrix, composite materials have improved mechanical and physical characteristics, which is linked to their wide applicability. The use of composites is growing in a variety of sectors, including aerospace and automotive, where the mechanical qualities of the components are crucial.

The combination of less magnitude of CNT and elevated thermal conductivity of aluminium makes as very attractive nanocomposite for industrial applications like manufacturing industry. As a result, several researchers were inspired to create aluminium/CNT nanocomposites for a wide range of industrial uses by the complementary properties of CNT and aluminium alloys. Because of their unique properties, carbon nanotubes (CNTs) are a suitable strengthening operator in the framework of the aluminium (Al) metal matrix. Strengthening with CNT causes quality to increase without a noticeable weight increase.The mechanical and thermal property upgrades accomplished by expansion of CNT in Aluminium metal frameworks (Hashim Hanizam et al., 2019).

Metal Matrix Composites (MMC) founds their application in major industries including automobile, aircraft, marine, nuclear, chemical and cryogenics applications. Because of its exceptional resistance to wear and erosion, aluminium matrix composites (AMCs) are used in automotive applications for cylinders, cylinder blocks, and brake drums.Furthermore, grain refinement reduces grain size during the solidification phase of metal casting. The process strengthens cast alloys and improves their mechanical properties, including strength, hardness and elasticity. This improvement in the mechanical properties was attributed to the uniform distribution of the reinforcing nanoparticles and the low porosity of the grain refinement of the aluminium matrix. Following the application of certain material characterization procedures, the dendritic structure was lost and replaced with a more refined and finer structured structure.Refinement can also enhance surface finishes and improves tear resistance (Malek Ali ,2020).

For the tensile testing, yield strength was important because it characterizes the highest stress a material can tolerate before permanent deformation occurs. The yield stress of a material was often used by engineers to determine the maximum permissible load a designed part or structure can withstand. By knowing a material's yield strength, engineers can design safer and more durable parts. It is used to guarantee the quality of components, materials, and finished products within a wide range of industries. Besides, for information this project was conducted in laboratories at Universiti Teknikal Malaysia Melaka.

Bhaskar Chandra et al.(2018), synthesized aluminum alloy reinforced with different amounts of Al2O3 using stir casting technique.They demonstrated that the Al-5wt% Al2O3 composite increased hardness and ultimate tensile strength (UTS) by 26.3% and 14.3%, respectively. It was found that the stir casting method, the amount of reinforcement, and the nano size of the Al2O3 particles all had a significant impact on the improvement of the mechanical characteristics and microstructure. Stir casting was a well-known low-cost method for producing aluminum-based composites (AMMCs) because of its ease of use and capacity for large volumes of manufacturing.However, a number of challenges arose in handling all operations, including friction stir processing, isostatic pressing, and powder metallurgy (PM) because of the problematic homogenous dispersion of CNTs resulting from solid Van der Waals interactions among the CNTs.

1.2 Problem Statement

Controlling the interface in metal–CNT complexes is still a significant technological difficulty because of CNTs' limited affinity for metals. Defect-free CNTs' side walls are chemically inert, which prevents them from forming strong connections with metals. Consequently, the mechanical characteristics of the CNT–metal systems are substantially less than the theoretical expectations (S.Subramoney,2022).It is well-known that for superior mechanical properties, strong covalent bonds between CNTs and metals are desired in order to enhance the load transfer.

Because of their unusual size and properties, small carbon nanotubes (CNTs) can be challenging to deal with. Carbon atoms are arranged into cylindrical structures at the nanoscale called carbon nanotubes, or CNTs for short. They can have one or more walls and come in various diameters. Because small CNTs can be very light and prone to aggregation, they might be difficult to handle and disperse in solvents or matrices. They may bunch or cluster due to their large aspect ratio (Takahiro Maruyama,2021).

Compared to other metals like steel, cast aluminum alloys generally have lower tensile strength and fatigue strength. This means they can be more prone to bending or breaking under stress, especially repeated stress (Jawaid et al.,2023). So, CNTs was apply or used to enhance the mechanical properties.

1.3 Objectives

i. To determine the optimum percentage of Al2O3/CNT reinforced with aluminium alloy.

ii. To investigate the microstructural characterization of aluminium matrix composite.

iii. To examine the ultimate tensile strength, yield strength and elongation to fracture of aluminum matrix composite.

1.4 Scope of work

Based on the objectives of this project, the scope that can be drawn are:

i. Identify the improvement of mechanical properties of carbon nanotube-aluminium composite

ii. Produce carbon nanotube-aluminium matrix composite for permanent mold casting technique and apply the tensile test

iii. Investigate the effects of the amount of CNTs on the microstructure and mechanical properties of aluminium matrix nanocomposites by using Field Emission Scanning Electron Microscopy(FESEM)

1.5 Organization of the report

Chapter 1 of this report provides an overview of the study and title introduction. The issue statement and study background are covered in this chapter. This was followed by objectives to be achieved throughout the study and scope which narrows down the area of the study.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

A literature review is necessary to gather crucial data that is pertinent to this study. The study will be guided by a foundation of comprehensible and well-organized theoretical material. This chapter includes information on matrix composite feedstock for permanent mold casting process, multi-walled carbon nanotubes, mechanical properties of aluminium A356 matrix, optimisation techniques, process and types of testing approach involved. A study of the microstructure, phase characterisation, and characteristics of permanent mold casting carbon nanotube-aluminium composite was also included in this chapter.

2.2 Material Characteristics

2.2.1 Alumina

The most often used term for aluminium oxide is alumina (Al2O3). It is a durable technological ceramic with a superior blend of electrical and mechanical qualities. It works well in many different industrial applications. High hardness, wear resistance, low levels of erosion, high temperature resistance, corrosion resistance, and bio-inertness are characteristics of alumina. It is especially well suited for high temperature applications, such as thermocouple protection in high temperature measurement, because of its high temperature stability and thermal conductivity (C.Piconi,2021).

This material is amphoteric, meaning it interacts with both bases and acids. It looks white and exists as a solid. It has no smell and is water insoluble. This chemical is most frequently seen in its crystalline form.Alumina is generally considered safe for use in cosmetics and personal care products by various regulatory agencies. It has a low comedogenic rating and is unlikely to cause acne or clog pores.

Next,alumina is the most well-known and most commonly used fine ceramic material. It shares the same body of sintered crystal as ruby and sapphire. Since it has such great strength, resistance to corrosion, and wear, it has been utilised for decades in mechanical parts.Alumina is used as a filler in plastics, bricks, and other heavy clayware, such as kilns, since it is chemically inert. It is frequently used as an abrasive for sandpaper because of its extraordinary strength and hardness. Additionally, it is a cost-effective replacement for industrial diamonds.

Bauxite, a naturally occurring mineral with varying concentrations of hydrous (water-containing) aluminium oxides, is the raw material used to make alumina.Alumina is among the most commonly used and reasonably priced materials in the engineering ceramics family. Because the raw ingredients used to create this high-performance technical grade ceramic are affordable and easily accessible, the manufactured alumina forms offer good value for the money (Guido Busco,2023). Fine grain technical grade alumina has a very wide variety of uses, which is not surprising given its superb combination of characteristics and cheap pricing.

2.2.2 Carbon Nanotubes

A carbon nanotube is a nanoscale hollow tube made of carbon atoms. It is often referred to as a buckytube. The cylindrical carbon molecules have diameters ranging from a few nanometers to tens of nanometers, lengths up to millimetres, and high aspect ratios (length-to-diameter values) usually over 10^3. Carbon nanotubes have a particular character due to their unique one-dimensional structure and accompanying features, which gives them limitless potential in applications related to nanotechnology. One member of the fullerene family is the carbon nanotube.The sidewalls of carbon nanotubes are made of graphene sheets consisting of neighboring hexagonal cells. Carbon nanotubes are extremely robust and difficult to break, but they are still light.

One of the most studied nanomaterials is carbon nanotubes because to its remarkable mechanical, electrical, and thermal capabilities.. There are several types of carbon nanotubes which can be categorized by their structures namely single walled Nanotubes (SWNTs), multi-walled Carbon Nanotubes (MWCNTs) and Double-walled Nanotubes (DWNTs). Whereas single wall carbon nanotubes only contain one cylinder of carbon atoms while multiwall carbon nanotubes have many concentric cylindrical lattices of carbon atoms. Carbon nanotubes are utilized in energy storage, device modelling, automotive parts, boat hulls, sporting goods, water filters, thin-film electronics, coatings, actuators, and electromagnetic shields (Ahmed,2020).

In the presence of an electric current, nanotubes function as catalysts. As a result, molecules that come into touch with the reaction sites might get electron donations from them. The reaction is similar to what happens in fuel cells. In addition to unique nanostructures, they exhibit remarkable properties, some derived from the similar properties of graphite and some from their one-dimensional aspects. Depending on their chirality, CNTs can be either semiconductors or metals (Vasyl Harik,2022).

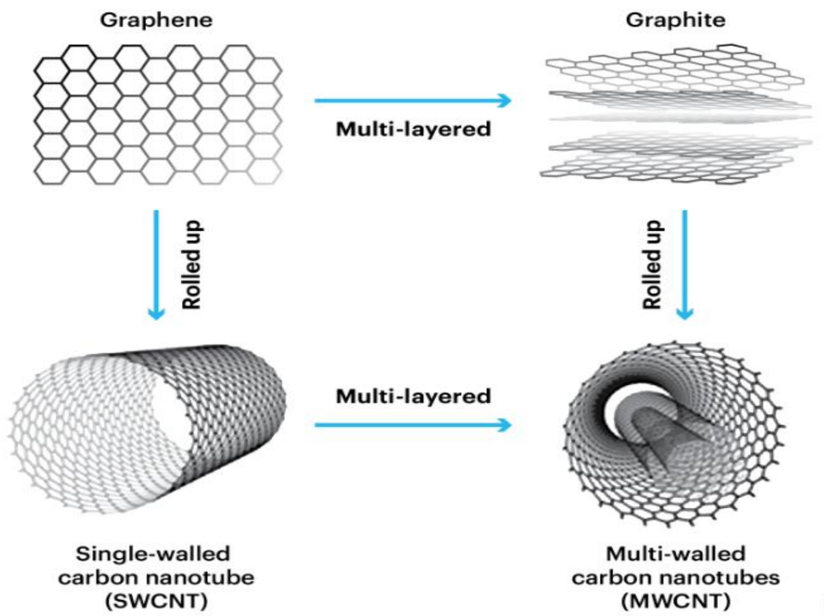


Figure 2.2.2.1:Schematic diagram types of carbon nanotubes

2.2.3 Aluminium

Aluminium is a soft, pliable, lightweight metal with a silvery white colour.A vast array of items, such as beer kegs, cans, foils, culinary utensils, window frames and aviation parts, are made of aluminium. Its unique qualities are the reason behind this. It is readily cast, machined, and shaped, and it has low density, non-toxicity, high thermal conductivity, and excellent corrosion resistance. It doesn't ignite or have a magnetic field either. It is the sixth most ductile and the second most malleable metal (F.R.Tuler,2020).

Given the low strength of aluminium by itself, it is frequently utilised as an alloy. Strong yet lightweight alloys include those made of silicon, magnesium, and copper. They play a major role in the building of aeroplanes and other transportation vehicles.Additionally, aluminium is frequently used in electrical transmission lines since it is an excellent electrical conductor. Compared to copper, it is less expensive and about twice as effective as a conductor per unit weight.Aluminium generates a highly reflective layer as it evaporates in a vacuum, reflecting both heat and light. Unlike a silver coating, it does not corrode (Taylor and S.R.,2021). These aluminium coatings are used in a variety of products, such as toys, ornamental paper, telescope mirrors, and containers.

To put it in perspective, our bodies only absorb a small portion of the aluminium that is present in the food we eat. Foods that have higher than usual levels of aluminium include tea, cheese that has been processed, lentils, and sponge cakes, as these foods include raising agents. Although aluminium is the most common metal in the crust of the Earth (8.1%), it is rarely encountered in nature uncombined. Typically, minerals like cryolite and bauxite contain it. These are silicates of aluminium.Furthermore, using recycled aluminium has strong financial and environmental benefits. One tonne of new aluminium is produced using 14,000 kWh. On the other hand, one tonne of aluminium may be recycled and remelted using just 5% of this. Aluminium alloys that are recycled or virgin have the same quality.

Last but not least, Tabereaux et al,(2022), aluminium is not only non-toxic but also does not produce any smells or contaminate everything it comes into contact with. Because of this, aluminium may be utilised in packaging for delicate goods like food or medications that call for aluminium foil.A piece of aluminium weighs just 2.7 g/cm3, one-third that of a piece of steel. Aluminium is a lightweight and flexible material that is also reasonably priced. Its low weight makes it simpler to handle in factories and on construction sites and also results in less energy being used during transportation.

2.3 Design Of Experiment

2.3.1 Taguchi Method

A product that never fails to carry out its intended function during its useful life is the aim of resilient design. Using the design of experiments theory, robust design methodology also referred to as the Taguchi technique,offers a means of creating robust design specifications. The process looks for product design parameter settings that will make the product insensitive to changes in the environment, degradation, and manufacturing abnormalities. It is sometimes more expensive to control the reasons of production differences than to make a process or product less susceptible to them (Kamaljit Singh Boparai & Gurmaheshinder Singh Sandhu ,2023).

System design, parameter design, and tolerance design are the three areas into which Taguchi divides off-line quality planning and improvement operations. The use of engineering and scientific knowledge to create a working prototype is known as system design. The prototype model outlines the fundamental design features of a process or product as well as its early configurations. A strategy for scientifically allocating tolerances to reduce the overall production and lifetime expenses of a product is called tolerance design (Abed Alaswad et al.,2020).

A robust design technique, namely, Taguchi method, is one of the best tools to optimise parameters for composite development. The Taguchi technique will be used for this project since it involves two parameters: the amount of carbon nanotubes (CNTs) and the percentage of alumina weight (wt.%). Each of these two parameters has three distinct values, giving each variable three levels.

2.3.2 Response Surface Methodology (RSM)

A collection of statistical and mathematical techniques known as response surface methodology (RSM) are used to create functional relationships between interest response, y, and a few correlated control factors (input variable) provided by x1, x2,..., xk. Temperature, speed, and the kind of material are few examples of RSM factor levels that are completely independent of one another. The amounts of the various components that make up RSM Mixture are dependent on one another, which helps to improve production processes in the chemical industry. It is often unknown, however it may be estimated using a low degree polynomial model of the kind

23 y =f'(x) β + ϵ

where d (≥1) donates a vector of p unknown constant coefficients known as parameters, β is a vector of p random experimental error assumed to have a zero mean, and x = (x1, x2,...,xk),f(x) is a vector function of p element which includes of powers and cross-products of powers x1, x2,..., xk up to a certain degree.(Khuri and Mukhopadhyay, 2019).

There are two main models are generally used in RSM:

i. The first-degree model

$$y = \beta o + \sum^{ki=1}(\beta_i x_{i+} \epsilon)$$

ii. The second-degree model

$$y = \beta o + \sum^{ki=1}\beta_i x_i + \sum^{i<j}\sum \beta_{ij} x_i x_{j+} \sum^{ki=1}\beta_{ii} x_{i2+} \epsilon$$

RSM performs a number of tasks in an optimisation approach, including variable screening, experimental design selection, model fitness assessment, identifying ideal circumstances, and extracting the best values from each variable under study. (Bezerra et al., 2020).

2.4 Casting

2.4.1 Vibration Casting

Meysam et al.(2021), summarized the effect of ultrasonic vibration treatment on light alloy materials. Numerous studies' findings showed that the application of ultrasonic vibrations can be used to produce low-solubility aluminium alloys as well as cavitations, fine-filtration of melts, melt degassing, spatial solidification, non-dendritic solidification, and enhanced semi-solid deformation.

An examined the impact of ultrasonic vibration on the aluminium alloy's solidification process at power levels ranging from 0 to 700 W. The dendrites were big and coarse when not subjected to ultrasonic vibration (0 W of ultrasonic power). When aluminium alloy was exposed to intense ultrasonic vibration, globular grains were produced. The aluminium alloy's grain size progressively shrank from 202 to 146 mm as the ultrasonic vibration power increased. With an increase in ultrasonic vibration power, the ultimate tensile strength rose from 145 to 195 MPa and the elongation to fracture increased from 2.3 to 5.2% (Wang et al.,2023).

The commercial uses of ultrasonic vibration technology are limited due to the challenges of using ultrasonic instruments on the foundry floor, despite the technique having positive impacts on the solidification properties of aluminium alloy.

2.4.2 Squeeze Casting

Squeeze casting is a hybrid of the forging and casting processes that may be carried out during melt solidification with the assistance of high pressure. The melting point of alloys can be altered by applying pressure to the molten metal as it solidifies, speeding up the solidification process. Additionally, it refines the macro- and microstructure, which helps to reduce the castings' gas and shrinkage porosities.

