To study the Hardness and Mechanical Properties of Aluminium Composite Reinforced with Titanium Carbide & Graphite.

By

Ramaneish
Sivaraj 22710

MECHANICAL ENGINEERING
UNIVERSITI TEKNOLOGI PETRONAS
JAN 20

To study the Hardness and Mechanical Properties of Aluminium Composite Reinforced with Titanium Carbide & Graphite.

By

RAMANEISH SIVARAJ

22710

Dissertation submitted in partial fulfilment of the requirements for the

Bachelor of Engineering (Hons)

(Mechanical Engineering)

JAN 20

Universiti Teknologi PETRONAS,
32610, Bandar Seri Iskandar,
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

To study the Hardness and Mechanical Properties of Aluminium Composite Reinforced with Titanium Carbide & Graphite.

By

Ramaneish Sivaraj

22710

Project Dissertation submitted to the

Mechanical Engineering Programme

Universiti Teknologi PETRONAS

in partial fulfilment of the requirement for the

BACHELOR OF ENGINEERING (Hons)

(MECHANICAL ENGINEERING)

Approved by,

____

(Assoc Prof Ir Dr Hj Hamdan B Hj Ya)

UNIVERSITI TEKNOLOGI PETRONAS

BANDAR SERI ISKANDAR, PERAK

JAN 20

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

(RAMANEISH SIVARAJ)

Abstract

Metal matrix composites are widely used in components of various components of industrial equipment because of their superior material properties like high stiffness to weight ratio and high impact strength and fracture toughness while compared to the conventional material. Even if Al has good mechanical but reinforcement is needed in order to make the composite properties better. Aluminium is often used in the aerospace industry, which has increased concern for fatigue failure. A material can still fail, even though it experiences a force much less than its yield point. Aluminium has good mechanical properties but enhancing with filler metal will make the composite more harder and increase in strength. This research paper shows the mechanical properties of the aluminum composite after reinforced with various percentage of TiC and graphite through powder metallurgy method. The experiment was completed by reinforcing different percentage of Titanium Carbide into the aluminum and the changes in mechanical properties and hardness were observed. This experiment clearly proves that as the percentage of titanium carbide increases the microhardness of the composite increases. The hypothesis was clearly proved when it shows the higher the percentage of TiC contain in the pure aluminum the higher the microhardness of the specimen. The test results showed increasing hardness of composites when compared with pure aluminum because of the presence of the increased reinforced material (TiC).

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1
INTRODUCTION

1.1 Introduction

Powder metallurgy is one of the best ways in industrial application because of a lot of benefits. Powder metallurgy is a way of producing component that can be modified easily through powder metallurgy method rather we compare with other manufacturing process. Aluminum is widely used in cars, aircraft engines and wings because it has excellent wear resistance, high strength and low weight ratio compared to conventional materials [1]. Ceramic particles are most widely used materials to reinforce with aluminium such as AL-SiC, Silicon Carbide (SiC). Titanium Carbide (TiC) when reinforced with metals tends to have high corrosion resistance, high hardness and higher wear resistance [2,3]. TiC have high ratio in strength to weight ratio where this is very important in automobile, aerospace, architectural and chemical industries. Literature shows that aluminium as matrix and TiC as reinforcement will increase the mechanical properties of aluminium [3,4]. Many scientific researches have been done through powder metallurgy by embedding particles as reinforcement on aluminium, where in this paperwork, an idea of reinforcing ceramic particles in aluminium is attempted. This research focuses more on enhancement of hardness and mechanical properties of aluminium alloy through powder metallurgy process by reinforcing with TiC and graphite as hybrid reinforcement.

1.2. Problem Statement

Most of today's products are available on the market but have poor mechanical properties without composite. Composite properties are very necessary for good mechanical properties. Aluminium is widely used in aerospace, car industries and in construction industries. Yet aluminum alloy does not use any product reinforce directly due to low properties. Several experiments have been conducted with different percentage of Titanium Carbide with the reinforced ratio of 3%,5% and 7% together with 0.5% graphite for each sample. Based on the experiments conducted the effect on strength, hardness, wear test, microstructure of different weight percentage of titanium carbide in the composite had been studied.

1.3. Objectives

The main objectives of this final year project are:

-To investigate the factors that affecting the strength and hardness of sintered aluminum-titanium carbide/graphite through different percentage of reinforcement ratio of Titanium carbide with the study of Vickers Hardness and Scanning Electron Microstructure.

1.4 Scope of Study

The objectives have been achieved after many tests had been done with various parameters. Firstly, Al powder was strengthened with TiC powder together with graphite. The procedure that utilized was powder metallurgy method. The physical & mechanical properties were assessed dependent on the microstructure studied and hardness test. The procedure likewise ought to be fundamentally examined, where the procedure was mixing the powders, compaction, and sintering. The principle pointed of this task was to clarify about the mechanical properties aluminum composite material reinforced with TiC and graphite. The task had two primary divisions. The principal division was through powder metallurgy technique. The materials required for the investigation were arranged effectively and executed with authorizations of higher experts in the mechanical engineering division of University Technology Petronas for the use of the machines in the mechanical engineering departments. The subsequent division was after the materials was created, considers were done utilizing various procedures and various machines. The test that were carried out to study the factors that affect the hardness and strength of the composite was Vickers Hardness test and SEM test.

CHAPTER 2
LITERATURE REVIEW

2.1 Composite

Composites are commonly delegated a generally new group of materials with a lighter weight and higher quality than conventional materials. Research is in progress in the preparing of composite materials in cutting edge fabricating innovation frameworks for their applications. Today, new plan contemplations in current advancements are totally not the same as regular ones [5]. Numerous composites utilized today are at the essential preferred position of materials innovation, with their presentation and costs appropriate to ultra-testing high mechanical applications [6]. .For instance, in ordinary structure contemplations, the lifetime of the materials is anticipated as 10^6 quantities of cycles utilized in typical assembling building, while in current innovations, the lifetime of new material composites, for example, rapid train, new air ship plan, aviation applications, new gas turbines, and so on is anticipated as 10^{10}–10^{11} or considerably more. Composite materials have supplanted numerous customary materials, for example, metals, earthenware production, woods, and polymers because of the points of interest that they offer, for example, explicit quality and solidness [5].

Most composites utilized today are at the essential advantage of the study of materials, with their presentation and costs perfect for innovative applications [5]. Composite advances are in this way significant for the improvement of utilizations for assembling designing. Composite handling and its utilization in modern applications incorporate logical information identified with the different fields of science, for example, physical science, science, hardware, software engineering, and eventually material science [5]. The assembling engineers are required to work with the architects of the materials–input that originates from logical research. On the off chance that the composite plan can be deliberately planned and the composite parts can be delivered accurately, composite advances will turn out to be a lot simpler and less expensive, and it is conceivable to improve both the quality and the unwavering quality of the composite item.

Lastly, to improve the mechanical properties of composites, the reinforcement is added to the matrix material. Then again, the utilization of single reinforcement in a grid can some of the time influence different composites ' mechanical and physical properties. Figure 2.1 shows a characteristic composite that exists in our body. Metal composite is a large-scale physical blend of physically or potentially synthetically isolated materials (stages) with the objective of incorporating useful properties of the composite materials in Figure 2.2.

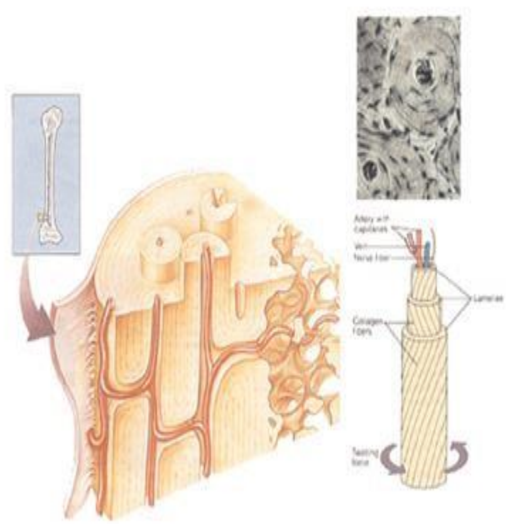


Figure 2.1: Structure of bone in living thing body as a natural composite [5].

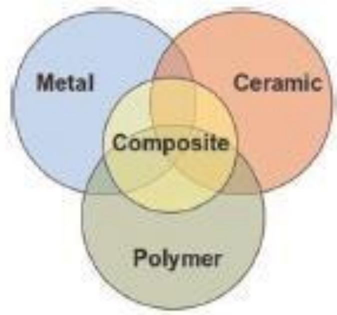


Figure 2.2: Isolation of composites within ceramic/polymers/metals [5].