Melted metal is typically put into a die that has been warmed. After filling is finished, the molten metal head is gradually subjected to high pressure using a ram. In order to guarantee that metal permeates the solidifying casting, pressure is used.In "direct" squeeze casting, a regulated speed is used to force the male die into the metal, causing it to create the desired shape without turbulence. A measured amount of molten metal (which needs to be clean, gas-free, and ideally filtered) is put into the female die casting or mould. The metal is subjected to pressures ranging from 50 to 150 MPa during the solidification process. After applying a graphite coat, the dies are heated (Surendran,2021).

Indirect squeeze casting involves injecting metal into the die chamber using a small-diameter piston. The primary method of indirect squeeze casting is vertical indirect squeeze casting.By shifting the shot sleeve vertically, the piston lifts from the bottom upward and uses a kind of counter gravity to force the metal into the cavity. It then maintains this pressure until the alloy has completely solidified. Although it is more difficult to obtain such good properties as with the direct process, high quality automobile parts have been produced (Meng et al.,2022).

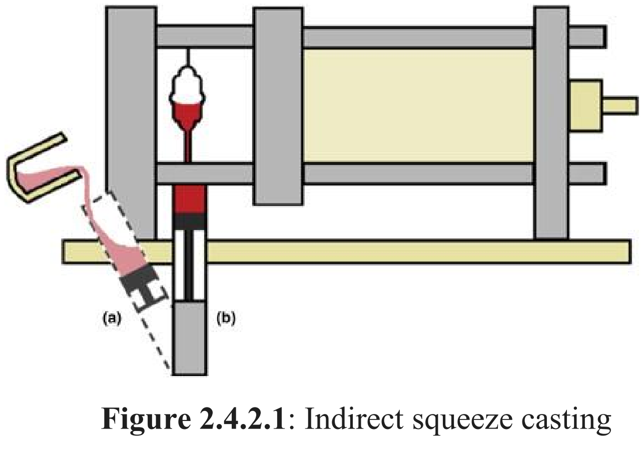


Figure 2.4.2.1: Indirect squeeze casting

Nonetheless, cycle time and component size are this process's primary drawbacks. The maximum size of the component has a significant impact on the size and capacity of the machine since the metal head must be pressurised. Furthermore, the cycle duration will be significantly increased by combining a pressurised solidification with gravity pouring.Issues with oxide inclusions being driven into the casting by pressurisation and with appropriate die venting to prevent entrapping air might also arise. This method is prone to errors in thin-walled castings.

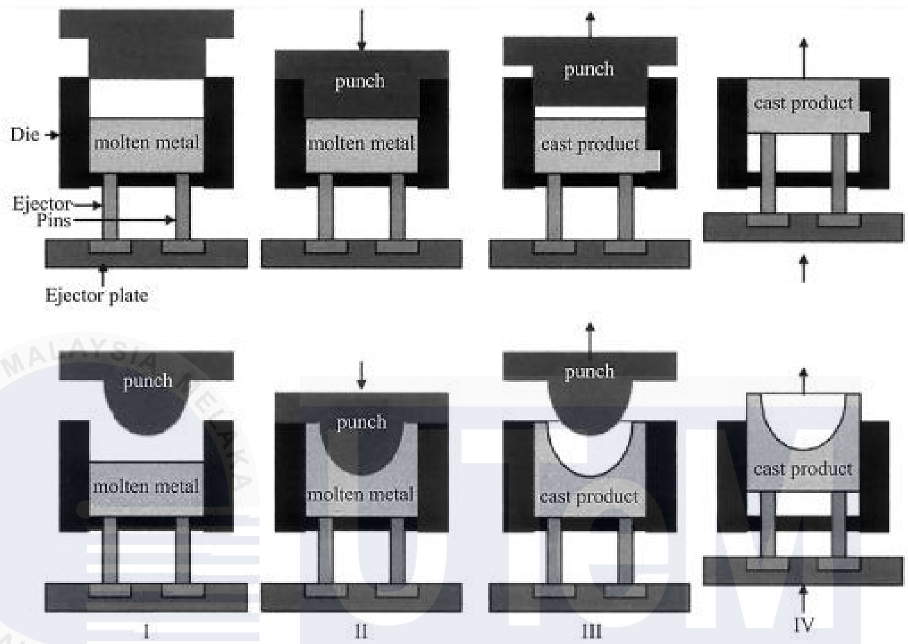


Figure 2.4.2.2: Squeeze casting process diagram

Since then, according to Dhanashekar et al.(2021), squeeze casting has been simplified and optimized to get the job done in only four steps:

Step 1: Melt the metal.

This procedure involves preheating the metal before it is combined with the die and put into the casting machine.Depending on the metal being used, the temperatures required to heat it might vary greatly, from 660°C (1220°F) to 3400°C (6152°F).

Step 2: Combine melt with die

The molten metal is poured or injected into the mould cavity (bottom die cavity) in the second process, where it is combined with the bottom half of the heated die with the aid of a launder.

Step 3: Pressuring and Closing the Die
Here, the melt is sealed off using the upper portion of the heated die, or punch. When the melt is sealed off, a ram is used to apply pressure, shaping the cast into the shape of the mould. Usually, pressures between 50 and 140 MPa are utilised to form the metal or die combination.

Step 4: Exiting or continuing the procedure
The punch is removed once the process of solidification is finished. To enable the operation to be repeated as quickly as necessary, the cast component is evacuated, the die is cleaned, and the melt stock is charged. As was previously noted, 50 to 40 MPa of pressure are needed to make the cast; but, in order for sufficient cooling to occur, the temperature must also be between 6 and 55 degrees Celcius.

2.4.3 INVESTMENT CASTING

A liquid substance is poured into a ceramic mould with a hollow hole in the appropriate shape during the investment casting manufacturing process, and the mould is then left to harden. To finish the procedure, the casting which has solidified is broken free from the ceramic mould.

A refractory substance is applied to a wax pattern during the investment casting process to create a shell. Subsequently, the wax is extracted and the melted metal is transferred into the mould. After the metal cools and solidifies inside the ceramic chamber, the ceramic is taken out of the metal casting. This method yields a net to near-net precision metal component that has a wide variety of applications across several sectors. Nevertheless, the investment casting technique of aluminium metal matrix composite has not been the subject of considerable investigation . Indeed, the disposable ceramic shell is not appropriate for this procedure because of its inherent fragility (Taccardo et al.2019).

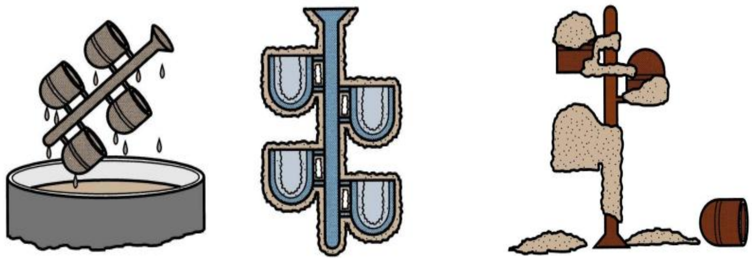


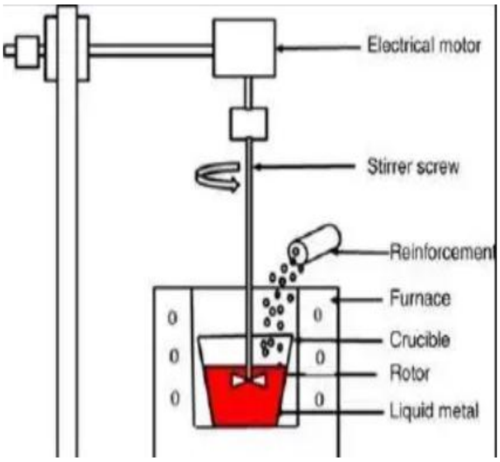
Figure 2.4.3.1: Investment Casting Process

2.4.4 STIR CASTING

Stir casting is one of the novel methods to produce metal matrix composites with more uniform distribution of matrix and reinforcement constituents. Using this method, the reinforcing particles are mechanically mixed into a bath of molten metal. Aluminium metal is melted in a crucible that has been heated to a consistent temperature. The crucible also has blades and a motor. To provide a continuous and smooth feed, the reinforcement is poured into the crucible above the melt surface at a regulated pace. To create homogenous composites, the reinforcing particles are uniformly mixed into the melts as a result of the blades rotating at moderate speeds.

Stir casting of metal matrix composites (MMC) began in 1968 when S. Ray stirred molten alloys containing ceramic powders to incorporate alumina particles into the aluminium melt. An essential part of this procedure is the furnace's mechanical stirring. Composites with up to 30% volume fraction of reinforcement can be made via stir casting. Particle characteristics and process variables, such as the wet state of the particles with the melt, mixing strength, relative density, and solidification rate, determine the ultimate distribution of the particles in the solid (Koppad et al.,2019).

In Figure 2.4.4.1 show that diagram of stir casting and the distribution of the particles in the molten matrix depends on the geometry of the mechanical stirrer, stirring parameters, placement of the mechanical stirrer in the melt, melting temperature, and the characteristics of the particles added.



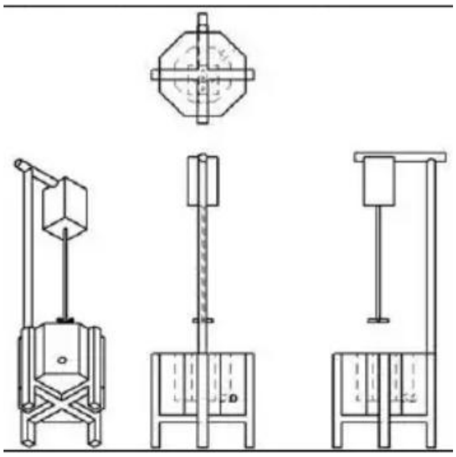


Figure 2.4.4.1: Stir Casting **Figure 2.4.4.2**: Schematic Stir Casting

MMCs can be produced in a variety of ways, and of all the liquid-state methods, stir casting technique is thought to offer the most engineering application potential in terms of both cost and production efficiency.Kumar et al.(2020),some of the issues that require careful consideration when creating metal matrix composites using the stir casting method are as follows:

-To attain even dispersion of the reinforcing material
-To attain wetability between the two principal components

Stirring speed is an important parameter to promote binding between matrix and reinforcement i.e. wettability. Stirring speed decides formation of vortex which is responsible for dispersion of particulates in liquid metal.

Stir casting experimental works generally involves three steps which including:

Step 1:
Preheat the boiler and leave the top lid open until the temperature of the charcoal reaches a stable combustion point. The cover (lid) is closed after the requirement is achieved. The metal fragments are ready to be added to the furnace crucible when it reaches a red temperature.

Step 2:

Aluminium scraps were cut into small pieces and hammered to get small tablets of aluminium scrap. After that, scrap aluminium was added to the graphite crucible to melt the metal entirely.

Step 3:

Stir the molten aluminium while continuously adding carbon nanotube (CNT) reinforcements to the crucible. Using tongs and further safety measures, the molten aluminium CNT composite in the crucible was removed from the furnace after five minutes.

Figure 2.4.4.3: Heating furnace,cut into small pieces and stir molten metal

2.4.5 MICROSTRUCTURE OF STIR CASTING PARTICLES

Mechanical stir casting use to create an aluminium metal matrix composite. Therefore, employing a robust design of experiment (DOE), specifically the Taguchi method, the optimisation and effect of variables such as amount of CNT and amount of wettability agent were examined.

Enhancing the material's hardness was more significantly influenced by the quantity of MWCNT. Higher hardness and tensile values were observed with a 0.5 weight percent CNT component. Low porosity and high-density dislocation may occur from the increased overall metal matrix density of 0.5 weight percent, which could be the cause of these findings. It was established how the influences will affect mechanical attributes including hardness and ultimate tensile strength (UTS) (Parikh et al.,2023).

There was also discussion of the microstructures' development. Ultimately, the optimised parameters were provided together with their effects on the alloy matrix composite reinforced with MWCNT.The impact of CNT on the mechanical characteristics of the metal composite has been the subject of a sizable number of published investigations. According to Parikh et al.(2023), mechanical stirring mixing in a liquid condition improved the aluminium alloy's hardness when the weight fraction of CNT was present. Many studies have been conducted on metal matrix composites (MMC) reinforced with multiwalled carbon nanotubes (MWCNTs). Superior mechanical characteristics and surface microstructure were achieved with increasing CNT(%) content.

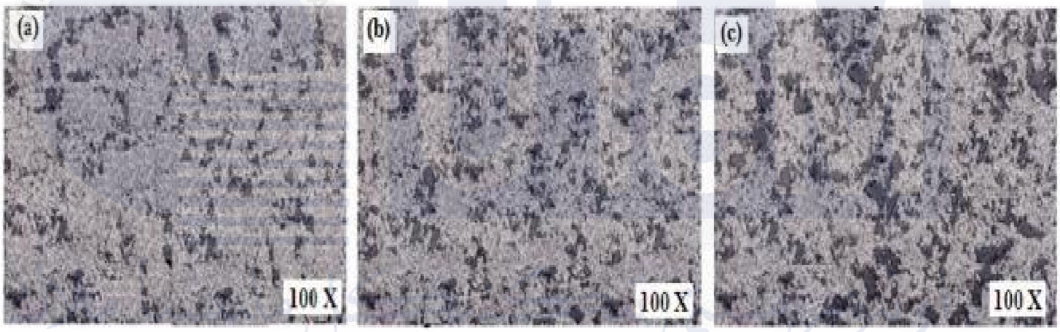


Figure 2.4.5.1: Microstructure of aluminium reinforced with (a) 5% (b) 10% and (c) 15% of CNT

2.5 Fabrication Process of Al-CNTs Metal Matrix Nanocomposites (MMNCs)

2.5.1 Powder Metallurgy (PM)

Al-based MMCs reinforced by CNT have been produced using a variety of handling techniques.One of the most documented methods for effectively generating CNT-reinforced aluminium matrix is classical powder metallurgy (PM) with various sintering techniques. The mechanical qualities of the components made by PM, however, may be jeopardised by the process's usual porosity. Forging and rolling are two examples of plastic deformation that can be used after PM to increase the density of the nanocomposites that are created. According to Sayed et al. (2019), deformation methods can also be utilised to align the CNTs and so obtain a notable gain in mechanical strength. This is in addition to improving the CNTs' dispersion and the density of the nanocomposites. In this work, better dispersion and an improved contact between the CNTs and the Al matrix are achieved through forging subsequent to manufacturing via powder metallurgy. The authors noted a notable improvement in mechanical qualities, which they ascribed to an improved load transmission system.

Among the post-processing methods most frequently mentioned for use in powder metallurgy-produced Al/CNTs is rolling.Based on Sayed et al.(2019), for instance, demonstrated how hot rolling efficiently creates Al/CNTs with a uniform distribution of reinforced material. Because of the mechanisms of load transfer and grain refinement strengthening, the nanocomposites demonstrated an exceptional balance between high strength and flexibility. Similar outcomes for Al nanocomposites reinforced with CNTs and created by plasma spark sintering (SPS) and hot rolling were reported by Casati et al.(2021). Al/CNT nanocomposites were created by Sayed et al.(2019) using powder metallurgy and a mixture of micro and macro rolling techniques. This method has been shown to be practical for achieving a good nanocomposite strength-ductility relationship. mechanisms of reinforcement such grain, higher dislocation density, and load transfer.

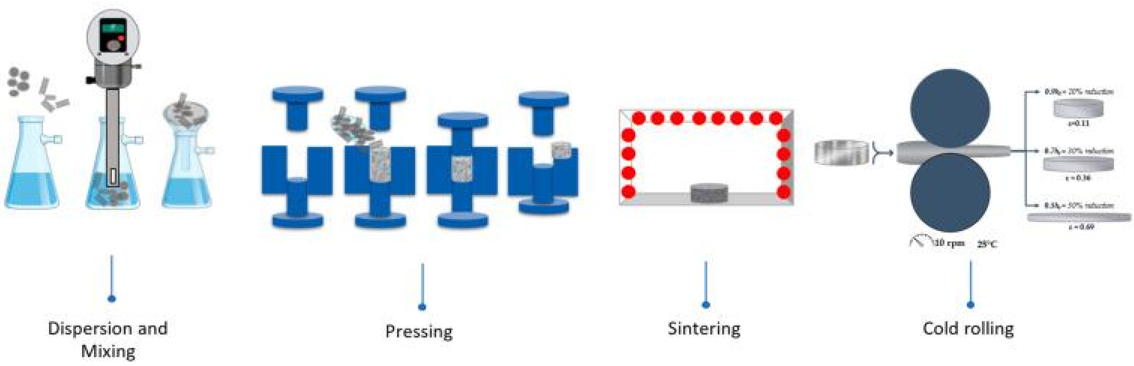


Figure 2.5.1: Powder Metallurgy Diagram

However, certain fundamental problems with producing CNT-fortified MMCs persist: Achieving a homogeneous scattering is challenging because of the fast agglomeration of carbon nanotubes (CNTs) caused by strong Van Der Waals forces, the attractive or unappealing communications between the carbon molecules, the need to maintain the CNTs' fundamental reliability during the assembly process, the control of sound holding, and the need for minimal interfaces to achieve an appropriate burden shift between stages due to the helpless wettability between carbon and metals, including Al. Several forms of powder metallurgy (PM) processes, hot and cold isostatic pressing, friction stir processing, and dispersion will be among the process that will be covered.

2.5.1.1 Ball Milling (BM) and Sintering

Powder metallurgy techniques have demonstrated potential for creating metal matrix composites reinforced with carbon nanotubes (CNTs). In this work, planetary ball milling was used to disperse five weight percent of multi-walled carbon nanotubes (MWCNT) in aluminium (Al) powder. While ball milling is a useful technique for dispersing carbon nanotubes (CNTs) in aluminium powder, it often causes the powder to undergo severe strain hardening, which could compromise the final properties of the composite. Even after being exposed to temperatures as high as 500°C for an extended period of time, the nanostructure held firm. It was found that during the milling process, impact and shearing action fractured the carbon nanotubes, resulting in a drop in length. To offer the milling goods a high level of toughness, MWCNT are added.

Grain size grew during high energy ball milling, leading to an increase in elastic modulus and nano hardness. A ball mill operates on the basis of impact; as the balls descend from close to the top of the shell, impact reduces particle size (Seki et al., 2022).A ball mill is a device with a hollow cylindrical shell that revolves on its axis. The axis of the shell may run parallel or perpendicular to the horizontal. It has some balls inside of it. The grinding media are the balls, which can be made of rubber, stainless steel, or steel (chrome steel). Typically, the interior surface of the cylindrical shell is lined with rubber, manganese steel, or another material resistant to wear.

The ball mill is used for grinding materials such as coal, pigments and felspar for pottery. Ball mills are also used in pyrotechnics and the manufacture of black powder, though certain pyrotechnic combinations, such flash powder, cannot be made with them due to their sensitivity to impact. Although they may be costly, high-quality ball mills can reduce mixture particles to as small as 5 nm, significantly boosting surface area and reaction speeds.

According to Bathula et al.(2020), process parameters can be optimised by using the response surface methodology. The range of parameters that will maximise or minimise the process parameters can be found with the aid of contour plots and response surfaces. Al powders were typically deformed into three phases during the ball milling process: they were first flattened into flakes, then they were cold welded into particles with a lamellar structure, and finally they were broken into smaller particles. In the meantime, CNTs were initially scattered around the Al flakes' surface before becoming occluded by Al and imprisoned in the cold-welded particles.The majority of the CNT/Al composites that were produced as a result showed better strength and modulus but low ductility, which was a clear disadvantage for their practical uses.

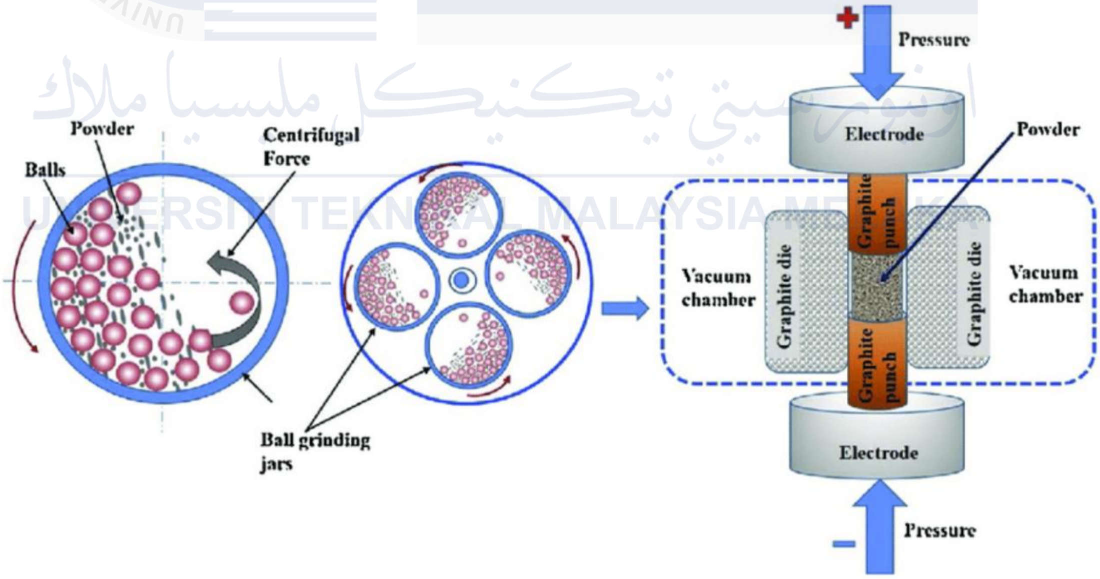


Figure 2.5.1.1: Ball Milling and Sintering Process

2.5.1.2 Ball Milling (BM) and Hot-Press Sintering (HPS)

To create Al-B master alloys, combinations of aluminium powder were ball milled and heated above 873 K (600 °C). Powder mixes that have been ball-milled exhibit layers of deformed aluminium and borax grains that get increasingly more refined as the milling time is extended. Thermite interactions between these layers are facilitated by thermal exposure of the mixes of ball-milled powder. When borax is heated to 873 K (600 Ò°C), it becomes dehydrated and is reduced by Al. The resulting B combines with the excess Al to form AlB2 particles that are distributed throughout the grains of aluminium. Along the contact between the layers of borax and aluminium, AlB2 particles begin to form (Schumann et al., 2021).

Both the size and the quantity of AlB2 particles increase with temperature, indicating that once nucleated, these particles expand easily to create hexagonal-shaped crystals that pass through the aluminium grains. After just one hour of ball milling, thermite can react with aluminium and borax. Additionally, the reaction of the powder blend to heat is unaffected by ball milling. On the other hand, more nucleation-reaction sites result from longer milling times, which guarantees a higher quantity of smaller AlB2 particles. The AlB2 platelets' size can be changed by adjusting the ball milling time. Either way, there are limited yields and large expenses associated with this process.

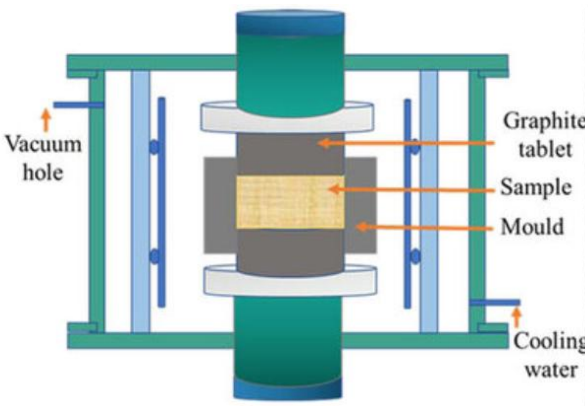


Figure 2.5.1.2: Ball Milling and Hot Press Sintering Diagram

2.5.1.3 Sparkle Plasma Sintering (SPS)

A relatively new method compared to traditional sintering, the SPS cycle has been examined by several specialists for the production of Al/CNT composites. Through the use of a beat direct current and kicking the bucket, the SPS measure rapidly heats the powder, hence increasing the sintering rate. In this cycle, the diffusion of electrical fields, joule heating, and sparkle sway pressure enable the high thickness and low porosity sintered component. This cycle normally works well for nanopowder mixes, however it doesn't offer enough chances for ideal grain growth. The SPS cycle and its post-preparing misshaping appear to be the means by which the solidification process is completed.

Although carbon nanotube (CNT) agglomeration can be effectively prevented with a short SPS protocol, SPS may allow for the persistence of groups that may have formed during preparation steps like mixing and compression. It has been found that the grouping problem can be solved by post-preparing distortion.But you can only prepare basic symmetrical shapes.The resulting ball-milled nanocomposite powders were initially introduced to a graphite die (50 mm in diameter and 12.7 mm in wall thickness) in order to stop material leakage (Bathula et al.,2020).Graphite foil separators were placed on top and bottom of the system. Graphite fibre was used to cover the die. The material was compressed at a pressure of 50 MPa using graphite punches following the insertion of the powder die into the vacuum chamber of the SPS equipment.

The sintering process was run at a heating rate of 50 °C per minute for five minutes at 620 °C. The system's temperature was monitored using a thermocouple attached to the graphite die while the SPS apparatus was operating at 1500 A and 2.5 V (Seki et al., 2021).After the system cooled to room temperature, the sintered nanocomposite was subsequently freed from the die. All sintered Al-based CNT nanocomposite specimens were thermally treated for 10 minutes at 650 °C in a furnace in order to promote consolidation. The density of the sintered disk-shaped (50 mm in diameter and 5 mm in thickness) nanocomposites samples was measured using the Archimedes technique with deionized water as the immersion medium.

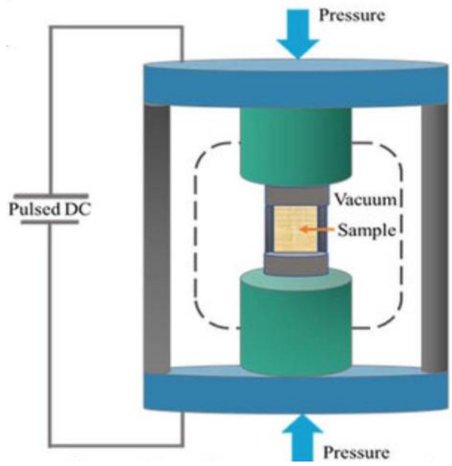


Figure 2.5.1.3 : Sparkle Plasma Sintering

2.5.2 Hot Isostatic Pressing (HIP)

Al–graphene composite powders were produced by the consolidation process using hot isostatic pressing (HIP). HIP occurred at 375°C for 20 minutes. Samples of pure Al, 0.1wt% graphene, and 1.0wt% MWNT were made. A low weight proportion of graphene was selected because, due to its larger interfacial contact area, its dispersion is more complex than that of CNTs. The billets were heated to 550°C for four hours after HIP, and then they were extruded using a 50 tonne extrusion press (Jiang et al.,2019).

When MWCNTs are present, aluminum's tensile strength can rise by as much as 12%. However, Al's hardness and tensile strength were decreased due to grapheme's propensity to form aluminium carbide during processing (Jiang et al.,2019). The type of the grapheme created by heat processes is what causes the creation of aluminium carbide. The formation of the aluminium carbide is because of the nature of grapheme that produced by thermal exfoliation/reduction of graphite .Besides,cycle times also can be slow.

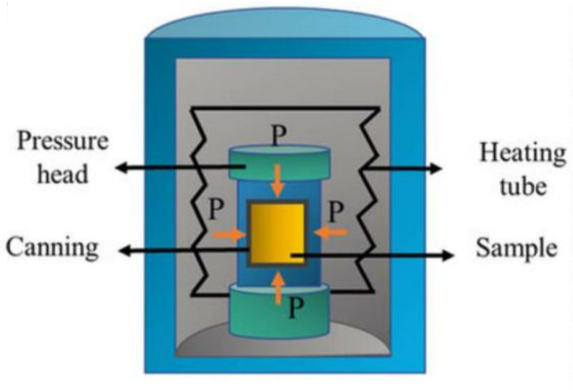


Figure 2.5.2.1: Hot Isostatic Pressing Process

2.5.3 Cold Isostatic Pressing (CIP)

There were two kinds of nanoparticles produced: rutile-TiO2 (99.8% pure, 30nm) and γ-Al2O3 (99.98% pure, 50nm). Furthermore, 99.98% pure Al and 98.5% pure Si powder, both measuring 25 µm, were manufactured. Using the dry mixing method, the alloy powder (Al-12%Si) was combined with either a single Al2O3 or a single TiO2. In order to attain a uniform dispersion of particles, four hours of 650 rpm mixing were done. Subsequent to cold compaction at 10 MPa pressure, a 90-minute sintering process at 520°C and a 2 L/min argon flow rate was conducted. The sample with 4 weight percent Al2O3 had the maximum hardness as a result of nano Al2O3's superior hardness over nano TiO2. It has been shown that following mechanical milling, the reinforcement nanoparticles scatter equally in the Al-12wt%Si matrix.When compared to base alloy and other nanocomposites, the nanocomposites reinforced with a single addition of 4wt% Al2O3 nanoparticles had the maximum hardness and wear resistance (Tadic, 2019).Parts, however, might need to be post-machined.

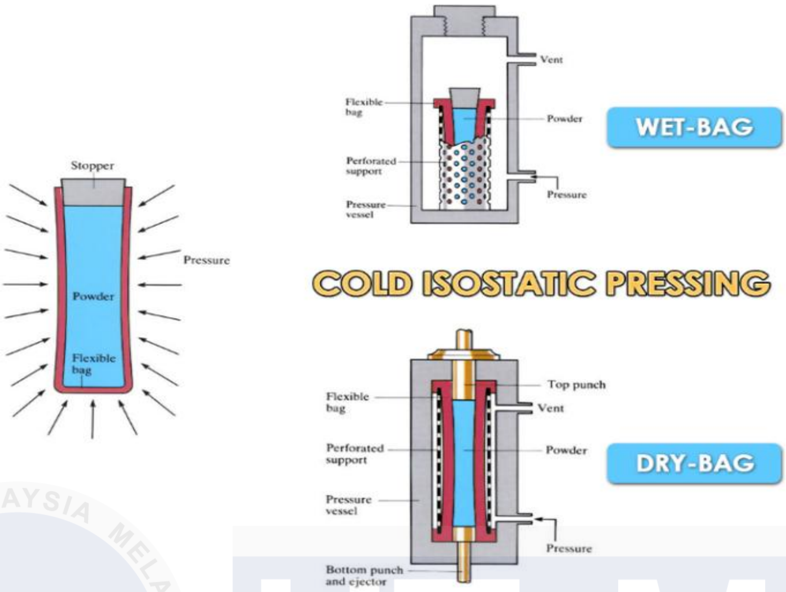


Figure 2.5.3.1: Cold Isostatic Pressing Diagram

2.5.4 Friction Stir Processing(FSP)

Grating mix handling (FSP) is a cycle that produces a fine-grain microstructure while occurring in a strong condition. Similar to FSW, this cycle is led by a pivoting mechanism that creates an extraordinarily plastic deformed zone on a substrate. The presence of fine, equiaxed grains framed in view of dynamic recrystallization is found in the grating zone. Although the FSP cycle has mostly been applied as a grain-refinement metric, it is also an effective method for composite assembly. The FSW cycle's employed twist or frictional power can lead to the welding of metal and carbon nanotubes (CNT) to generate a metal grid that is strengthened by CNT. Morisada et al. synthesised an Al/CNT composite using the FSP cycle. The researchers mentioned that although the grains are purified and CNTs are distributed across the metal grid, the analysed data did not show a decrease in grain size. Reducing the pace at which tooling is developed led to better CNT dispersion, which in turn extended the blending hour. According to their observations, the CNTs are uniformly dispersed throughout the network with sufficient holding, improving the mechanical properties of the framework and refining the grain (Ma Z.Y., 2021).

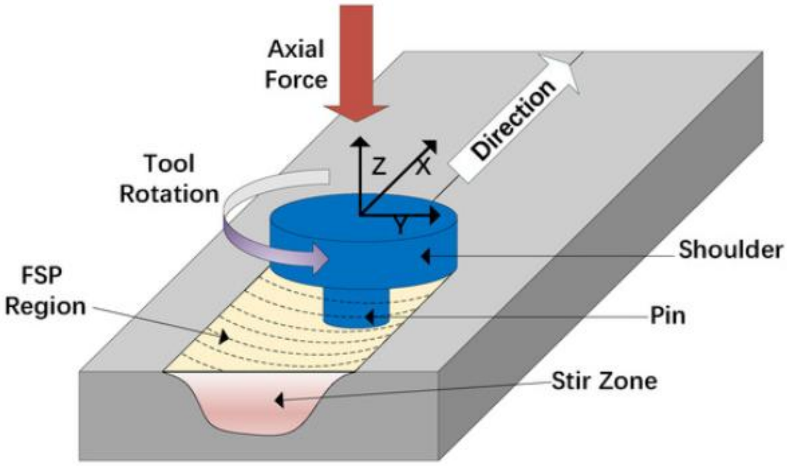


Figure 2.5.4.1: Schematic diagram FSP

2.5.5 Spread Dispersion(SD) /Rolling Process

A recently developed manufacturing technology called the SD/moving cycle is suitable for the design of Al-based composites with tiny nano-layered structures. This cycle was used by Xiang et al. to produce composites covered in Al/CNTs. They obtained Al-based composites with a tiny nano-layered structure by combining the electrophoretic affidavit (EPD) of CNTs with 50 µm Al foils (Zhang et al.,2019). This was done surprisingly. The uniform appropriation of CNTs on Al foils without any agglomeration was achieved by employing the EPD cycle. The deposition duration might be adjusted to alter the CNT layer's thickness. Additionally, the boundaries of the composites' layered structure can be controlled by selecting Al foils with different thicknesses. After the stacked Al foils were hot-moved, a 60% drop in aggregate thickness was observed.