2.2 Metal Matrix Composite.

MMCs are delegated composites that are built by a mix of at least two materials in which in any event one is steel. Built MMCs made from nonstop or intermittent filaments, bristles, or metal particles accomplish exceptionally high individual quality blends and explicit modules [7]. Engineered MMCs composed of continuous or discontinuous fibers, whiskers, or metal particles achieve very high individual strength combinations and specific modules [7]. Table 2.1 shows the different properties having different kind of properties.

Table 2.1: Representative properties of selected materials in each matrix class are presented [7].

Material	*Class*	*Density (g/cm³)*	*Modulus (GPa)*	*Tensile strength (MPa)*	*Tensile failure strain (%)*	*Thermal conductivity (W/m K)*	*CTE (ppm/K)*
Epoxy	Polymer	1.8	3.5	70	3	0.1	60
Al 6061	Metal	2.7	69	300	10	180	23
Ti (6Al–4V)	Metal	4.4	105	1100	10	16	9.5
SiC	Ceramic	2.9	520	–	<0.1	81	4.9
Al_2O_3	Ceramic	3.9	380	–	<0.1	20	6.7
Borosilicate	Ceramic	2.2	63	–	<0.1	2	5
Carbon	Carbon	1.8	20	–	<0.1	5–90	2

2.2.1 Composite Constituents

Structural MMCs comprise of nonstop or discontinuous fibers, whiskers or strands, bristles, or particles in a compound framework that strengthen or give the matrix the fundamental properties that cannot be accomplished in solid alloys [7]. Specific metals were utilized in MMCs as significant segments, including aluminum, copper, steel, titanium, magnesium, and so forth. Lighter metals, for example, aluminum, magnesium and titanium are normally utilized in basic applications, while cobalt and cobalt nickel compound grids are ordinarily utilized as steel for high temperature purposes [5].

2.2.2 Fabrication Process of MMC

There are various strategies to create MMCs. It is possible to acquire specific characteristics profiles by modifying the system, handling and completing, just as by the state of the support parts, despite the fact that a similar shape and amounts of the segments are involved [4]. Melting metallurgical procedures, powder metallurgical procedures, cold isostatic pressing of powder mixture and fiber clothes, joining and welding of semi manufactured items, and so forth are among the procedures that are utilized [7]. Different properties and profiles of the last MMC can be acquired by modifying the approach and parameters of the framework even with a similar synthesis and measure of lattice and fastener.

2.2.3 Self MMC Healing

Information has developed in the field of inorganic self-recuperating materials as of late. Natural structures that can self-fix harm are the reason for this property. Although the applied research here is in its relative infancy, the capability of these materials is huge, as though the material were self-mending, explicit weakness and quality misfortunes can be alleviated.

The test of making a self-recuperating MMC is an overwhelming assignment as metals have high melting temperatures and oneself fix process must happen at high temperatures or specific situations [7].

2.2.4 Metal Matrix Composites Classification

Based on the matrix material MMCs are arranged into various classes relying on their matrix materials. Figure 2.3 shows the utilization of matrix materials in industries and for other use looking at which is generally utilized which isn't utilized a lot. A few instances of most regularly utilized metallic lattice designs are;

-Magnesium composites

-Titanium composites

-Copper composites

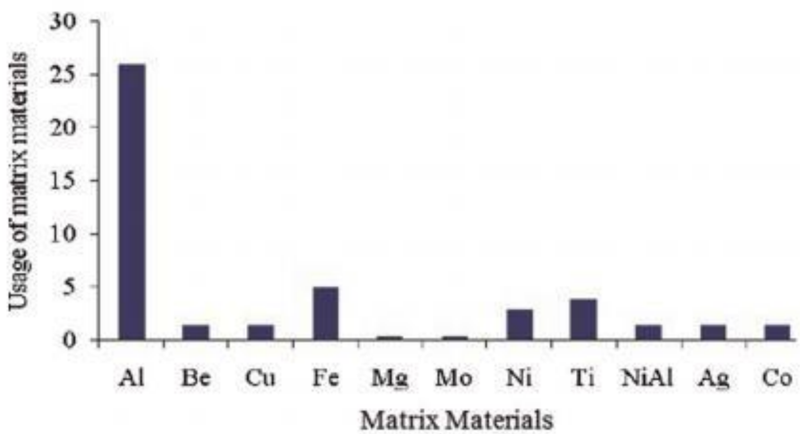


Figure 2.3: The different volume used in Metal Matrix Composite [7].

MMC is mostly contemplated in aluminum-matrix composites, it is broadly utilized in the car and aviation ventures. Reinforcement compounds, for example, SiC, Al2O3, and B4C can be effectively and productively blended in molten aluminum. Magnesium-matrix composites have same advantages, however they are not normally utilized contrasted with aluminum-based MMCs because of assembling imperatives and lower warm conductivity [7]. Magnesium–grid composites have been created for the space industry thank to the low thickness of magnesium and its combinations. In view of their great quality at high temperatures and magnificent consumption opposition, titanium compounds are utilized as lattice material in the production of MMCs. Titanium composites hold their quality at higher temperatures contrasted with aluminum, which is useful in the production of flying machine and rocket whose operating speed are very high [7].

2.3 Aluminium Based on MMC

` The most broadly utilized MMCs in automotive and aviation applications are aluminum based MMCs. This is basically because to its kind of qualities, for example, increase in strength, improved in toughness, reduced in density, improved temperature properties, controlled thermal expansion and improved wear resistance [4]. Aluminum is utilized as a key metal grid constituent underway of composite materials [8]. The mixing of at least two materials in which one is matrix, and another is filler materials brings about Metal Matrix Composite. The best mechanical properties which are not accomplished by conventional materials are given by Aluminum Metal Matrix Composite [9]. One of the constituents in aluminum-based MMCs is an aluminum/aluminum composite (i.e., Al-Si, Al-Cu, Al-Si-Mg combinations), which frames a permeating system and is known as a matrix phase. The other component is reinforced in this matrix of aluminum/aluminum combination and goes about as reinforcement, ordinarily non-metallic and commonplace earthenware production. Figure 2.4 shows the microstructure of a SiC particle reinforced with aluminum matrix material.

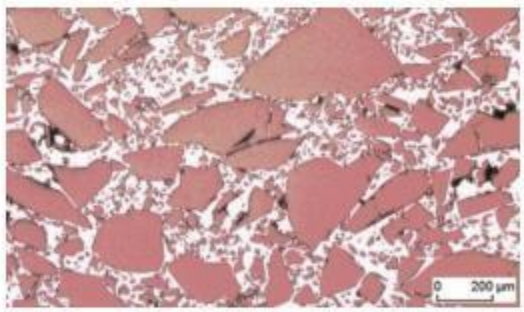


Figure 2.4: Silicon Carbide reinforced with an aluminium matrix composite [9].

MMCs dependent on aluminum are proposed to replace some materials in a few applications, including aluminum compounds, ferrous and titanium alloys and composites dependent on polymer. Contrasted and unreinforced materials, the principle focal points of aluminum based MMCs are:

- the stiffness is improved
- the density is reduced equivalent to reduce in weight
- the thermal expansion coefficient can be controlled
- enhanced and custom fitted electrical execution
- improved in wear resistance
- The damping abilities will be improved.

To prove it better, these advantages can be measured. For instance, pure aluminum elastic modules can be expanded from 70 GPa to 240 by embedding consistent aluminum fiber with 60 vol percent. In Figure 2.5, shows the comparison of stress strain curve of aluminium with reinforcement and without reinforcement.

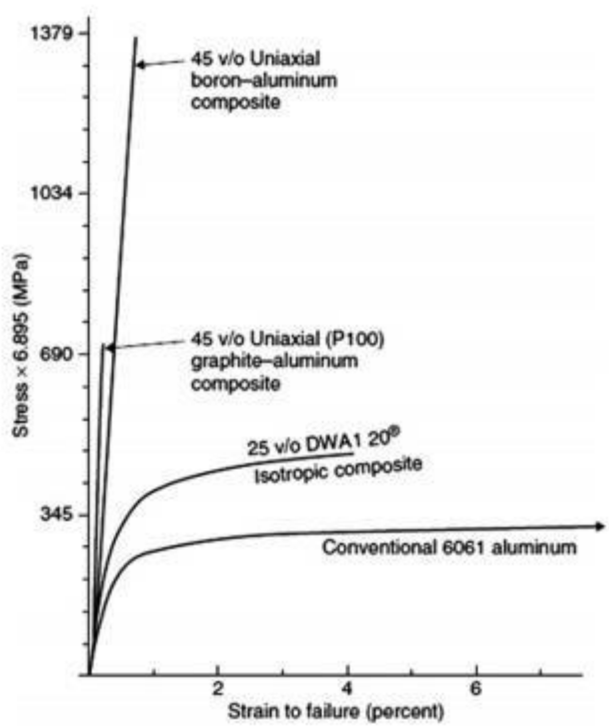


Figure 2.5: The Comparison of stress strain curves of Aluminum Composite [7].