In comparison to the usual uniform composites, the tiny nano layered structure creates enormous back pressure in the composites supplied by CNTs layers that prevent the disengagements slip and, as a result, achieves increased productivity for reinforcing and hardening. The increased energy needed for break growth and the large Schmid factor in relation to the basal slip framework are what extract the strength gain (Somayeh et al., 2020).

2.5.6 Permanent Mold Casting

Permanent mold casting, also known as gravity die casting or permanent mold casting, is a metal casting process that utilizes reusable molds to produce consistent and repeatable metal parts. This process is typically used for high-volume production of parts with complex shapes and tight tolerances.

According to (Francis,2022),the mould is ready for the casting process; it is commonly composed of metal.Usually, the mould consists of two parts: an upper and a lower component that can be connected to create a full mould.The inside surfaces of the mould are coated with a refractory substance to enhance heat resistance and reduce wear.When the mould is put together, the ultimate shape of the intended metal item is represented by the cavity that is created by the combined halves.The finished casting can be removed from the mould with ease thanks to its design.

The mould is heated to a certain temperature prior to the casting process starting. This guarantees appropriate metal flow and aids in improving the cast part's surface finish.The mould is filled with molten metal, often aluminium or another non-ferrous alloy(Samal et al.,2022).The main force filling the mould cavity is gravity. Because of gravity, the molten metal pours into the mould.The molten metal cools and solidifies once the mould cavity is full.In order to achieve the appropriate mechanical qualities and lower the possibility of faults, a controlled cooling procedure is essential.

The newly created casting is visible when the mould is opened, following the solidification of the metal.The riser,an extra piece of material that aids in feeding the casting as it cools may be present in the casting, which is still fastened to the sprue, the conduit through which metal is poured (Babu et al.,2020).The casting is then taken out of the mould, and any extra material like the riser and sprue is cut away.To achieve certain specifications, the casting may go through further operations like machining or finishing.

For the subsequent casting cycle, the mould is then reset.Because the entire process is repeated from pouring to removing parts permanent mould casting is appropriate for large-scale manufacturing.Benefits of permanent mould casting include superior surface polish, affordability for big production runs, and the capacity to create intricate designs with precise tolerances. The appliance, automotive, and aerospace sectors frequently employ it(Francis,2022).

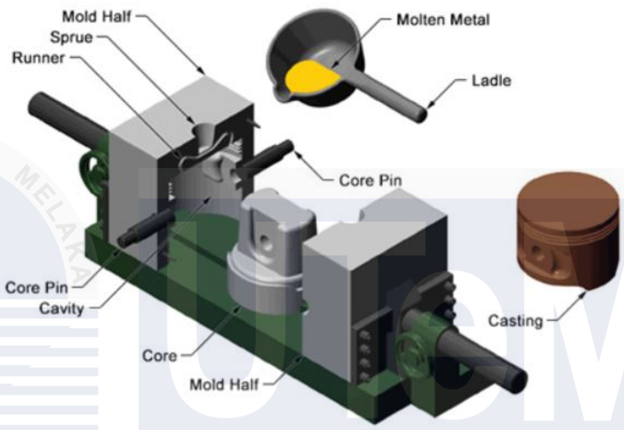


Figure 2.5.6.1: Permanent Mold Casting

2.6 Micro Structure Characterization

2.6.1 X-Ray Diffraction

A potent analytical method for examining a material's crystalline structure is X-ray diffraction (XRD). It offers details on the orientation of the crystal, the arrangement of atoms in the crystal lattice, and other structural properties of the material. The foundation of X-ray diffraction, which happens when X-rays interact with crystalline materials, is the principle of XRD.Because of interactions with the atomic arrangement of the crystal, X-rays encounter both constructive and destructive interference when they contact a crystal lattice.X-rays with a particular wavelength are produced by an X-ray source, which is often a cathode-ray tube.Targets for cobalt (CoKα), molybdenum (MoKα), and copper (CuKα) are frequently utilised X-ray sources(Raval et al.,2019).

The material being studied has to be crystalline in nature. Remarkable diffraction patterns are not produced by amorphous materials.Usually, the material is finely pulverised to guarantee that the crystals are oriented randomly. The foundation of X-ray diffraction (XRD) is Bragg's Law, which connects the interplanar spacing (d) in a crystal lattice to the angle of X-ray incidence (θ)(Raval et al.,2019).

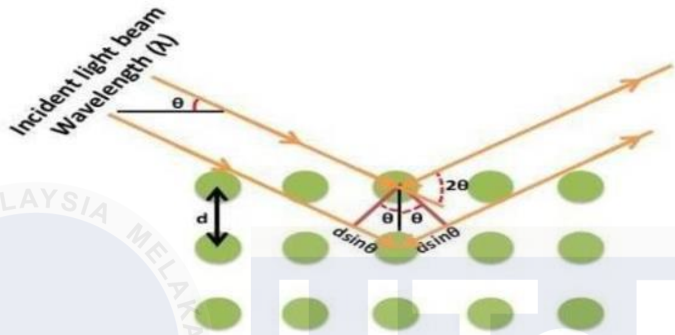


Figure 2.6.1.1: Illustration according Bragg’s law

The equation is given by: $2d\sin(\theta) = n\lambda$, where n is an integer and λ is the wavelength of the incident X-rays.

After the sample is exposed to X-rays, the diffracted rays are gathered on a detector.Diffraction peaks are bright spots on the detector that appear when X-rays interact constructively at certain angles due to the crystal lattice planes in the sample.A particular collection of the material's crystallographic planes is represented by each peak.

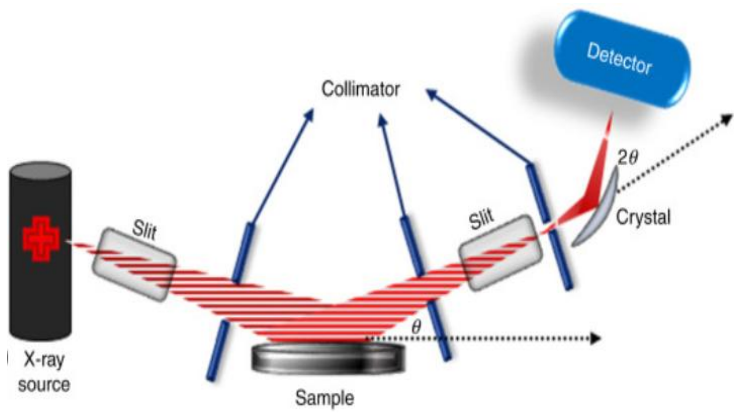


Figure 2.6.1.2: X-Ray Diffraction Diagram

2.6.2 Optical Microscope(OM)

Often referred to as a light microscope, an optical microscope (OM) is a commonly used tool for observing and magnifying small objects or specimens using visible light and lenses. In many scientific disciplines, such as biology, medicine, materials science, and quality control, it is a vital instrument. To accomplish magnification, optical microscopes combine objective and eyepiece lenses. Multiplying the objective lens's magnification by the eyepiece's magnification yields the overall magnification.Furthermore, resolution describes a microscope's capacity to discern between two objects that are tightly spaced apart (Ebnesajjad,2021). Both the light's wavelength and the lenses' numerical aperture have an impact.Having enough light is essential to getting sharp, detailed photographs. The amount and direction of light that reaches the specimen are managed by the diaphragm and condenser.

The distinction in hue or brightness between the object and its surroundings is known as contrast. Contrast can be improved via staining techniques, phase contrast, and differential interference contrast (DIC) (Ebnesajjad,2021).The thickness of the specimen in simultaneous sharp focus is known as the depth of field. Both the light's wavelength and the objective lens's numerical aperture have an impact.

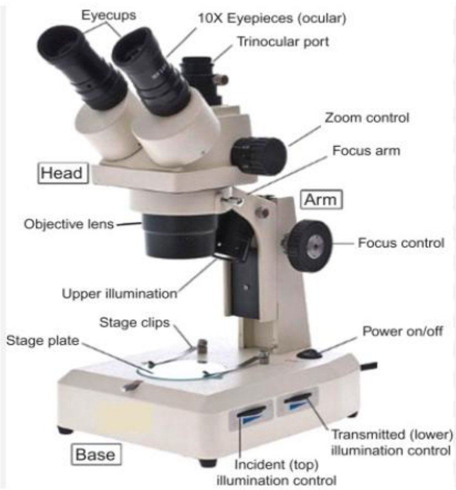


Figure 2.6.2.1: Optical Microscope Parts

2.6.3 Energy Dispersive Spectroscopy(EDS)

The elemental composition of a sample can be examined using Energy Dispersive Spectroscopy (EDS), a technique that is used in conjunction with electron microscopy. It offers details on the kinds and concentrations of elements found in a substance. EDS is widely integrated into scanning electron microscopes (SEM) and transmission electron microscopes (TEM) to enhance the analytical capabilities of these devices.

EDS works on the premise that a sample will release distinctive X-rays in response to interaction with a high-energy electron beam. Every element's atomic structure is linked to a distinct set of X-ray energy.The X-rays are detected using a solid-state X-ray detector (Hiroyuki Kitajima & Seiichi Suzuki(2022). Energy-dispersive detectors and silicon drift detectors (SDD) are common types of detectors.For EDS examination, samples must be sufficiently thin to allow electrons to pass through and interact with the substance.

Inner-shell electrons are ejected from the sample as a result of interactions between the electron beam from the microscope and the atoms.Afterwards, electrons with higher energy levels undergo a transition to occupy the vacancies in the inner shells, which causes distinctive X-rays to be released.The X-rays that are released have energy that is unique to the elements that are in the sample. Every element emits distinctive X-rays with distinct energy signatures.Plotting X-ray intensity versus energy, the X-ray spectrum is recorded by the EDS system.The peaks in the spectrum represent the distinctive X-rays emitted by various elements.

Both quantitative and semi-quantitative analyses of the elemental composition can be performed with EDS.Comparing peak intensities allows for the estimation of relative elemental concentrations in semi-quantitative analysis.Calibration standards are used in quantitative analysis to find the absolute concentrations of elements.The sensitivity of EDS is limited, especially for light elements.Peak overlap could be an issue, making it difficult to discern between elements with similar energy values (Plotnick,2020).

Figure 2.6.3.1: Energy Dispersive Spectroscopy

2.6.4 Field Emission Scanning Electron Microscopy (FESEM)

Using a concentrated electron beam, Field Emission Scanning Electron Microscopy (FESEM) is a sophisticated method that enables high-resolution imaging of surfaces at the nanoscale. An improvement over conventional Scanning Electron Microscopy (SEM), FESEM is especially helpful for investigating materials with intricate features and nuances. Compared to a tungsten filament in a standard SEM, a field emitter source in a FESEM enables a much narrower electron beam and greater resolution imaging.The field emitter, which is the electron source in a FESEM, is frequently composed of tungsten or tungsten-based material (Shaji et al.2018). Through a mechanism known as field emission, this source permits the emission of electrons, producing an extremely focused and fine electron beam. To focus the electron beam to a precise location, FESEM requires sophisticated electron optics. High resolution and magnification are accomplished by the combined efforts of the condenser and objective lenses.

When compared to typical SEM, FESEM can reach better resolution, frequently in the subnanometer range. It is hence appropriate for imaging nanostructures and fine details.To avoid charging effects, samples used in FESEM must be conductive or covered in a thin conductive coating (Orasugh et al.,2020).The preparation of the sample is crucial, and artefacts that could impair the quality of the imaging must be avoided. FESEM is capable of functioning in multiple imaging modes, such as backscattered electron imaging (BEI) and secondary electron imaging (SEI), each of which offers distinct surface information.

Samples can be imaged in three dimensions using FESEM. Researchers can generate detailed three-dimensional (3D) representations of the sample surface by obtaining and reconstructing photos from various angles.Numerous scientific and industrial fields, such as materials science, nanotechnology, biology, geology, and semiconductor research, make extensive use of FESEM. Because FESEM is a complex instrument, it needs to be operated and maintained carefully. Even with conductive coatings, sample charging effects can still happen, particularly with insulating samples.For best results, high vacuum conditions are typically needed (Shaji et al.,2018).Scanning of Field Emissions for scientists and researchers that require high-resolution imaging of surfaces at the nanoscale, electron microscopy is an invaluable tool. It is useful in many different scientific fields because of its capacity to give comprehensive information about the topography and composition of materials.

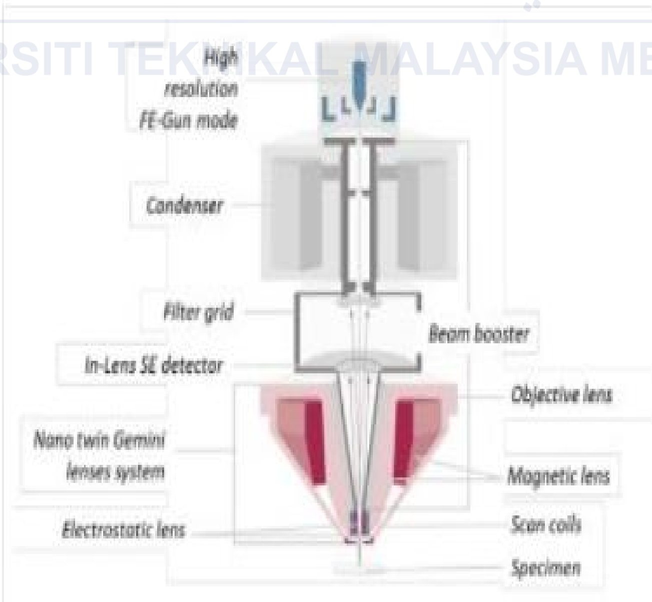


Figure 2.6.4.1: FESEM main parts image

2.7 Mechanical Test

Evaluating a material's mechanical properties through testing yields important details about how the material will behave under different circumstances. Engineers and researchers can better understand how materials react to stresses, deformations, and environmental conditions thanks to these experiments.

In order to determine the mechanical characteristics of the unreinforced compounds and composite materials, uniaxial pressure tests were performed on the composites. A general strain pressure test framework with a crosshead speed at room temperature was used to conduct the pressure tests. From the bends, the instances' pressure, yielding loads, and strain estimates were calculated. To determine the ideal normal worth, three tests were conducted for every example collection. (Suzuki et al., 2019)

2.7.1 Hardness Test

A Vickers hardness testing equipment (Akashi MVK-H1) equipped with a precious stone indenter under the heap applied of 300 N and stay season of 10s was used to estimate microhardness. In the results, the average of five spaces was used for every sample. (Suzuki et al., 2019)

2.7.2 Tensile Test

A basic mechanical test called a tensile test, sometimes called a tension test, involves applying a controlled force to a sample of material until it fails. Finding out the material's mechanical characteristics under axial load is the aim of this test. The test can yield important details regarding the ductility, strength, and other mechanical properties of the material(Jawaid et al.,2023).

Typically cylindrical in shape, tensile test specimens have a reduced section known as the gauge section. The sample is prepared in compliance with particular engineering specifications or standards.The device tracks the applied force and the specimen's corresponding elongation or deformation during the test. Utilising this data, a stress-strain curve is produced.

CHAPTER 3
METHODOLOGY

3.1 Introduction

The methods, materials, and equipment employed in this study are explained in this chapter. The detailed explanation of the methods used to ascertain the mechanical characteristics of processing carbon nanotube-aluminum composites by the permanent mould casting process. This chapter covers the project development and the approach used to support the objectives as outlined in chapter 1.

3.2 Gantt Chart

An undertaking plan is graphically represented by a Gantt chart. It illustrates the beginning and end dates of a few activities or works that incorporate such as achievements, assignments and conditions. Typically, the vertical axis displays all of the tasks or activities involved in the project, while the horizontal axis depicts time,that can broken down into days, weeks, or months.The Gantt chart for PSM 1 and PSM 2 are shown below in Figure 3.2.1 and Figure 3.2.2 .Besides, the Gantt chart for this PSM 2 also attached to appendices.

TASK	WEEK 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Title Selection	■														
Title Confirmation	■														
Discuss with supervisor about project		■													
Search for relevant references(journal,article)		■	■	■	■										
Chapter 1 (problem statements,objectives)			■	■											
Chapter 2 (literature review)				■	■	■	■								
Chapter 3 (methodology)								■	■	■	■				
References and Formatting											■				
Safety Briefing												■			
Logbook Submission to Supervisor												■			
Poster Presentation														■	
Improve Report													■	■	
Final Report Submission															■

Figure 3.2.1: Gantt chart for PSM 1

TASK	WEEK 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Discuss with supervisor about project	■	■				■		■	■		■	■			
Search for relevant references(journal,article)	■	■													
Raw Materials Preparation		■													
Weighing the reinforcements material			■												
Chapter 4&5 (result,discussion, conclusion) lecture			■												
Do casting process					■	■									
References and Formatting Lecture						■									
Sample Preparation							■	■							
Logbook Submission to Supervisor									■						
Do cutting and CNC machining									■	■					
Apply microstructure characterization techniques									■	■	■				
Tensile Test & Hardness Test											■	■			
Poster Presentation												■			
Technical Paper Lecture & Submission												■	■		
Improve Report													■	■	
Final Report Submission														■	■

Figure 3.2.2: Gantt chart for PSM 2

3.3 Flowchart of Overall Research

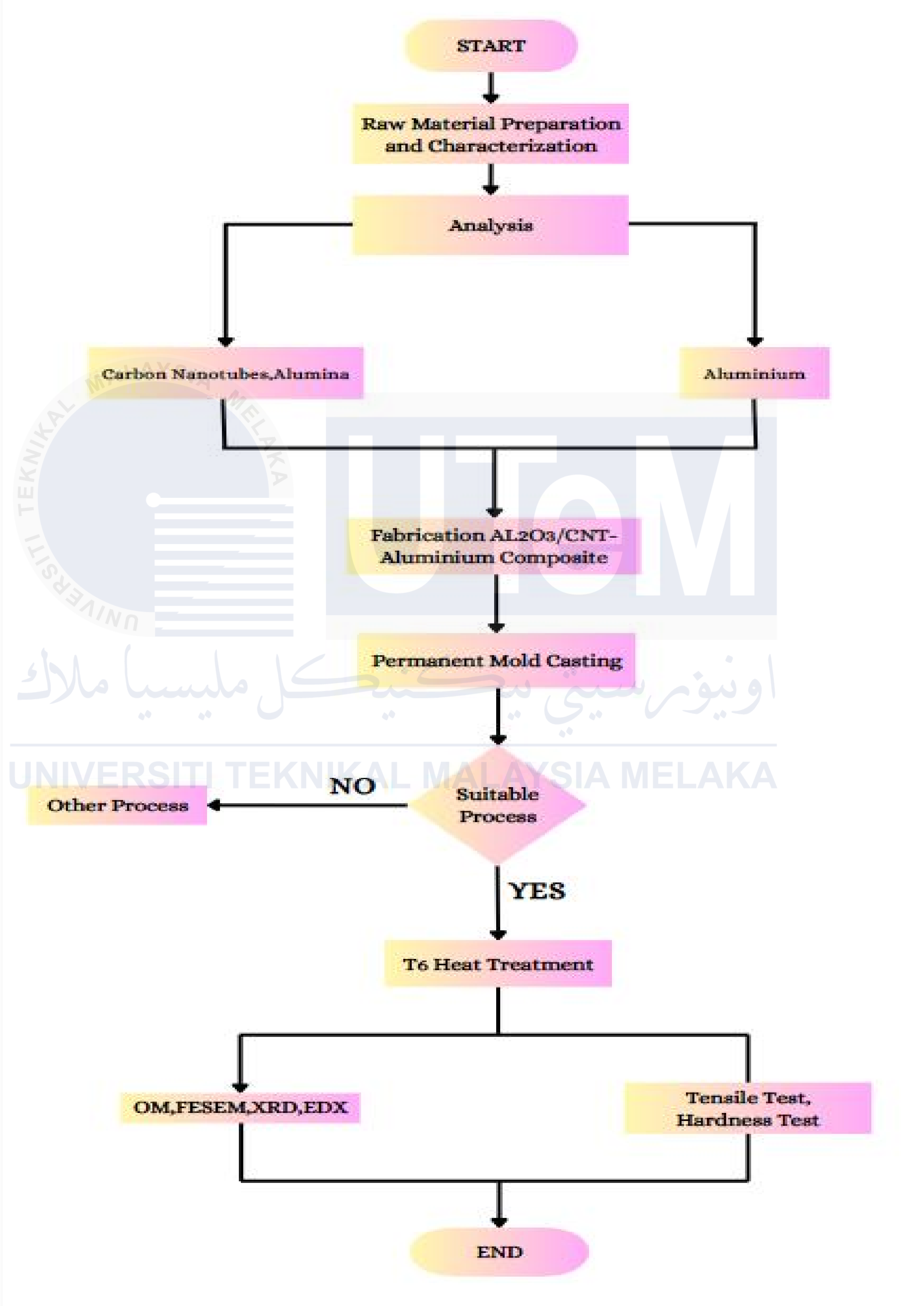


Figure 3.3.1: Flowchart Overall Research

3.4 Raw Materials

The raw material will be A356 aluminium alloy, which has several chemical compositions standard as shown in the Table 1. This project was made using a permanent mould casting process at the Faculty of Industrial and Manufacturing Technology and Engineering Laboratory of Universiti Teknikal Malaysia Melaka. The reinforcements also were provided by the same faculty involved at Universiti Teknikal Malaysia Melaka. The reinforcements, multi-walled carbon nanotubes (MWCNTs) and alumina received in powder.

Table 3.4 : Chemical compositions of A356

Element	Al	Si	Cu	Mg	Mn	Fe	Zn	Ni	Ti
Wt (%)	Balance	7.2	0.02	0.29	0.01	0.18	0.01	0.02	0.11

3.5 Design of Experiment (DoE)

The strategy of any assignment that aims to illustrate and elucidate the variety of data under circumstances that are assumed to mirror the variety is known as the Design of Experiment (DoE). Mostly related to tests when the plan gives conditions that directly affect the variety, the phrase can also refer to the plan of semi-analyses, where common situations that affect the variety are selected for perception. In its simplest form, an exam aims to predict the outcome by showcasing a variation in the prerequisites, which is mentioned by a minimum of one independent factor also referred to as "input factors" or "indicator factors."

3.5.1 Taguchi Method

DoE comes in a variety of forms, including the Taguchi Method, Respond Surface Method, and Full Factorial. The Taguchi approach is widely regarded as one of the most effective experimental processes for identifying the minimum number of experiments that must be carried out while remaining within the parameters and levels that are permissible. Since there are two variables in this project,the amount of CNTs and the percentage of alumina weight (wt.%),the Taguchi method was used. Each of these two parameters has three distinct values, giving each variable three levels.Table 2 below shows the Taguchi table information that involved in this project.

Table 3.5.1: Taguchi table that involves amount of CNTs and percentage of alumina weight(wt%) as the parameters.

Run	Aluminium Alloy(gram)	AL2O3(%wt)	Al2O3 (gram)	CNT(%wt)	CNT (gram)	Stirring Duration (minutes)
1	400	0.25	1	0.075	0.3	5
2	400	0.25	1	0.075	0.3	5
3	400	0.375	1.5	0.125	0.5	5
4	400	0.375	1.5	0.125	0.5	5
5	400	0.5	2	0.2	0.8	5
6	400	0.5	2	0.2	0.8	5

1 run=produce 2 samples

3.6 Experimental Procedures

3.6.1 Permanent Mold Casting of CNT/Al alloy composite

In order to create feed stock for heat treatment, the A356 aluminium particulate reinforced with MWCNT composite was fabricated using the permanent mould casting method. This phase involves the melting process and creating an A356 particle reinforced with MWCNT, which is subsequently cast into an ingot to create a cylindrical billet. The flow chart for the permanent mould casting process was shown in Figure 3.6.1.1.

In addition, the mould must be robust enough to withstand the high temperatures that come with molten aluminium.As the casting is being done, make sure there is adequate ventilation to allow gases to escape. Gravity assists in the mould filling. Surface finishing or machining may be required to meet the final component specifications.

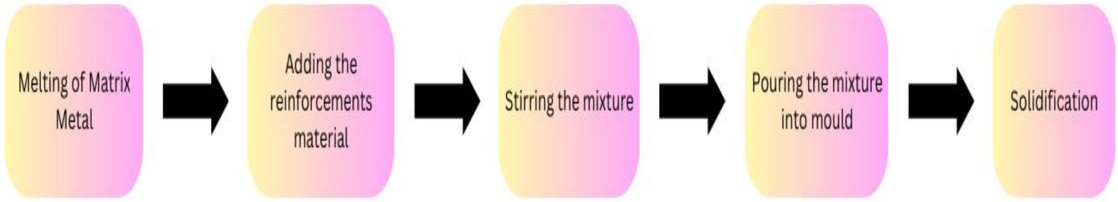


Figure 3.6.1.1: Permanent mould casting process flow

3.6.2 T6 Heat Treatment

In addition to increasing the strength of aluminium alloys, thermal treatment with the T6 method also increases the metals' hardness. The precipitation-hardening process begins with the solution treatment, also known as solutionizing. In this stage, the alloy was heated to its maximum temperature of 530 °C for eight hours.The majority of the intermetallic compounds and alloying components dissolve at this temperature, forming a homogenous solid solution in the aluminium matrix.

After being heat-treated, the casting products are quenched in water at room temperature (27°C) and allowed to undergo the ageing stage for three hours at 155°C.That ageing was the third stage of the process,involves heating the supersaturated to a temperature below the maximum temperature that may be reached in order to produce a finely dispersed precipitate.

3.7 Microstructure Characterisation of Carbon Nanotube-Aluminium alloy

After the T6 heat treatment procedure was finished, the microstructure of an A356 aluminium matrix composite reinforced with CNT particles will be examined to obtain the desired results. Because a material's microstructure can affect its physical properties, such as its hardness, strength, toughness, ductility, and corrosion resistance, microstructure analysis is crucial. The four microstructural examination methodologies that have already been applied during this project's duration were listed below.

3.7.1 Optical Microscope (OM)

Several microstructural elements, including phases, defects, and grain boundaries can be seen and recorded using this optical microscope, which helps with the investigation of structure-property relationships.It also exposed grain expansion and phase transitions through the examination of microstructural changes over time or in different environments.This technique was helpful for assessing the purity of a material, examining its microstructure and spotting deterioration indicators.

The process of analysing a material under an optical microscope entails a number of steps to get it ready for observation and then utilize the microscope to reveal hidden details. Prior to being used, the samples were prepared by grinding, polishing by using DIAMAT Polycrystalline Diamond, ultrasonic bath (about 2 minutes), drying, and etching with Keller reagent (in 10-12 seconds) to draw attention to particular features.

After being prepared, the sample was put on a stage and examined under a microscope. The next step is to set up the microscope, which involves adjusting the light source and selected the right objective lens to achieve the required magnification. The condenser lens, focusing light onto the sample, was also optimized. With the sample secured on the stage, the coarse and fine focus knobs were used meticulously to achieve a clear and sharp image. At last, the analytical stage starts. For a closer look, watched the sample, note their observations, and sometimes modify lighting or magnification.

3.7.2 X-Ray Diffraction (XRD)

A non-destructive analytical method called X-ray Diffraction (XRD) literally shines a light on a material's crystalline structure. XRD offers a lot of information about a sample, including its atomic arrangement, the presence of crystal phases, and even flaws in the crystal lattice. This was accomplished by analysing how X-rays interacted with the sample. X-rays, a kind of electromagnetic radiation with a wavelength similar to the distance between atoms in crystals, were used in X-ray reflectometry (XRD). This X-ray beam interacted with the atoms in a crystalline material when it struck it. The X-rays were directed in particular directions by the way these atoms behaved like a diffraction grating. The material's crystallite size and each phase's relative abundance were disclosed by the peak intensity.

The samples were ground into a fine sample to ensure X-rays interacted with numerous crystals and produced a representative diffraction pattern.Subsequently, the sample was positioned on an internal holder within the apparatus. The detector was placed at a particular angle and the X-ray source was turned on.The sample was bombarded by the X-ray beam, , and the diffracted X-rays were captured by the detector. Over a predetermined period of time, the detector constantly scanned across several angles (2θ) to measure the intensity of the diffracted beam at each angle.The collected data was transformed into a diffractogram, a graph depicting the intensity of the diffracted X-rays versus the angle (2θ). Figure 3.7.2.1 shows the Rigaku XRD machine.

Figure 3.7.2.1: Rigaku XRD machine

3.7.3 Field Emission Scanning Electron Microscopy (FESEM)

Field Emission Scanning Electron Microscopy (FESEM) was a powerful imaging technique that allows scientists to peer into the microscopic world at incredibly high magnifications. Unlike traditional Scanning Electron Microscope (SEM), FESEM utilizes a special electron source to achieve superior resolution, enabling the visualization of features as small as a few nanometers.

The sample must be prepared carefully, which includes grinding, polishing, ultrasonic bath, etching and drying processes. Artefacts that could lower the image quality must be avoided.The FESEM chamber was filled with the prepared sample. An electron beam that is concentrated was produced when the field emission gun (FEG) was turned on. Detectors were positioned to capture the emitted signals.

The electron beam meticulously scanned across the sample's surface in a raster pattern. The informations about the surface topography and elemental composition of the sample was revealed as the beam interacts with it.The selected signal determines the kind of image that was created; backscattered electrons show the distribution of elements, while secondary electrons offer high-resolution surface details. Figure 3.7.3.1 below describe the flow of sample preparation that already apply for this project before did the FESEM technique and Figure 3.7.3.2 shows the FESEM machine.

Figure 3.7.3.1: Flow of Sample Preparation

Figure 3.7.3.2: Model Evo,Hitachi FESEM machine

3.7.4 Energy Dispersive X-Ray (EDX)

EDX, or Energy-Dispersive X-ray Spectroscopy, works hand-in-hand with FESEM (Field Emission Scanning Electron Microscopy) to provide a comprehensive analysis of a sample.The sample preparation of the material was comparable to that needed for FESEM imaging. The sample was positioned beneath the concentrated electron beam inside the FESEM chamber.The X-rays are detected by an EDX detector within the FESEM chamber. Each X-ray's energy was analysed by the detector, which produces a spectrum. By examining the X-ray spectrum, the EDX programme determines which elements are in the sample by analyzed the distinct energy signatures of individual X-rays. Additionally, each element's relative abundance within the examined area can be measured by the software.

3.8 Tensile Testing

The tensile specimens were prepared according to the American Society for Testing of Materials (ASTM E8M-04) deliberating concept. Next, with using a 100 kN of capacity for the controlled universal testing equipment or machine , tensile tests were carried out in accordance with the design matrix (Ranjan & Bajpai,2021). The samples already shaped or prepared following the standard ASTM E8M-04 dogbone measurement shape and the dimensions needed. The machine is going to be attached to a metal matrix composite, and it is going to draw breaks at a speed of 5 millimetres per minute. The ultimate tensile strength, yield strength and elongation values are the characteristics that will be identified.Figure 3.8.1 shows the ASTM E8M-04 standard and the dimensions apply for conducting this project and Figure 3.8.2 depicts the machine that was used to perform the tensile test.

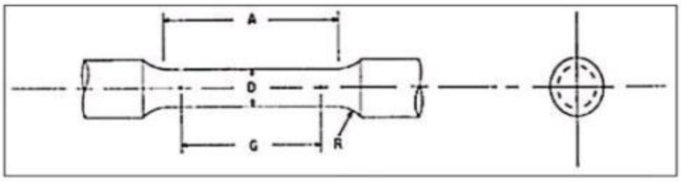


Figure 3.11 (ASTM E8M-04)

Table 3.4 Small-Size Specimen Proportional to Standard

ASTM E8M	09	06	04	25
G - Gage length	45.0 ± 0.1	30.0 ± 0.1	20.0 ± 0.1	12.5 ±0.1
D - Diameter (Note 1)	9.0 ± 0.1	6.0 ± 0.1	4.0 ± 0.1	2.5 ±0.1
R – Radius Fillet, min	8	6	4	2
A – Length of reduced section, min (Note 2)	54	36	24	20

Figure 3.8.1: ASTM E8M-04 Standard and dimensions apply for dogbone shape

Figure 3.8.2: Tensile Test machine

3.9 Hardness Test

One of the most sophisticated ways to assess a material's hardness was the Vickers hardness test. Vickers hardness testers will be utilised for the hardness testing, and HV was used to express the test findings. The composite sample's microhardness was assessed using Vickers' hardness testing apparatus in order to determine its total hardness.