In numerous basic, nonstructural and practical applications for different designing fields, aluminum–matrix composites have been utilized throughout the years. Quality, financial and ecological advantages give main thrust to the utilization of aluminum–grid composites in these sectors. Metal–Matrix Composites division are lower fuel usage, lessen noise and lower fuel consumption [7].

2.4 Filler materials as reinforcement in MMC & AMMC

Because of their solid solidarity to-weight proportion, Corrosion resistance, simple treatment and formability, aluminum and its compounds have been broadly utilized in aircraft industries. Components like mechanical airframe, fuselage, wing skin, and numerous fundamental structures are made utilizing aluminum and its compounds. Strengthening fillers can be included enormous sums. Along with these properties, Titanium Carbide has excellent strength to weight ratio which is particularly in need to the aerospace, chemical, and architectural industries [10]. Some plastics may contain as much as 60% strengthening fillers [11]. Reinforcement in aluminum metal matrix composites can be in particulate, whisker, or continues fibers [12]. The filler is a metal or artistic unique, or a small scale or nanoscale macrobiotic mixture. It is viewed as a mix if multiple materials or ceramic production are utilized as fillers. Elastic modulus, low thickness and low chemical reactivity. Aluminum compounds display high quality and specific modulus are yet are restricted to low temperature applications. This marvel could be improved by presenting the TiC reinforced particles into aluminum matrix [13]. The mechanical properties of aluminum compounds can be customized to the application through the expansion of reasonable ceramic production, for example, BN, SiC, Al2O3, Mn, MgO, and. SiC have high thermal conductivity, unrivaled quality, and low thermal conduction and can keep up the quality against a high temperature and chemical reaction [14]. Expansion of filler materials improves solidness, strength, hardness, temperature significantly [15]. Figure 2.6 shows properties of Titanium Carbide on the grounds that in this paper the primary center is to know the properties of Aluminium when reinforced with titanium carbide.

Titanium Carbide Properties (Theoretical)	
Compound Formula	N/A
Molecular Weight	59.89
Appearance	Powder or solid in various forms
Melting Point	3160 °C, 3433 K, 5720 °F
Boiling Point	4820 °C, 5093 K, 8708 °F
Density	4.93 g/cm^3
Solubility in H2O	N/A
Exact Mass	59.947946
Monoisotopic Mass	59.947946

Figure 2.6: Properties of Titanium Carbide [14].

2.5 Rules of Mixture in MMC

Many researches associated with testing the mechanical conduct of fiber-strengthened composites use what is meant by to "Rule of Mixture" (from this point forward referred to as ROM) to foresee and additionally look at the quality properties of the composites. The ROM is only an operational apparatus that uses the segment properties ' weighted volume average in isolation to acquire the property size for the composite [16]. Specifically, the composite pressure is written on account of a composite containing uniaxially adjusted, continuous fibers.

$$\sigma_c = \sigma_f V_f + \sigma_m V_m, \tag{2.1}$$

Where in equation (2.1), o is the axial pressure, V is the part's volume division and the memberships c, f and m refer to the composite, fiber and matrix. One may compose another ROM relationship for the flexible module under is strain conditions, for example the longitudinal strain in the parts being equivalent.

$$E, = E_f V_f + E, \quad V \tag{2.2}$$

Where in equation (2.2) E is the flexible unit and the memberships are as before the modules. Eq. (2) disregards any transverse strain emerging on account of the diverse contractile inclinations of the parts (i.e, vf not equivalents to v, where v is Poisson's proportion). Be that as it may, for metallic frameworks, the distinction in Poisson's proportion of the two parts is commonly unimportant and the ROM esteems are commonly seen as inside the points of confinement of the exploratory error [16].

2.6 Metal matrices Processing

There are such a significant number of methods for preparing metal network composite. The fundamental 3 different ways of handling are liquid state method, solid state method and in-situ method. Matrix and reinforcements are synthetically reinforced or precisely bolted together [17]. Figure 2.7 shows structure of handling strategies. Preparing of metal grid composites (MMC) can be grouped into three primary classes:

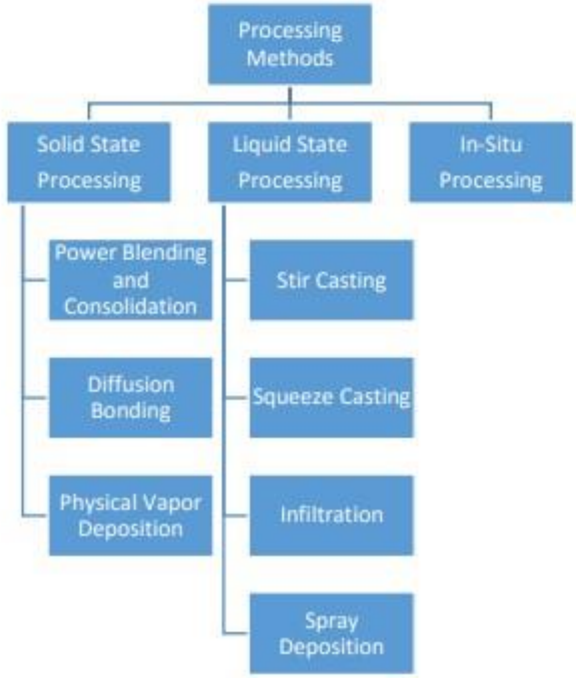


Figure 2.7: Processing methods involved in Metal Matrix Components [17].

2.6.1 Solid state Processing

Powder mixing and integration and mechanical vapor deposition are the primary manufacturing methods of this process.

a. <u>Powder Blending and Consolidation</u>

Metal composite powder is blended in dry state or fluid suspension with short fiber or ceramic. In the wake of mixing, the blend is additionally prepared by cold compaction, canings, degassing's, and high temperature consolidation [17].

b. <u>Diffusion Bonding</u>

The interdiffusion molecules on the under-pressure metal surfaces create holding between the matrix and fibers. This handling procedure is generally utilized with consistent/spasmodic filaments for MMCs in aluminum or magnesium.

c. Physical Vapor Deposition

In the stage, the fume is made and applied, at that point the condensation happens in this locale to make a fiber covering. The statement recurrence is around 5-10 micrometer for each moment. Cold squeezing and cold isostatic squeezing combine the coated strands.

2.6.2 Liquid State Processing

a. Stir casting

Focus on making stronger the combination of liquid metal melting and then wait until the mixture turn into solid. In general, the particle will be in molten alloy shaped by spinning impeller.

2.6.3. In- Situ Processing

Handling in-situ requires reaction of chemicals which make a procedure of reinforcement inside a metal matrix. The precipitation can be form by reinforcements. This methodology furnishes the lattice fortification framework with thermodynamic proficiency. The strengthening surfaces are additionally liable to be without pollution and a stronger matrix scattering bond can accordingly be accomplished. Figure 2.8 shows various way to process MMC.

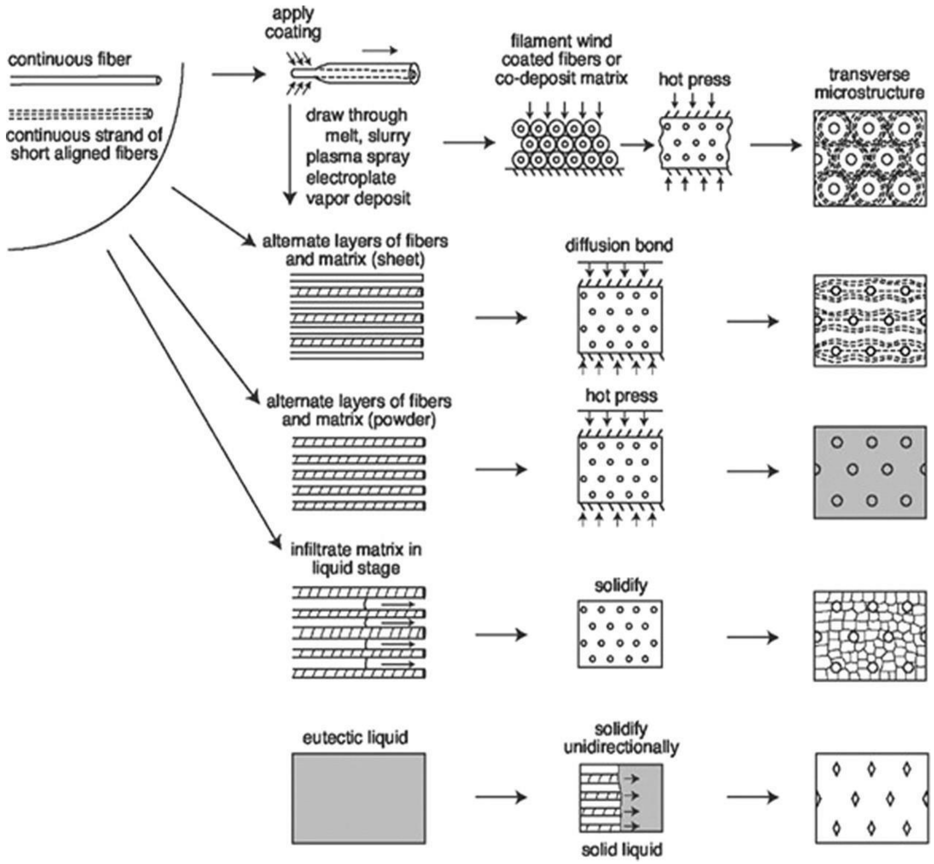


Figure 2.8: How matrix materials are made [17].