Make sure the samples surface were dry, clean, and free of impurities before performing the hardness test.To get a smooth and even finish, the sample's surface was polished. This was essential for precise measurements of the indentation.Next, select the suitable test load according to the material and the required indentation size. Vickers tests typically handle loads ranging from 10 grammes to 100 kilogrammes.If using a microscope, adjust its focus to clearly view the sample surface and indenter tip.If using a light source, position it to illuminate the indentation area for better visibility.Using the controls on the machine, carefully lower the indenter tip towards the sample surface.Once the tip touches the surface, apply the chosen test load for a predetermined dwell time (typically 10 to 15 seconds). This dwell time allows the material to fully deform under the load. After the dwell time, the load was automatically released.

CHAPTER 4
RESULT AND DISCUSSION

4.1 INTRODUCTION

This chapter's main goal is to present and examine the data that was obtained from the completion of the hardness and tensile tests as well as the microstructure and fracture investigations that followed. This section presents the analysis and findings derived from the experiment that was conducted. In order to accomplish the study objectives, a rigorous research methodology was employed. This section provides a comprehensive explanations of the result obtained in order for more understanding.

4.2 INVESTIGATE THE PARAMETER

4.2.1 Processing Parameters

Table 4.2.1: Parameters Setting

Run	sample	Aluminium Alloy(gram)	AL2O3(%wt)	Al2O3 (gram)	CNT(%wt)	CNT (gram)	Stirring Duration (minutes)
1	S1	400	0.25	1	0.075	0.3	5
1	S2	400	0.25	1	0.075	0.3	5
2	S3	400	0.375	1.5	0.125	0.5	5
2	S4	400	0.375	1.5	0.125	0.5	5
3	S5	400	0.5	2	0.2	0.8	5
3	S6	400	0.5	2	0.2	0.8	5

The Taguchi technique created six samples with different CNT contents and percentage of alumina weight parameters.These two factorial levels has been divided into 3 different groups which is AL2O3 0.25% CNT 0.075% , AL2O3 0.375% CNT 0.125% and AL2O3 0.5% CNT 0.2%. This technique involved 1 run produced two samples that used for division before T6 heat treatment and after T6 heat treatment.Through the use of this approach, comparisons between the mechanical characteristics and microstructure analysis before and after the T6 heat treatment were achieved. For this project, the aluminium alloy weight (in gram) and stirring time (in minutes) serve as constants or fixed values.

Samples 1,3 and 5 undergo the T6 heat treatment which make them heated to maximum temperature of 530 °C for eight hours at the first stage of solution treatment.After that,the casting products were quenched in water at room temperature(27°C) and allowed to undergo the third stage of heat treatment process called ageing at 155°C for 3 hours.The T6 heat treatment process was not applied to the remaining three samples.The microstructure of aluminium alloy A356 may be significantly enhanced by the combination of T6 heat treatment and multi walled carbon nanotube (MWCNT) reinforcement. By meticulously controlling the duration of stirring and the method of casting, the MWCNT were uniformly distributed throughout the aluminium matrix, enhancing their performance.

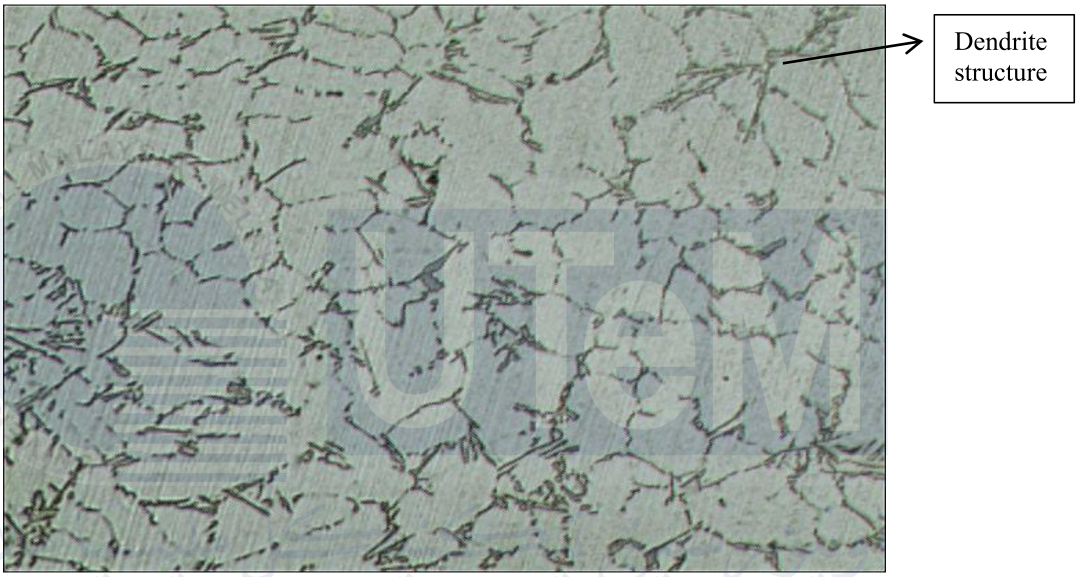
The surface morphology and element results of all 6 samples were obtained by FESEM and EDX analysis.Furthermore, tensile and hardness tests were performed on all six samples to ascertain their mechanical characteristics, including their yield strength, ultimate tensile strength, and percentage of elongation values.

4.3 MICROSTRUCTURE ANALYSIS

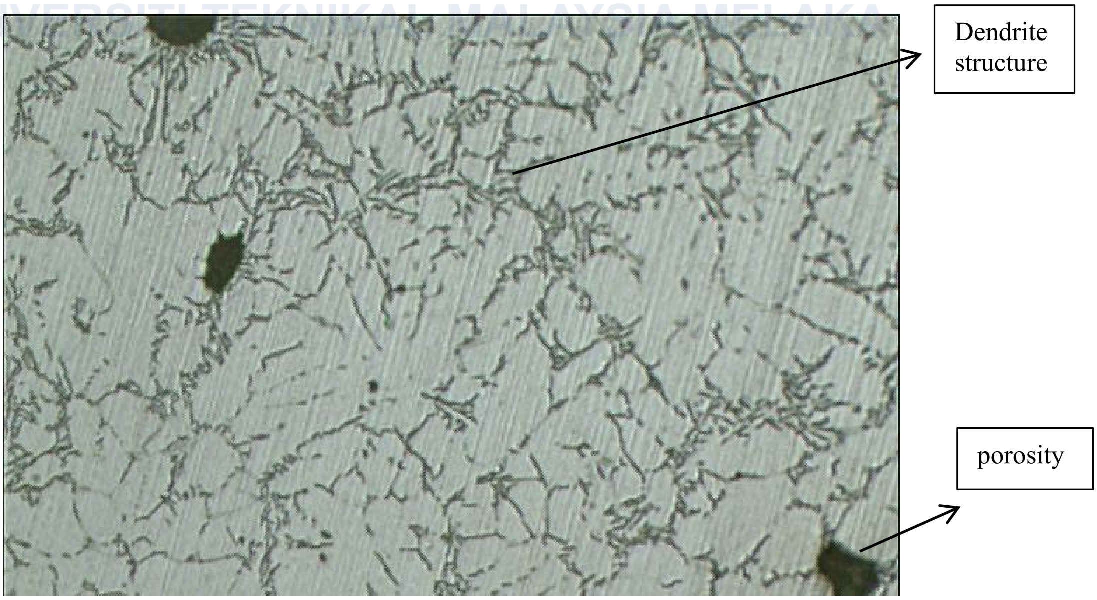
Microstructure analysis is the study of a material's microscopic structure. It provides an explanation of material behaviour. OM, XRD, FESEM, and EDX were employed in this project. Grain size, boundaries, phases, crystal structure, chemical composition, and surface topography were all disclosed by these techniques. Microstructure analysis helps identify the flaws, contaminants, and structural irregularities that could affect the performance of a material. The primary analysis technique apply was FESEM. High-resolution imaging, surface topography analysis, and composition analysis are made possible by FESEM.

4.3.1 Optical Microscope-before T6 heat treatment

The samples exhibits large and irregular grain size result.This could be as a result of the casting process' quick solidification, which limits grain growth.The current configuration of the parts results in non-uniform mechanical characteristics, a drop in strength, a reduction in ductility, and an increase in failure susceptibility.



i. AL2O3 1 gram,CNT 0.3 gram



ii. AL2O3 2 gram, CNT 0.8 gram

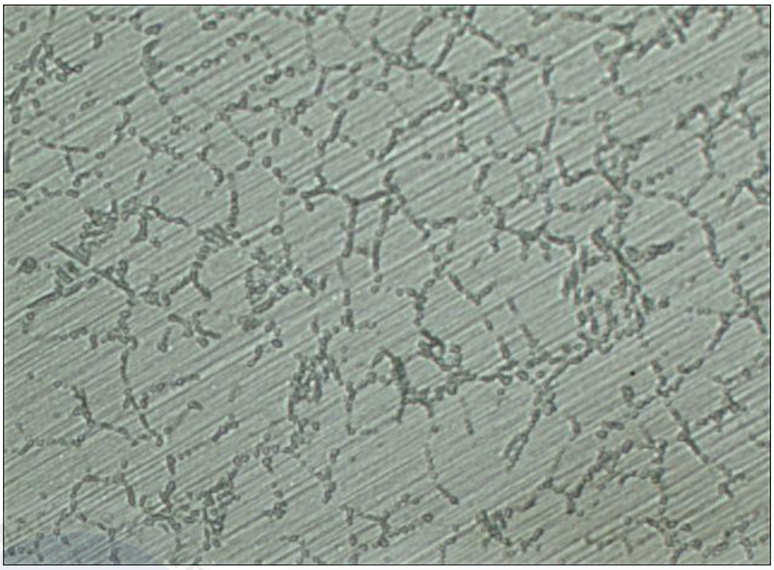
Figure 4.3.1.1: OM images were obtained for samples with varying CNT amounts and percentage of alumina weight but the same does not undergo the T6 heat treatment process

These microstructure images reveal the presence of several fragmentation of the dendritic structure.During solidification (pouring too quickly), turbulence or shear forces in the molten metal can cause dendritic arms to break off and become shards scattered throughout the casting.Because of retained liquid between fragments, excessive fragmentation can cause weak regions in the casting and porosity (small holes).The term "porosity" in castings describes the undesired cavities, air pockets, or holes in the hardened metal. It's a big deal because it can have a big impact on the end product's performance and quality. Like microscopic cracks, pores degrade the casting's overall structure and increase its vulnerability to stress-induced fracture.

4.3.2 Optical Microscope - after T6 heat treatment

There are significant shifts in the material's atomic structure. The procedure promotes the growth of reinforcing layers in the material, which results in a more even and refined grains structure result.The material's structure and grain may become more distinct with increased strength and hardness. The T6 thermal treatment improves the material in several ways. These modifications enhance the microstructure and performance of the material.This improved interfacial bonding between the reinforcements and the matrix can lead to enhanced mechanical properties.

i. AL2O3 1 gram, CNT 0.3 gram



ii. AL2O3 2 gram, CNT 0.8 gram

Figure 4.3.2.1: OM images were obtained for samples with varying CNT amounts and percentage of alumina weight but the same which undergo the T6 heat treatment process

An uniformly microstructure sized with equiaxed (spherical) shape was produced by the heat treatment process.The metal was heated throughout the heat treatment procedure to a certain temperature range, usually slightly below its melting point.The current elongated dendritic grains break apart and become unstable at this temperature.As new, equiaxed grains proliferate, the dendritic structure was replaced. The final microstructure consists of uniformly sized, spherical grains. Equiaxed grains generally lead to better strength, ductility, and toughness compared to a dendritic structure.This heat treatment refines the grain structure, leading to improved mechanical properties.Besides, there was an uniform distribution occur.An uniform distribution of microstructure in a casting product refers to having grains of similar size spread evenly throughout the material. This was desirable because it leads to consistent properties across the entire casting and lead to minimize the defects.

4.3.3 XRD Analysis-comparison before and after undergo T6 heat treatment

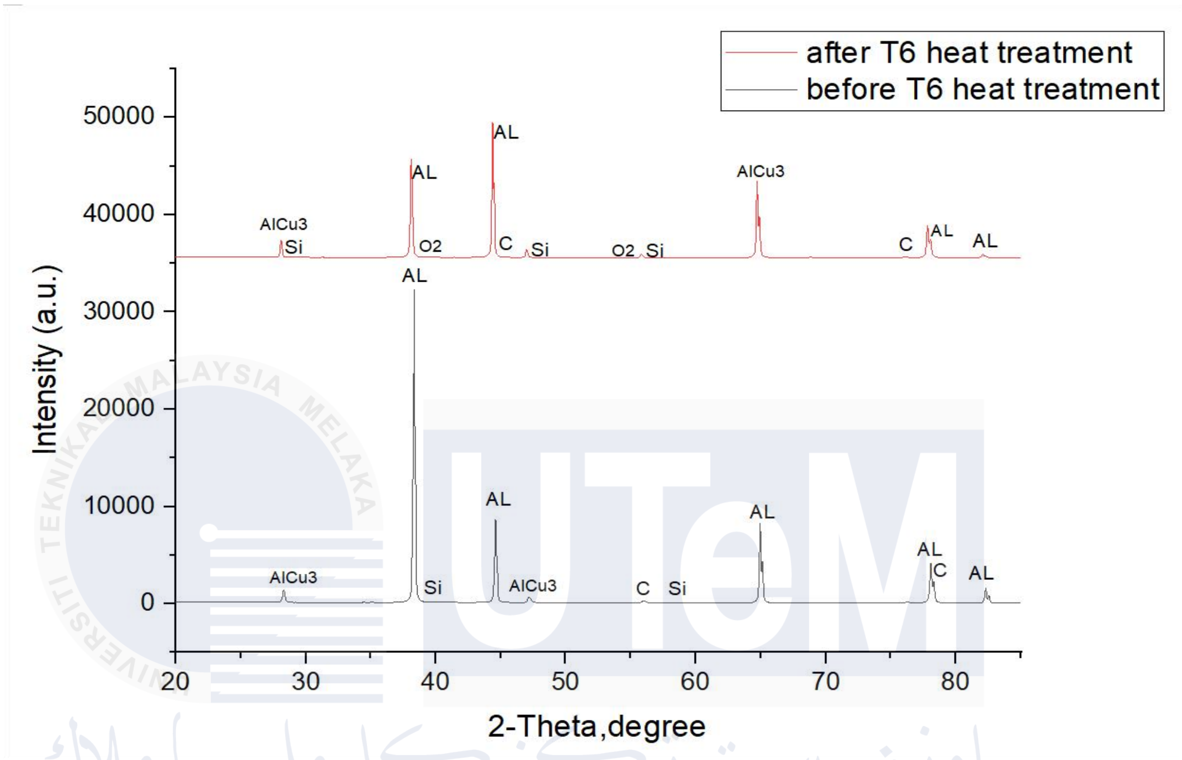
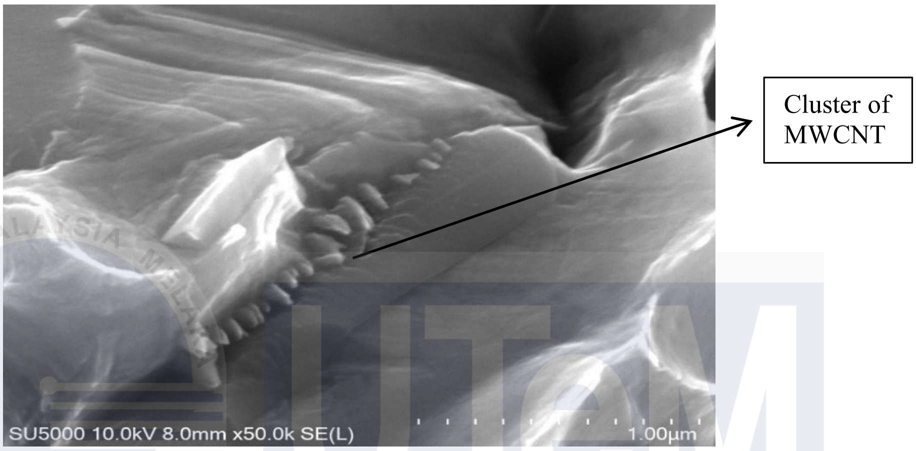


Figure 4.3.3.1 : XRD result analysis

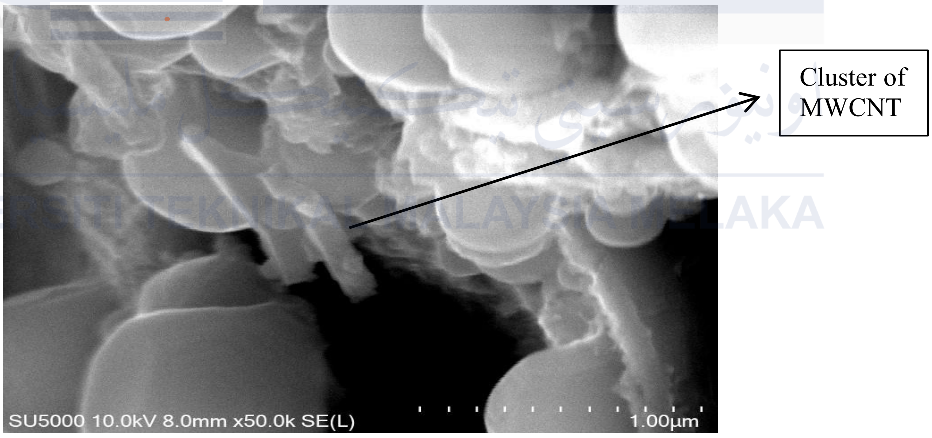
The XRD peaks represented aluminum exclusively because the added constituent (the CNTs) was quite low in concentration . Based on before T6 heat treatment result,it reveals two small peaks of AlCu3 intermetallic phases and there are C peak (at 77- 2θ degree) with another one little peak of C. This observation demonstrates that CNTs have been incorporated into the aluminium alloy. Following the T6 heat treatment, the AlCu3 intermetallic phase showed a high peak (65 -2θ degree) and the C peak was minimal. This indicating that the CNTs were partially decomposed and phase change was happen.