2.7 Powder Metallurgy Process

To produce composites or prepare Nano composites Powder metallurgy is one of the best ways [18]. Figure 2.9 shows variable techniques for combination of metal framework by means of powder metallurgy. Upon compaction, for specific time and temperature, the billets are warmed in a heater to can pores and accomplish high strength [19]. The parts can be utilized following the sintering procedure, yet a few sections may enable the activity of auxiliary completing to decrease pressure.

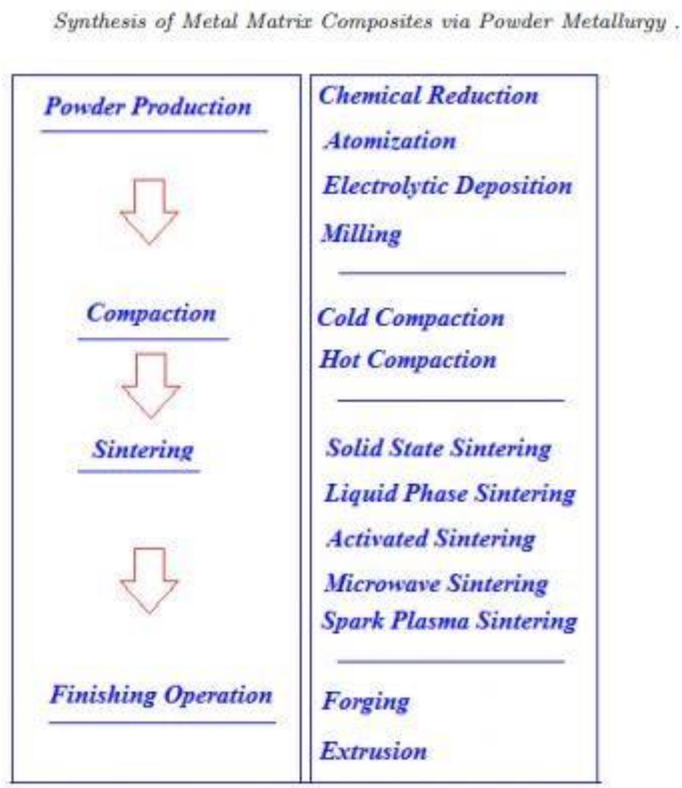


Figure 2.9: Process involved in powder metallurgy of MMC [9].

2.7.1 Powder Production

There several ways to produce powders. One of the general methods to produce powder is by using atomization. By using atomization titanium alloy, stainless steel, and nickel alloy can be produced [19]. Similarly, iron, copper and silver powders can also be fabricated by electrolysis technique.

2.7.2 Blending

To achieve homogenous distribution of particle sizes and to reduce the porosity blending should be done.

2.7.3. Sintering

Heating the green compacts in for example furnace at a controlled atmosphere is to tie the particles, this process is called sintering. It must be conducted below its melting point in various furnace like walking beam furnace, mesh belt furnace and pusher type furnace [2]. Many scientific researches show that when sintering is done at its maximum temperature the surface will be looking so perfect. Hypothesis has been explained that when the sintering temperature increase gradually, the material properties also will increase [19].

2.7.4 Finishing Process

Graphite is used as an alloying component in powder metallurgy to increase the strength of the sintered components. Based on the sintering process, graphite with various grain sizes must be used for metal graphite alloys and the particle size of the graphite must be optimally related to the metal particle size. A high purity and rapid reactivity of the used graphite origin is necessary in order to achieve a short production time and the highest possible density with a high tensile strength of the finished products [19]. A constant graphite performance is needed for the producers of powder metallurgy to ensure absolute process stability. While looking at the various applications of graphite-like particle size powder metallurgy parameters, the purity, particle form, and surface shows that the graphite grades produced by the tailor or very specific solutions are required.

2.8 Application of MMC AND AMMC

Together with the Manufacturing costs is very widely used in current industry. The main reason is firstly its chemical and physical property, secondly because of the product high quality. MMC are used in different applications, including ;

- Aerospace
- Electronic
- Automotive

- Usage for electric power transmitter material
- Sports Equipment
- Highly wear resistance material.

Another main reason is MMC are widely used in car parts such as engine components, brake components, tire rims and etc. In automotive sector they are pros and cons one of the disadvantages is its highly cost expensive. The utilization of MMC is also important in aircraft industry. This is because it has high stiffness and strength and fatigue resistant. The MMC is mainly used in military and commercial aircraft [7]. Boeing aircraft (Figure 2.10), designers made a good decision by using MMC for wings and other parts. Compared to more traditional aluminum models, this solution provides an average weight saving of 20% [7].

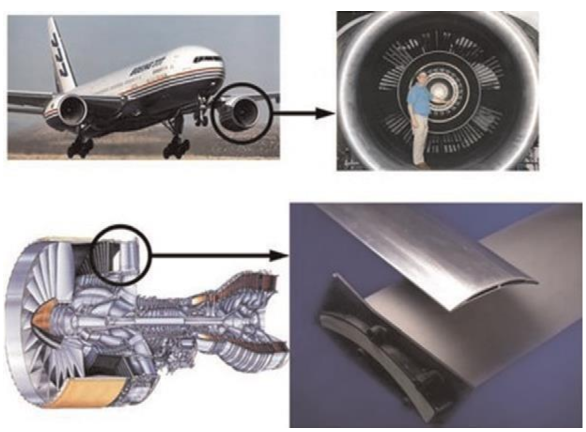


Figure 2.10: Boeing aircraft [7].

Aluminium is one of the main things that always car industry uses for its car application. This is because aluminium part have specific and different capabilities for each car part as has shown in Table 2.2. On the other hand, the use aluminium is not only used in car industry but also used in many industries such as in turbine, pump, rod etc. Aluminium has many benefits and the summarized benefits of the usage of aluminium in industry is summarized in Table 2.3. There are many solid reasons to choose aluminium over other materials:

- Reduced weight of aircraft engine components

- The operating temperature of engine increase
- The stiffness and strength will increase
- Thermal coefficient expansion can be adjusted.

Table 2.2: Aluminium Matrix Composite for Car Application [9].

Material	*Application*	*Improved Property*	*Feature*	*Manufacturer*
Al-shore fiber	Piston ring	Abrasion resistance performance, lower cost	High-temperature engine	Toyota
Al-shore fiber	Piston combustion bowl	High-temperature performance	Improved durability	Consortium
Al-shore fiber	Selective reinforcement of motor block	High-temperature performance	Improved durability	Peugeot
Al-shore fiber	Cylinder liner	Improve stiffness, wear resistance, better heat conducting, closer tolerances	Improved durability	Honda
Al-SiC particles	Connecting rod	Specific strength, specific stiffness	Higher performance	Nissan
Al-Al_2O_3 fiber	Connecting rod	Specific strength, specific stiffness	Higher performance	Chrysler

Table 2.3: Applications of MMC in different industries [7].

Composite	Components	Advantages
Aluminum–silicon carbide (particle)	Piston	Reduced weight, high strength and wear resistance
	Brake rotor, caliper, liner	High wear resistance, reduced weight
	Propeller shaft	Reduced weight, high specific stiffness
Aluminum–silicon carbide (whiskers)	Connecting rod	Reduced reciprocating mass, high specific strength and stiffness, low coefficient of thermal expansion
	Sprockets, pulleys, and covers	Reduced weight, high strength and stiffness
Aluminum–aluminum oxide (short fibers)	Piston ring	Wear resistance, high running temperature
	Piston crown (combustion bowl)	Reduced reciprocating mass, high creep and fatigue resistance
Aluminum–aluminum oxide (long fibers)	Connecting rod	Reduced reciprocating mass, improved strength and stiffness
Copper–graphite	Electrical contact strips, electronics packaging, bearings	Low friction and wear, low coefficient of thermal expansion
Aluminum–graphite	Cylinder, liner platon, bearings	Call resistance, reduced friction, wear and weight
Aluminum–titanium carbide (particle)	Piston, connecting rod	Reduced weight and wear
Aluminum–fiber flax	Piston	Reduced weight and wear
Aluminum–aluminum oxide fibers–carbon fibers	Engine block	Reduced weight, improved strength and wear resistance
Supper alloy-based composite (Ni–Ni_3Nb)	Turbine blades	Fatigue resistance, impact strength, temperature resistance
Cu–Nb, Cu–Nb_3Sn	Super conductor	Superconducting, mechanical strength, ductility
Cu–W	Spot welding electrodes	Burn-up resistance

CHAPTER 3
METHODOLOGY

3.1 Methodology Flow Chart

Research methodology flowchart below shows that what is the working process that had been planned for the whole Final year Project which is for 28 weeks equivalent for 2 semesters. After study the design of experiment to develop an Aluminum hybrid composite reinforced with Titanium Carbide & Graphite can be achieved within the given timeline. The figure 3.1 below explain the flow of research methodology.

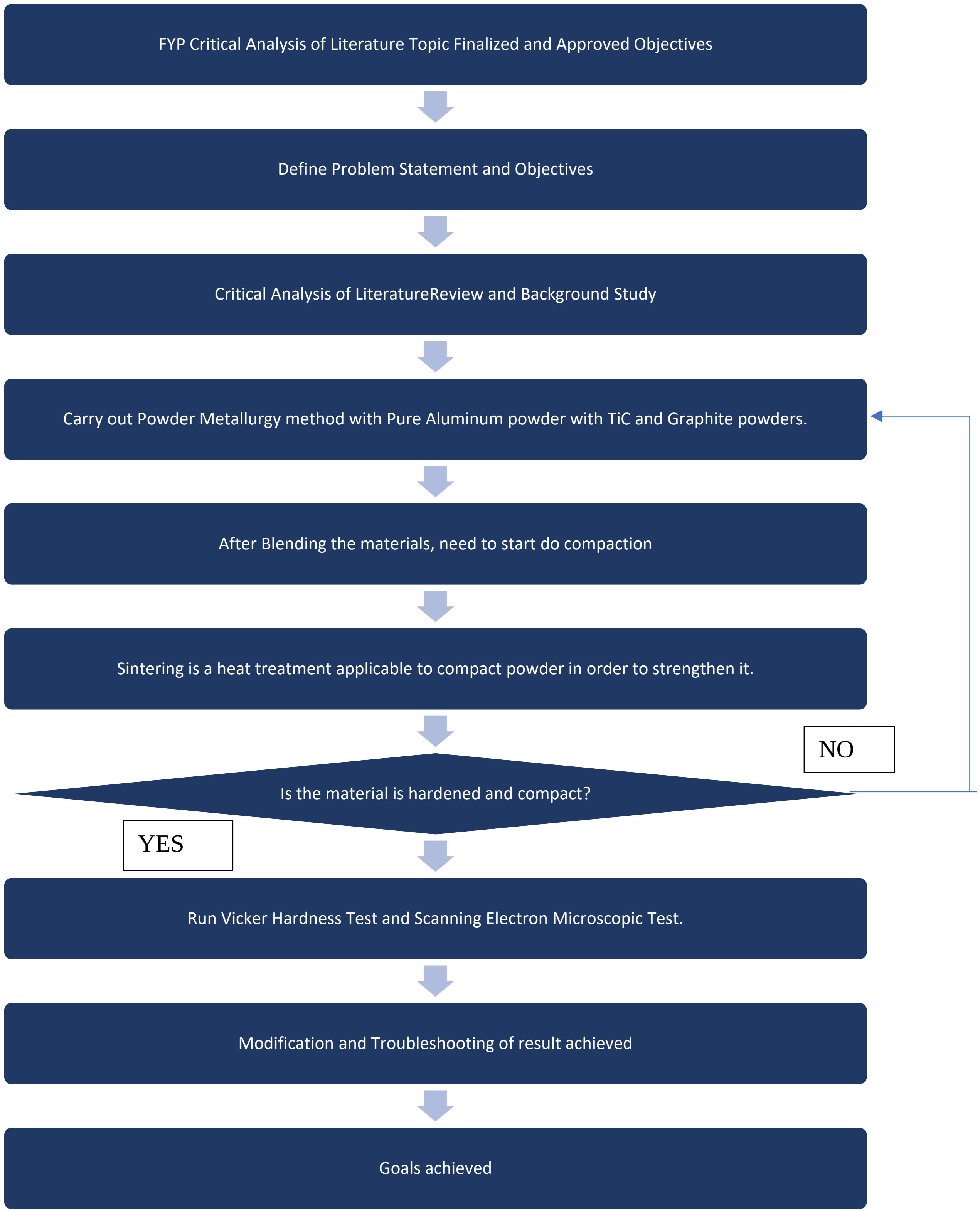


Figure 3.1 Research Methodology throughout FYP 1 and FYP 2

3.2 Powder Metallurgy Process

Aluminum was reinforced with titanium carbide and graphite in powder metallurgy form. Firstly, the proposition of matrix metal and reinforcement materials was weighed using precision weighing balance .It will be weighed carefully to get exact amount of Aluminum powder with various weigh proportion of titanium carbide which is 3%,5% and 7%.Graphite was grinded using mortar grinding in order to make it as micron size so it will blend eventually with the two powder. Ball mill is very important in order to blend both the mixture homogenously. Compaction machine was used to compact the homogenized powder mixture in order attain the green compacts. The compaction force was 500Kn, and the sintering temperature was kept constant at 500 ° C for all samples. The specimen is weighted and compacted with different pressures and held at a temperature of 500° C in the furnace, for 7 hours. The specimen was then collected and held for cooling at room temperature for 15 hours. Electron microscopy analysis will be done in order to see the sights of metallurgy products produced [20]. Parts of the specimen will be grounded and cleaned with the standard grades of emery sheets in this way to accomplish surface roughness closer to the 1 micron. Then to test the properties hardness test was conducted as explained in experimental procedures. Figure 3.2. shows generally how is the process of powder metallurgy from beginning until the end.

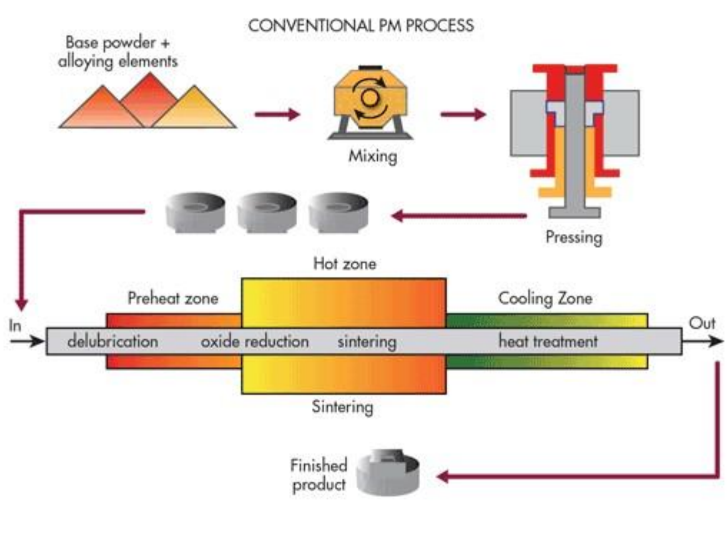


Figure 3.2: Conventional Powder Metallurgy Method

So firstly, aluminium powder was oxidized so, grinding the powder was the only solution to make the powder soft enough to blend with other powder. So nearly 250 grams was measured and grinded in the mortar grinder around 20 minutes. So, this is the before and after effect of the grinding. The graphite powder is very coarse and was grinded in order to make it into micron size. Titanium carbide powder arrived in fine micron size. Figure 3.3; A),B),C) and D) shows step by step machine used as been explain in above methodology, A) shows the powder before grinding, B) shows the mortar grinder used to grind the powder, C) The powder change into fine powder when it is grinded for first round, D) shows the second round and the powder is now completely fine.