Prior to T6 heat treatment, aluminium has its highest peak position, which was followed by the next two higher peaks of aluminium (at 44 and 65 -2θ degrees). However, after undergo the T6 heat treatment,aluminium was not at the peak position for the first two highest peak states, but was close to both peaks.This indicates a shift in orientation.Then, there was an oxygen element for after undergo T6 heat treatment result. Oxygen can react with metal atoms to form oxides. These oxides may appear as separate phases in the XRD pattern, depending on their crystal structure and concentration.

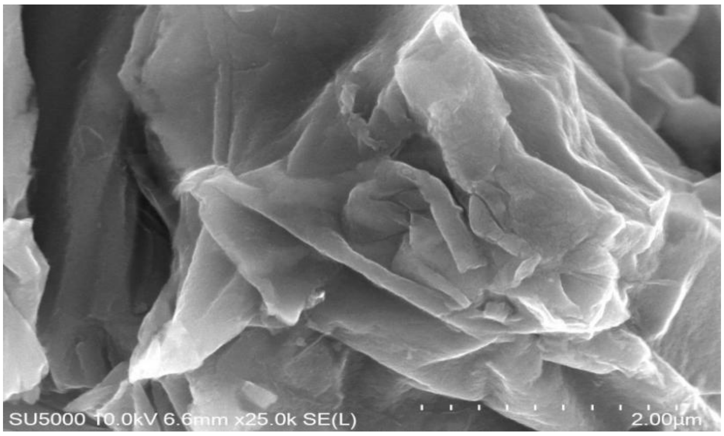
4.3.4 Field Emission Scanning Electron Microscopy-before T6 heat treatment



i. AL2O3 1gram,CNT 0.3 gram



ii. AL2O3 1.5 gram,CNT 0.5 gram



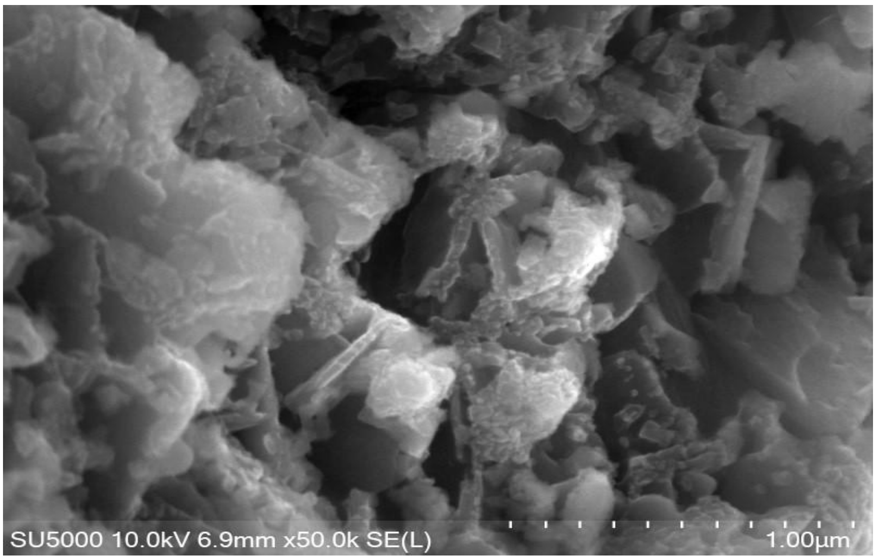
iii. AL2O3 2 gram,CNT 0.8 gram

Figure 4.3.4.1: FESEM images result for samples with varying MWCNT and alumina contents before undergo T6 heat treatment

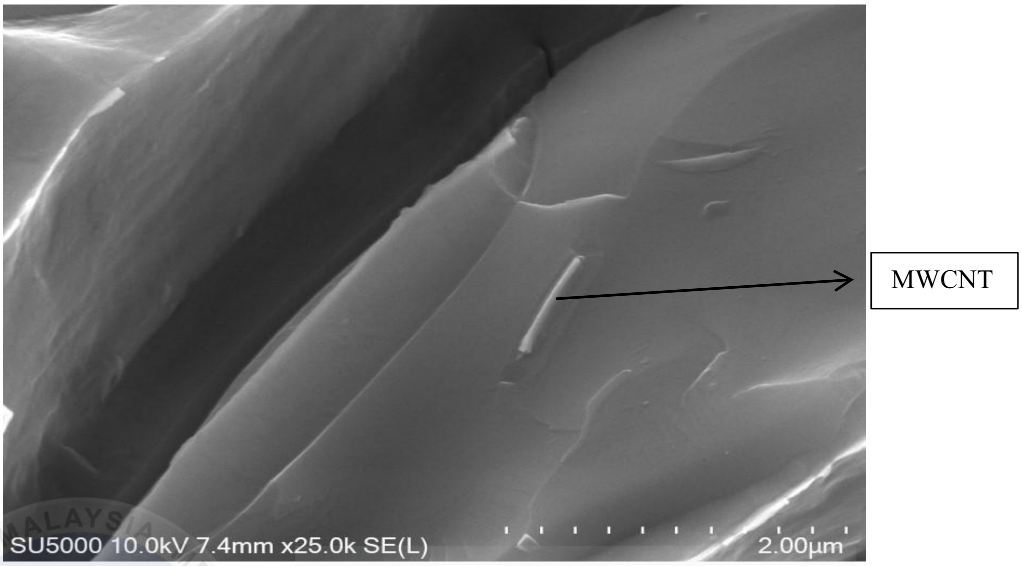
Based on these results,it reveals clustering of multiwalled carbon nanotubes (MWCNT) reinforcements, indicating uneven distribution from the casting process.These clustering of MWCNT effect can occur due to the weak attractive forces exist between all atoms and molecules. Due to the large surface area and high aspect ratio of MWCNTs, these forces become significant, causing nanotubes to stick to each other.Furthermore,it illustrates that the reinforcement materials was not fully merge together within the composite.

MWCNTs should ideally be evenly distributed throughout the material that they are strengthening. The ability of individual nanotubes to transfer stress inside a composite is limited by clusters, which function as big particles. Areas of the composite with high and low concentrations of MWCNTs can result from clustering. The mechanical and electrical properties of the material become low and inconsistent as a result.

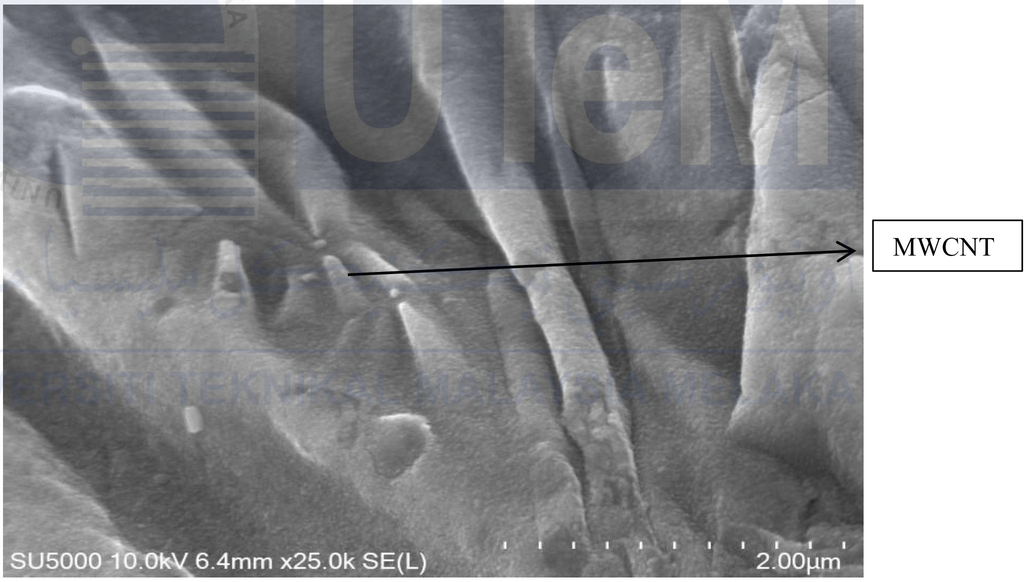
4.3.5 Field Emission Scanning Electron Microscopy-after T6 heat treatment



i . AL2O3 1 gram,CNT 0.3 gram



ii .AL2O3 1.5 gram,CNT 0.5 gram



iii. AL2O3 2 gram, CNT 0.8 gram

Figure 4.3.5.1: FESEM images result for samples with varying MWCNT and alumina contents after undergo T6 heat treatment

Images result show a finer and more refined grains structure due to heat treatment process. Additionally, better dispersion of Al2O3 and CNTs was observed throughout the microstructure, frequently along the grain boundaries of the refined Aluminium grains, indicating improved interfacial bonding between the reinforcements and the matrix. A more uniform microstructure was achieved by redistributing some of the segregated elements through the solution treatment step.

T6 heat treatment doesn't directly eliminate porosity, but the presence of precipitates can sometimes act to hinder crack propagation around existing pores, potentially improving toughness.Finer grain size and reduced segregation after T6 heat treatment can improve the ductility of the casting. The term ductility describes a material's capacity for plastic deformation prior to fracture.

However,the high temperature of heat treatment process might cause some CNT agglomeration, reducing their effectiveness as reinforcement. Besides,the particles (alumina and MWCNT) may shift slightly as a result of heat treatment, improving dispersion along the refined structure's grain boundaries. As a result, the aluminium alloy's mechanical qualities were improved.

Overall, heat treatment refines the grain structure and improves the distribution of Al2O3 and CNT reinforcements in AL2O3/CNT aluminum alloy composites. These microstructural changes contribute to significant improvements in strength, hardness, and other mechanical properties of the material.

4.3.6 Energy Dispersive X-Ray- comparison before and after T6 heat treatment

i .Sample AL2O3 1 gram,CNT 0.3 gram; before undergo T6 heat treatment

EDAX APEX

test 1

Author: User Apex

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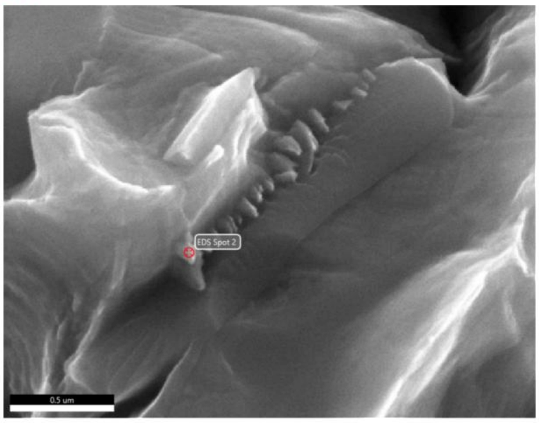
Sample Name: DCNT

TS4



eZAF Quant Result - Analysis Uncertainty: 8.76 %

Element	Weight %	Atomic %
C	20.5	36.0
O	4.5	5.9
A l	51.3	40.2
S i	23.8	17.9

ii .Sample AL2O3 1 gram,CNT 0.3 gram; after undergo T6 heat treatment

EDAX APEX

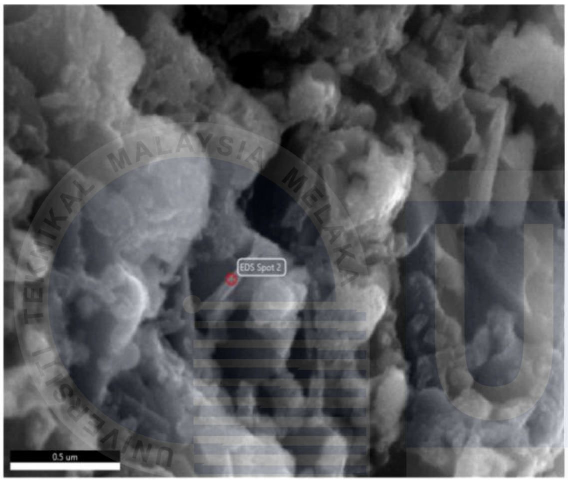
test 1

Author: User Apex

Creation: 6/11/2024 12:56:36 PM

Sample Name: DCNT

TS6



eZAF Quant Result - Analysis Uncertainty: 8.07 %

Element	Weight %	Atomic %
C	14.5	27.2
O	3.1	4.4
Al	76.6	63.8
Si	5.7	4.6

Figure 4.3.6.1: EDX results obtained for sample with CNT 0.3 gram

In addition to FESEM, energy-dispersive X-ray spectroscopy (EDX) proved a useful method for analysing AL2O3-CNT composites. The anticipated elements, such as carbon (C) from the CNTs and aluminium (Al) from alumina (AL2O3), were confirmed to be present by EDX. It can determine the elemental distribution by running EDX spot analyses on various sample locations. This may highlight regions with higher concentrations of CNTs or those rich in alumina.

Based on the sample result obtained, percentage of carbon weight more higher before undergo the heat treatment process with 20.5% value compared to 14.5% after undergo the T6 heat treatment process based on the different area that was investigated. Next, both of the results show that aluminium element contribute to the highest percentage of weight compared to others element that involves.The percentage of weight for Si element before undergo the T6 heat treatment was 23.8% and decrease to 5.7% after apply the T6 heat treatment process at different regions of the sample.This show that the percentage of weight for Si element more higher than

C element for before undergo the T6 heat treatment result. Last but not least, both result show that oxygen (O) element that has the lowest value of weight percentage which is 4.5% and 3.1%.

iii .Sample AL2O3 2 gram,CNT 0.8 gram; before undergo T6 heat treatment

EDAX APEX

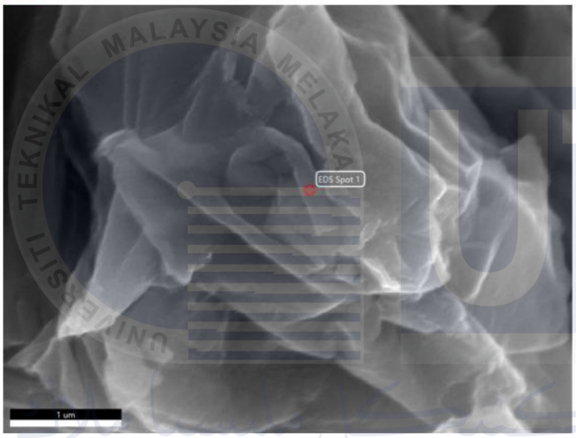
test 1

Author: User Apex

Creation: 6/11/2024 12:43:26 PM

Sample Name: DCNT

TS2



eZAF Quant Result - Analysis Uncertainty: 16.28 %

Element	Weight %	Atomic %
C	22.7	36.4
O	18.0	21.6
A l	46.4	33.1
S i	13.0	8.9

iv. Sample AL2O3 2 gram,CNT 0.8 gram; after undergo T6 heat treatment

EDAX APEX

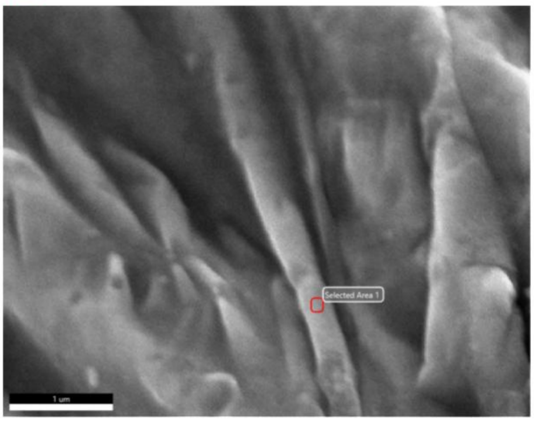
test 1

Author: User Apex

Creation: 6/11/2024 12:19:28 PM

Sample Name: DCNT

TS1



eZAF Quant Result - Analysis Uncertainty: 99.00 %

Element	Weight %	Atomic %
C	27.3	43.0
O	12.8	15.1
A l	58.7	41.1
S i	1.2	0.8

Figure 4.3.6.2: EDX results obtained for sample with CNT 0.8 gram

According to the EDX study of this sample, the percentage of carbon weight increased with the T6 heat treatment process, coming in at 27.3% thereafter, compared to 22.7% prior to the process based on the various areas that were examined. Next, both of the results show that aluminium element contribute to the highest percentage of weight compared to others element that involves.Prior to undergoing the T6 heat treatment, the Si element's weight percentage was 13.0%, and after the technique was applied to various sample locations, it was 1.2%. Besides, the two results demonstrate that, when compared to other elements involved, the Si element's weight percentage contributes to the lowest value, which is 13% and 1.2%. Last but not least, for the oxygen (O) element, contribute to 18% weight percentage value before undergo the T6 heat treatment process and decrease to 12.8% weight percentage value after undergo the T6 heat treatment process.