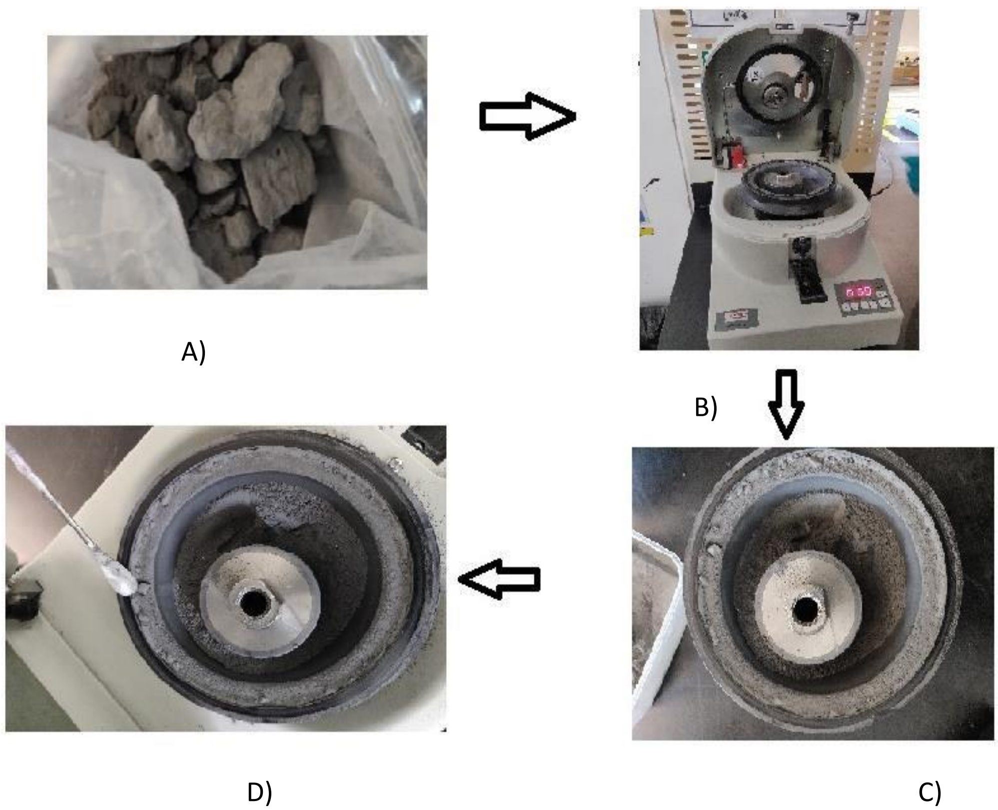
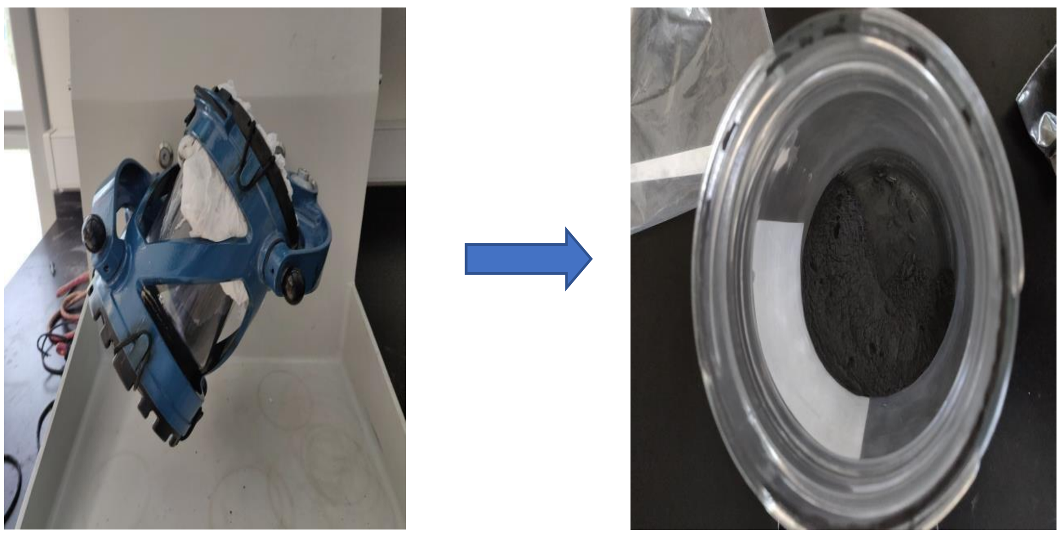


Figure 3.3: Grinding process of pure aluminum powders; (A) Pure oxidized Aluminum Powder, (B) Grinding the powders into micron size, (C) Coarse powder, (D) Final product of the powder after being grinded for 30 minutes

Blending powder was very important to make sure the substance particles are homogenously mixed .Figure 3.4 ; A) and B) shows step needed for blending the mixture of graphite powder, aluminium powder and also titanium carbide powder, A) shows tubular mixer machine used mix the powder, B) shows the after effect of mixing the powders.



A) B)

Figure 3.4: Powders being blended in tubular mixer;(A) Powder being mixed in tubular mixer, (B) Final product after the powders being mixed for 90 minutes.

After the blending process, the specimen needed to be compress in order to maintain with the punches to form the compact. Compaction will make any form of powder to be shape in its desired shape. The compaction process take place in Block 13 under supervision of lab technician. and the force that were used to compact the powder was 500 Kn. Figure 3.5: A), B), C) and D) shows the step by step process of compaction of powder before and after. After the compaction process the powder specimen was shaped into its desired shape.

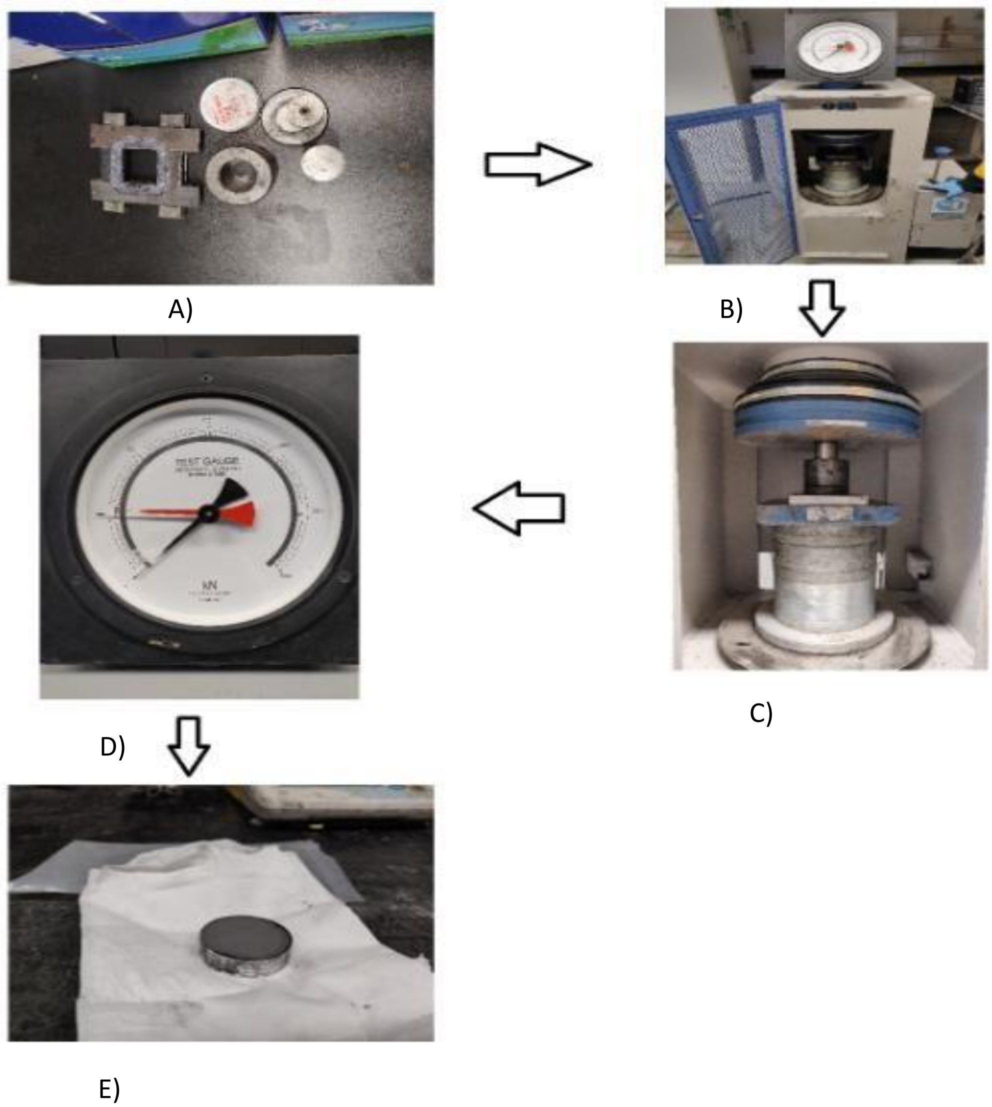


Figure 3.5: Compaction process, A) Punch, dye and wax needed in the process, B) Compaction machine in Block 13, C) Pressing of the dye giving impact to the powder, D) Pressure used in compaction process, E) End product of compaction

After the compaction process sintering process needed to be done in order to make the specimen more solid and in order to impart the strength. Temperature that usually used in sintering process is below the melting point of specific material. Sintering is significant because it will remove the pressing lubricant exist by evaporation and burning of vapor. Other than that, it will also reduce the surface oxides that remains in the powder particles in the compact. The sintering process takes place in Block 17 under supervision of lab technician. The temperature used for the heat treatment was 500°C for 7 hours. Figure 3.6 shows the image of tube furnace used in the heat treatment.