4.4 Fractography Analysis using FESEM

SEM fractography is a technique that involves the analysis and examination of fractured materials' surfaces using scanning electron microscopy. This site provides thorough insights into failure causes, fracture morphology, and crack patterns. This study improves the performance of materials and makes it easier to identify the underlying causes of failure.

4.4.1 Dimple Fracture

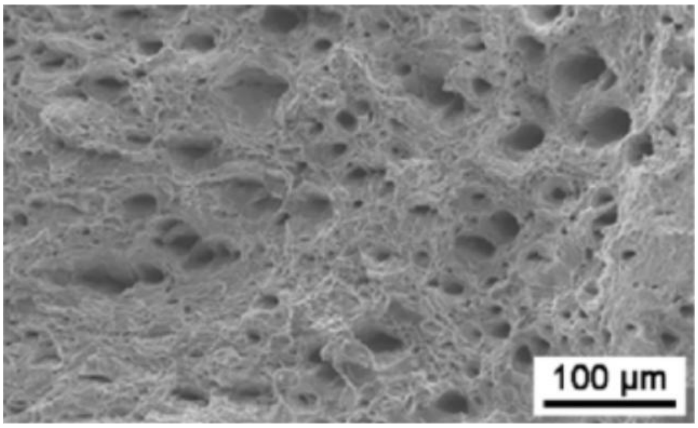


Figure 4.4.1.1: Dimple fracture obtained from the sample

Dimple fracture is a type of ductile fracture characterized by the presence of microscopic depressions or 'dimples' on the fracture surface. The microvoid coalescence mechanism during plastic deformation and subsequent fracture was responsible for the creation of these dimples.Dimpled fracture surfaces have a rough, fibrous appearance and show as many tiny depressions or craters under a FESEM. Though they can vary in size and shape, the dimples are often elliptical or circular.Examining dimple fractures in materials reinforced with MWCNTs was a useful technique for determining the effectiveness of the reinforcing and for understanding the underlying mechanisms that lead to enhanced ductility and fracture toughness. The presence of dimple fractures can be an indication that the metal has been overloaded and is at risk of failure.

4.4.2 Cluster of MWCNTs

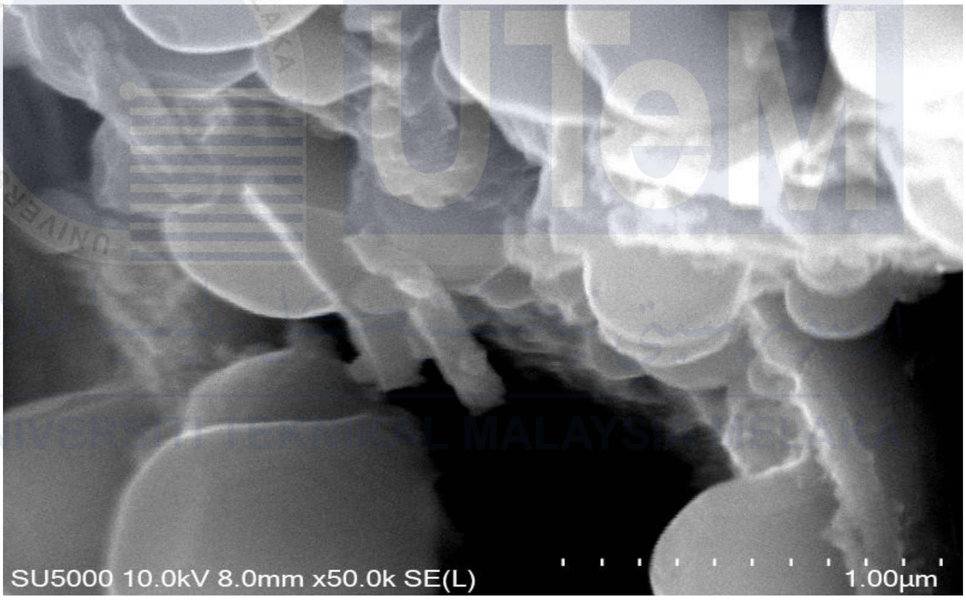


Figure 4.4.2.1: Cluster result of MWCNT

MWCNT clusters are collections of single nanotubes. These clusters may be produced via synthesis and handling, or by Van der Waals interactions. In nanocomposite materials, MWCNT clusters may change the dispersion and distribution of nanotubes. Improved mechanical and electrical properties were achieved by reduced clustering and enhanced matrix-MWCNT interfacial contact through a consistent MWCNT dispersion. Nanotubes are dispersed and prevented from clustering by sonication, functionalization, and surfactant treatment.

4.5 Mechanical Testing

4.5.1 Tensile Test

The highest stress that a material can withstand before breaking or cracking under a tensile load was known as its ultimate tensile strength (UTS). Since it represents the maximum of the stress-strain curve found during tensile testing, it is an essential metric for figuring out the strength of materials and building structures. Tensile testing results are displayed in Figure 4.5.1.

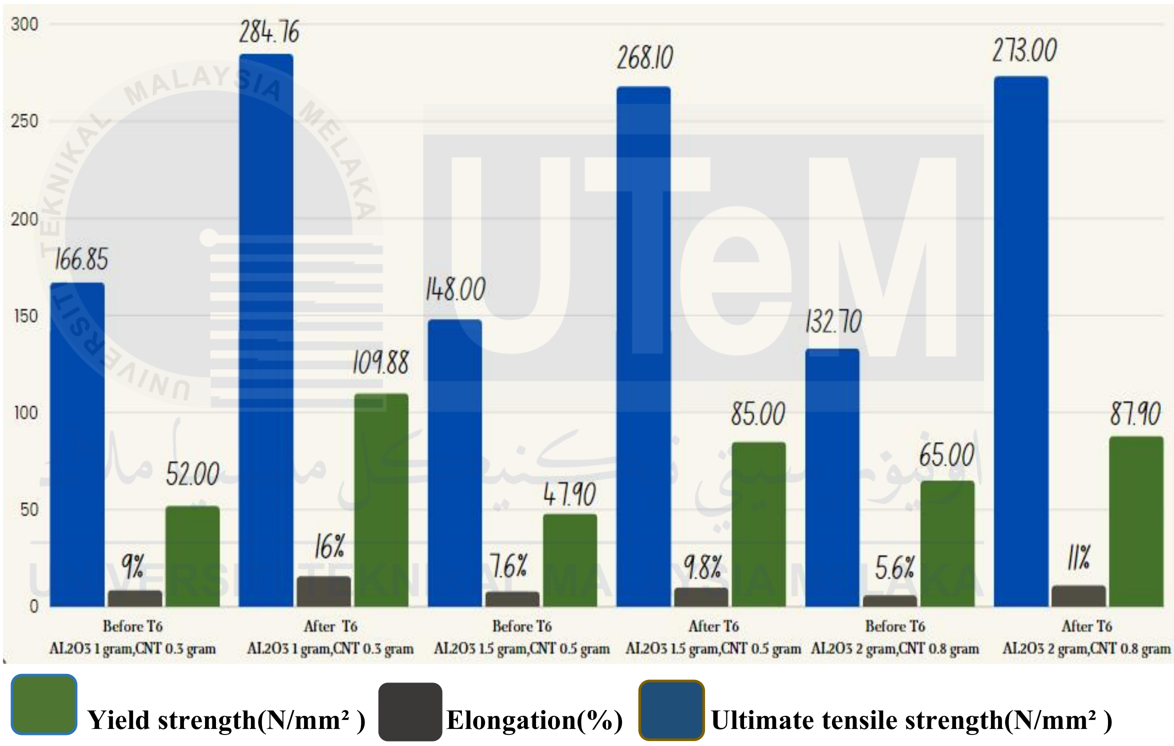


Figure 4.5.1.1: Tensile Test result

The ultimate tensile strength (UTS) bar graph provides important information about the mechanical characteristics that the examined specimens exhibit. In contrast to the other samples that were tested, Sample AL2O3 1 gram, CNT 0.3 gram (after T6) clearly shows the greatest value of Ultimate Tensile Strength (UTS), with a value of 284.76 N/mm². Then, followed by Sample AL2O3 2 gram,CNT 0.8 gram (after T6) and Sample AL2O3 1.5 gram,CNT 0.5 gram (after T6) with 268.10 N/mm² value for the next two samples with higher value of UTS. The UTS Sample AL2O3 2 gram,CNT 0.8 gram (before T6) indicates that the strength of the material falls below the expected threshold. The intentional addition of multi-wall carbon nanotubes (MWCNTs) to the mixture at a concentration of 0.2% demonstrates a deliberate attempt to enhance the mechanical properties of the materials. It is plausible, therefore, that the unequal dispersion of the constituent materials such as alumina and multiwalled carbon nanotubes within the composite may have jeopardised the integrity of the sample.

Furthermore, it is commonly accepted that a figure with the highest percentage of elongation was preferable to one with the lowest. A material's ductility, or its capacity to undergo plastic deformation (stretch) before breaking, was indicated by its elongation percentage.As demonstrated by the results, Sample AL2O3 1 gram, CNT 0.3 gram (after T6) also contribute to the highest elongation(%) value, whereas Sample AL2O3 2 gram, CNT 0.8 gram (before to T6) yield the lowest value, 5.6%. Brittle materials were usually those with low elongation percentages. They shatter with very little plastic deformation. In applications where an unexpected failure could have dire repercussions, this can be problematic.

As can be seen from the yield strength bar graph, samples that go through the T6 heat treatment process have the three highest values, which are 109.88 N/mm², 87.90 N/mm², and 85.00 N/mm².A high yield strength material can bear more pulling power before it starts to permanently distort. For applications where the material must retain its shape under strain, this is crucial.Thus, in general, the heat treatment procedure can improve the samples' mechanical properties.

4.5.2 Hardness Test

To measure a material's hardness, the Vickers hardness test was used. The measurements of a diamond indentation's dimensions on a material's surface were made. The Vickers hardness test works very well for determining how hard materials with thin coatings and finely grained structures. Six samples in all, split into two different groups, were evaluated in this investigation. The total of three samples were subjected to T6 Heat Treatment and the other three were not. Through the use of T6 Heat Treatment, the mechanical properties and ductility of a matrix composite reinforced with MWCNT and alumina particles were compared and assessed.The hardness Vickers test result was displayed in the figure below.

Table 4.5.2: Hardness Test result values

Sample	Undergo T6 heat treatment	Hardness (HV)
AL2O3 1 gram,CNT 0.3 gram	YES	93.2
AL2O3 1 gram,CNT 0.3 gram	NO	82.0
AL2O3 1.5 gram,CNT 0.5 gram	YES	88.5
AL2O3 1.5 gram,CNT 0.5 gram	NO	80.1
AL2O3 2 gram,CNT 0.8 gram	YES	92.0
AL2O3 2 gram,CNT 0.8 gram	NO	77.8

From Table 4,proved that sample AL2O3 1 gram, CNT 0.3 gram (after T6) contributes to enhance of highest hardness value (93.2 HV).This result was closely related and supports the results obtained from the tensile test.This indicate better dispersion of Al2O3 and CNTs was observed throughout the microstructure, frequently along the grain boundaries of the refined Aluminium grains. All samples that undergo T6 heat treatment process show increase in value and give greater values compared to the rest of the samples that not undergo T6 heat treatment process. Sample AL2O3 2 gram,CNT 0.8 gram (before T6) gives the lowest value of hardness (77.8 HV) among all the six samples.This effect can occur due to the weak attractive forces exist between all atoms and molecules.

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 INTRODUCTION

This chapter presents the study's outcomes and conclusions, which are derived from the objectives established.The results of the implementation phase are presented in this report along with suggestions for future improvements. This chapter serves as an invaluable conclusion to the research, providing a concise synopsis of the results and suggesting areas for further development. It appropriately draws attention to the achieved outcomes and points up prospective paths for further development.

5.2 CONCLUSION

5.2.1 Objective 1 Achievement

The goal of the study was to determine the optimum percentage of AL2O3/CNT in reinforcement of aluminium alloy. The hybrid material was treated during the investigation to increase its tensile strength, soften it, and produced more refined microstructure. The study found that, after undergoing the T6 heat treatment process, the optimum percentage of AL2O3/CNT in reinforcement was 0.25 % Al2O3 0.075% CNT. This was achieved by carefully managing the overall process variables, such as temperature and time. This study provides valuable insights into the appropriate handling of the total samples involved, which give impact for the final outcome.

5.2.2 Objective 2 Achievement

Objective 2 was to investigate the microstructural characterization of aluminiumm matrix composite. An inquiry into how to improve the microstructure of an aluminium matrix composite by reinforcing the MWCNT with casting and T6 heat treatment was conducted using a systematic approach. FESEM was used to analyse the surface morphology and produced clear images, while XRD was used to identify the crystallographic phases that are present in a material. This is crucial for understanding a material's properties and behaviour. Sample AL2O3 1 gram, CNT 0.3 gram (after T6) also which exhibit results with refined structure, enhanced bonding structure, and uniform distribution in comparison to other samples, according to the analysis.

5.2.3 Objective 3 Achievement

Objective 3 was to examine the ultimate tensile strength, yield strength and elongation to fracture of aluminum matrix composite.All the composite samples were put through a series of tests to determine their tensile strength and hardness.The results demonstrated that the highest values of ultimate tensile strength, yield strength, and hardness were found in the Sample AL2O3 1 gramme and CNT 0.3 gram (after T6), which again satisfied the mechanical properties.

5.3 RECOMMENDATIONS FOR FUTURE WORK

1. Consider of using further characterization methods in addition to hardness and tensile testing. Determine whether the composite is appropriate for a given application by looking at its fatigue behaviour, impact resistance, and thermal stability, for example. To learn more about the characteristics of the composite, do out in-depth material characterisation.

2. The mechanical and ductility characteristics of the aluminium matrix composite may be improved by examining and adjusting T6 heat treatment parameters such as temperature and duration. This will optimise the outcome, improving property value. Examine a greater variety of treatment scenarios methodically and how they affect the performance of the material.

5.4 Project Limitations

The following limitations were encountered during the study:

1. The limited number of available optical microscope for do the microstructure characterization of the samples involve can result in longer waiting periods and slower movement rates to complete this project if shared with other students.

2. Another limitation of this project was the unavailability of the ideal testing equipment, specifically the Vickers hardness testing machine in my faculty. As a solution, need to do the hardness test at an off campus technology faculty where need to prioritize students under their faculty first.This also slows down the progress of the project.

3. Another limitation was the limited range of reinforcements material used for this project. The investigation involved manipulating the reinforcements material across three variables. However, the chosen variables may not cover the entire range of possible combinations, potentially limiting the understanding of the optimal mechanical properties condition for the composite material. Apply a broader range of reinforcements material options could provide additional insights and further optimize the material's properties.

5.5 LIFELONG LEARNING

As a student conducting research on the mechanical properties and microstructure characterization via heat treatment of aluminium matrix composites, I have learned a great deal about the effects of T6 heat treatment processes on the properties of the material. This research made it easier to gain a deeper understanding of material science's basic ideas, experimental techniques, and potential improvements to composite materials' effectiveness.

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APPENDICES

Gantt Chart PSM 2

TASK	WEEK														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Discuss with supervisor about project															
Search for relevant references(journal,article)															
Raw Materials Preparation															
Weighing the reinforcements material															
Chapter 4&5 (result,discussion, conclusion) lecture															
Do casting process															
References and Formatting Lecture															
Sample Preparation															
Logbook Submission to Supervisor															
Do cutting and CNC machining															
Apply microstructure characterization techniques															
Tensile Test & Hardness Test															
Poster Presentation															
Technical Paper Lecture & Submission															
Improve Report															
Final Report Submission															