Figure 3.6: Tube furnace used to heat the specimen under 500°C for 4 hours.

3.3 Experimental Procedure

The hardness test and SEM test was done in UTP laboratories. To research the construction and operation of a diamond polishing machine including sample preparation for microstructure analysis. Figure 3.7 shows laboratory that will be used to conduct the experiment with the help of lab assistant in UTP.

Figure 3.7: Grinding and Polishing machine located in Analytical Lab (04-02-10), University Technology Petronas

Hardness measuring systems and tools cover all the major testing methods for steel, plastic and rubber hardness testing. Figure 3.8 Hardness Testing Machine located in Analytical Lab (0402-10), University Technology Petronas

Figure 3.8: Hardness Testing Machine in Block 16 UTP

SEM machine is a device that scans electron microstructure of specimen to know the percentage of mixture present in a specimen. Figure 3.9 shows the SEM machine that will be used to see the composition of material.

Figure 3.9: SEM MACHINE

3.4 Project Details

Based on the knowledge from literature review these was the guidelines for the project. The machines are readily available in UTP laboratory, some of the machine selection is still under progress. Table 3.1 shows the exact composition of weight needed to measure before the experiment so that the it follows the project objectives.

Table 3.1: Percentage of composition of powder for AL-TiC

No.	**Formulation Name**	**Aluminium (Al) (Vol%)**	**Titanium Carbide (TiC) (Vol%)**	**Graphite (Vol%)**
1	Al-Tic 0.00	100	0	0
2	Al-Tic 0.03	97	3	0.5
3	Al-Tic 0.05	95	5	0.5
3	Al-Tic 0.07	93	7	0.5

- The materials are the Aluminum powder, titanium carbide and graphite must be mixed and prepared according to the weight percentage listed above.

•After weighed the powders, using ball mill, the powder was blended so that the mixture is uniform. The powders were compacted in a Compaction machine. The force was 500Kn to compact the samples. After that, the specimen was under heat treatment which the sintering temperature was in a constant 500°C for 6 hours and then held for cooling at room temperature for 15 hours.

•After the samples was prepared Vicker Hardness test were done to know the hardness and strength and SEM test were taken to relate the microstructure with the property of the specimen.

3.5 Gantt Chart

Gantt Chart below shows that the planning done for the past 14 weeks to successfully plan and finish my Final Year Project 1. Table 3.2 shows the Gantt chart and the milestone that have been achieved within this semester.

Table 3.2: Gantt Chart of FYP

Week	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Project title confirmation & project discussion with SV together with Master student.														
Identification of experimental review and methodology.														
Identification of design of experiment.														
Critical literature review on related topic.														

Preparation and submission of Extended Proposal														
Preparation and Presentation of Proposal Defense														
Project Activities														
1.Ordered the materials with laborotary GA.														
2.To plan the machines that will be using for the whole project in UTP.														
Data collection and Preparation for Interim Report														
Submission of Interim Report														
FYP MILESTONE														
PROJECTS MILESTONE														

`

3.6 Key Milestone

Table 3.3 shows the key milestones that are identified in this project as illustrated in the Gantt chart (refer Table 3.2). This is to ensure that the progress of the project is right on track.

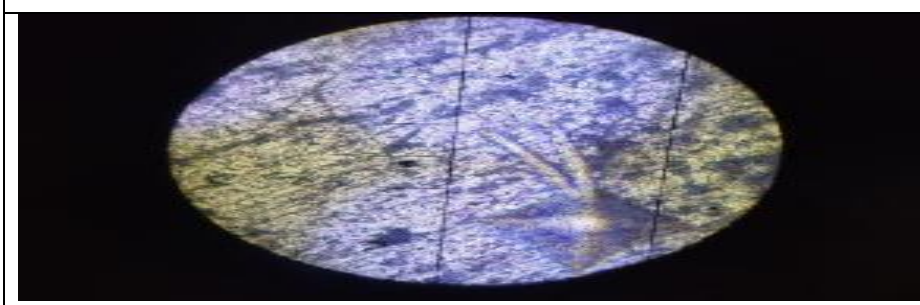
Table 3.3: Key Milestones for FYP

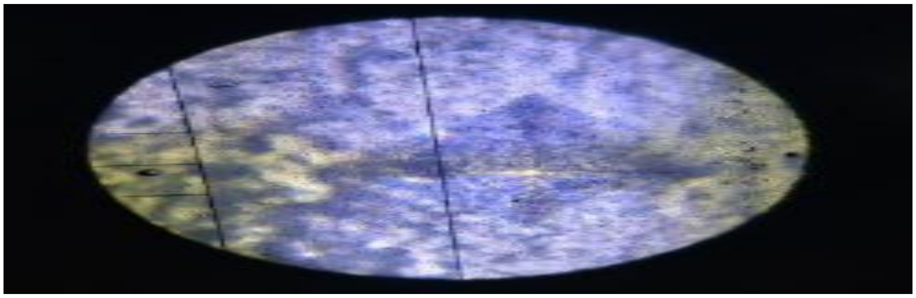
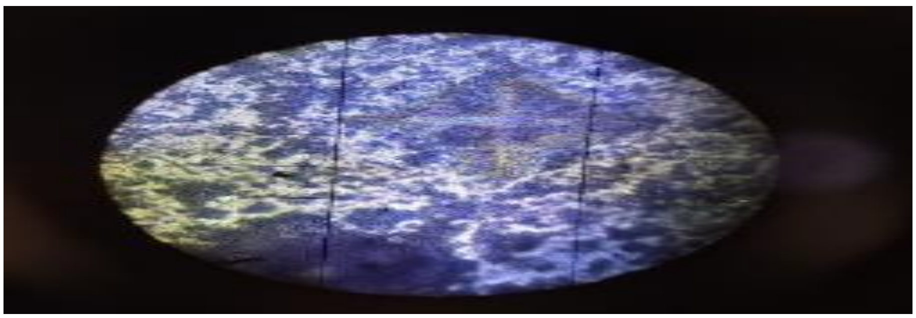
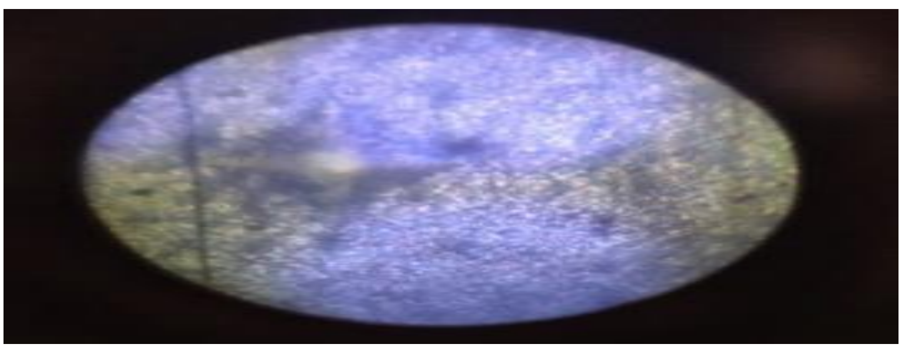
Week	**FYP Markers**	**FYP 1 Activities**
2		The project title were confirmed with my supervisor Dr.Hamdan and also Master student who will guide me on 12 September 2019,Thursday.
8		Preparation and presentation of Proposal Defence was completed on 10th October 2019. .
14		Submission of complete interim report in Turnitin and also to my Supervisor and Internal Examiner.
Week	**Project Markers**	**FYP 1 Activities**
4		Identification of design of experiment,which is how to prepare the methodology,how to get the results planning like that were made on 25th September 2019.
9		Materials was sent to order to lab GA one week earlier so that materials will get early which was on 16th September 2019.

Chapter 4
Results and Discussions
4.1 Hardness Test

Vicker hardness testing machine was used to carry out hardness test. Firstly, the surface was polished, after that the diamond indenter was used to make a small dent on the surface which was polished just now. Then the diameters of the dent will be measured in order to get the hardness. The specimen that I used in this test is pure aluminum specimen, pure aluminum with 3% of TiC & 0.5% graphite, pure aluminum with 5% of TiC & 0.5% graphite and pure aluminum with 7% of TiC & 0.5% graphite. For every sample I did the measurement 2 times, in order to assure the results are valid. The test load which is used is 200gf with indentation period of 25 seconds. Table 4.1 shows the surface images of the specimens after already indented for 25 seconds and the reading of the hardness.

Table 4.1: Surface Image and Microhardness of the Specimens

Vicker Hardness Surface Image	Results
	Pure Aluminum First reading- 37.5HV Second reading- 38.9HV

	Pure aluminum with 3% of TiC & 0.5% graphite First reading-42.5HV Second reading- 41.7HV
	pure aluminum with 5% of TiC & 0.5% graphite First reading-49.2HV Second reading-50.4
	pure aluminum with 7% of TiC & 0.5% graphite. First reading-70.2HV Second reading- 68.0HV

Based on the results of hardness test from Figure 4.1, it proves that the aluminium without reinforcement have very low hardness value when we compare with the reinforced specimens. This result proves that it will be faster solidification as the percentage of TiC increases. Faster solidification is to enhance mechanical property and makes finer grain size. In addition, because of the increased in strain energy, the hardness of the specimen increased, when the peripheral of particles dispersed in matrix. Figure 4.2 proves the increase in percentage of hardness of the composite when reinforced with TiC. When 3%

of TiC is added the hardness of aluminum increased by 7.2% compared to pure aluminium .The most drastic change in hardness was when 7% of TiC is added the hardness increases around 70.2% which is from 38.9HV INTO 70.2HV.When there is hard reinforcement particles which is TiC, it will increases the load bearing capacity if the specimen and also will limit the matrix deformation by limiting the movement of dislocation.

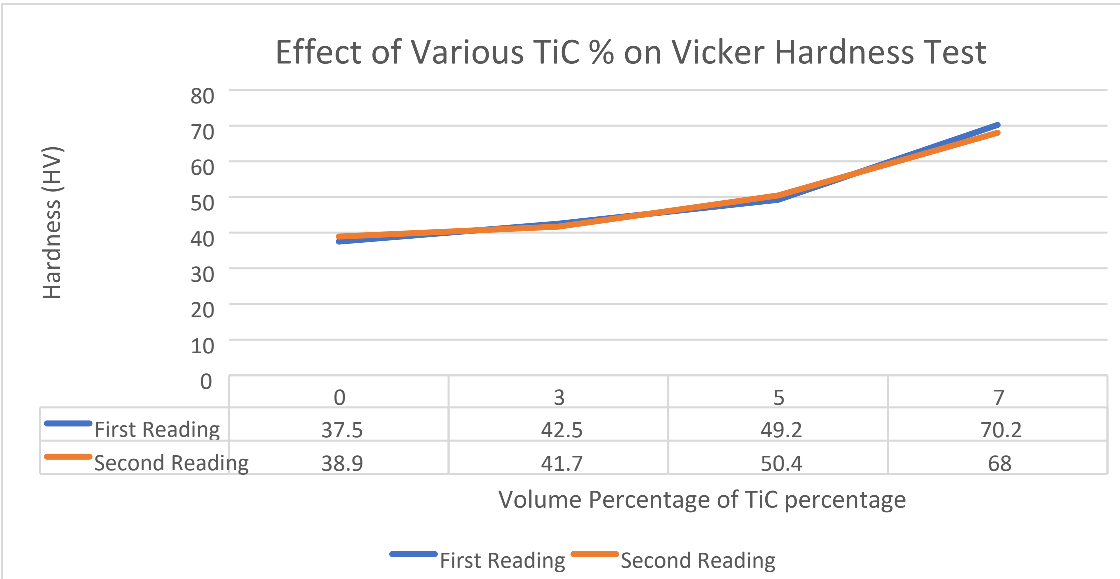


Figure 4.1: Effect of Various TiC % on Vicker Hardness Test

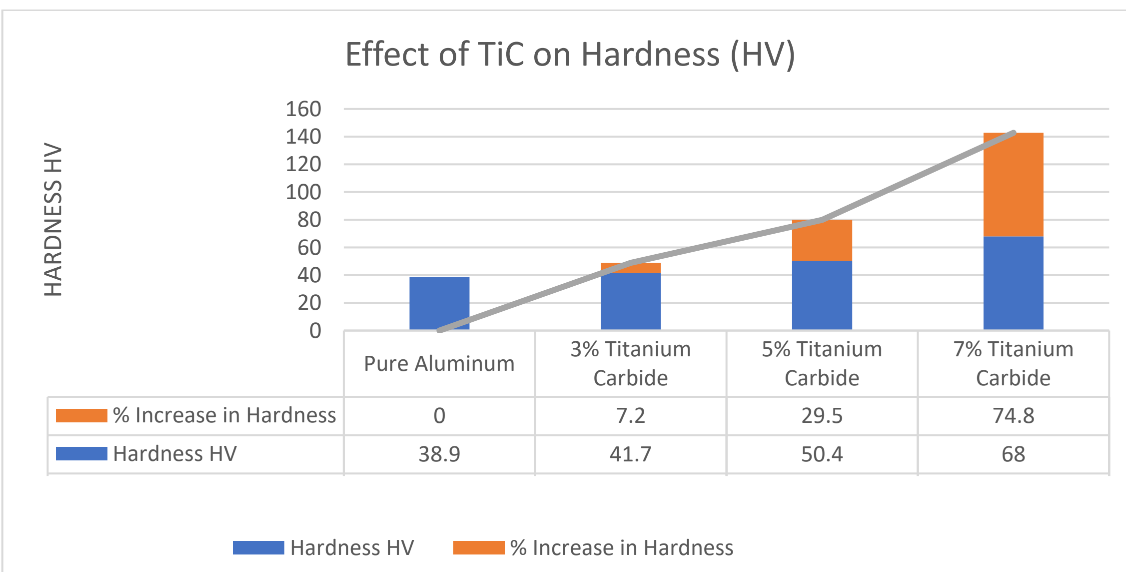


Figure 4.2: Effect of TiC on Hardness (HV)

4.2 Microstructure

The scanning of electron microscope of the four specimen is shown in Figure 4.3 shows SEM images of Pure aluminum, Figure 4.4 Pure aluminum with 3% of TiC & 0.5% graphite, Figure 4.5 shows Pure aluminum with 5% of TiC & 0.5% graphite and lastly Figure 4.6 shows Pure aluminum with 7% of TiC & 0.5% graphite. Based on the microscopic examination, it is proved that the reinforcement particles was uniformly distributed over the matrix materials with titanium carbide and the segregations was also confirmed. Based on the SEM images it clearly shows the main influences for hardness of composites will increase as percentage of TiC increases. It is clearly can be observed that hardness of the specimen increases as reinforcement (TiC). Figure 4.4 clearly shows there is no addition of any impurities or any reinforcement in Pure Aluminum. Figure 4.5 shows the addition of 3% of TiC and 0.5% of Graphite into the sample to reinforce the pure aluminum. Figure 4.6 & Figure 4.7 clearly shows that hexagon shaped confirms the presence of Titanium Carbide particles in the pure aluminum.

4.3 Influence of Titanium Carbide on Microhardness

One of the reason for increase in hardness is because the absence of porosity. Microstructural changes taking place at higher processing temperature also influences the hardness of composites. When there is an increase in TiC it will the decrease the aluminum matrix impact strength. The composite hardness increased 74.8% when 7% of TiC is added, this clearly proves that the higher the percentage of TiC the higher the hardness of the aluminium composite from this experiment. Another reason for increase in hardness is the variation in plastic deformation of composites due to the hard TiC particles. The absence of porosity in the composite is also one of the solid reason for hardness of the composite increases. Another influence for the hardness of composites is microstructure changes will occur during higher processing temperature. Besides that, hardness of the aluminium composite increases because Orowan and Hall-Petch strengthening mechanism in the matrix [8]. Heat treatment and also processing methods are also one of the factors that impact the hardness.

4.4 Influence of Titanium Carbide on Strength

Strength is one of the main parameters that need to focus in this experiment. This experiment was tested with maximum of 7% of Titanium Carbide because high concentration of TiC also will decrease the strength and hardness as reported by other researchers [8].When high percentage of TiC it will lead into brittle nature composite which will decrease the strength of a composite. When percentage of TiC increases the ductility of aluminum matrix decreases, it also causes increase in stress concentration areas leading into propagation of minor cracks. When stress concentration areas occur, it will form into debonding of Aluminum and Titanium Carbide this will reduce the strength of the aluminium.

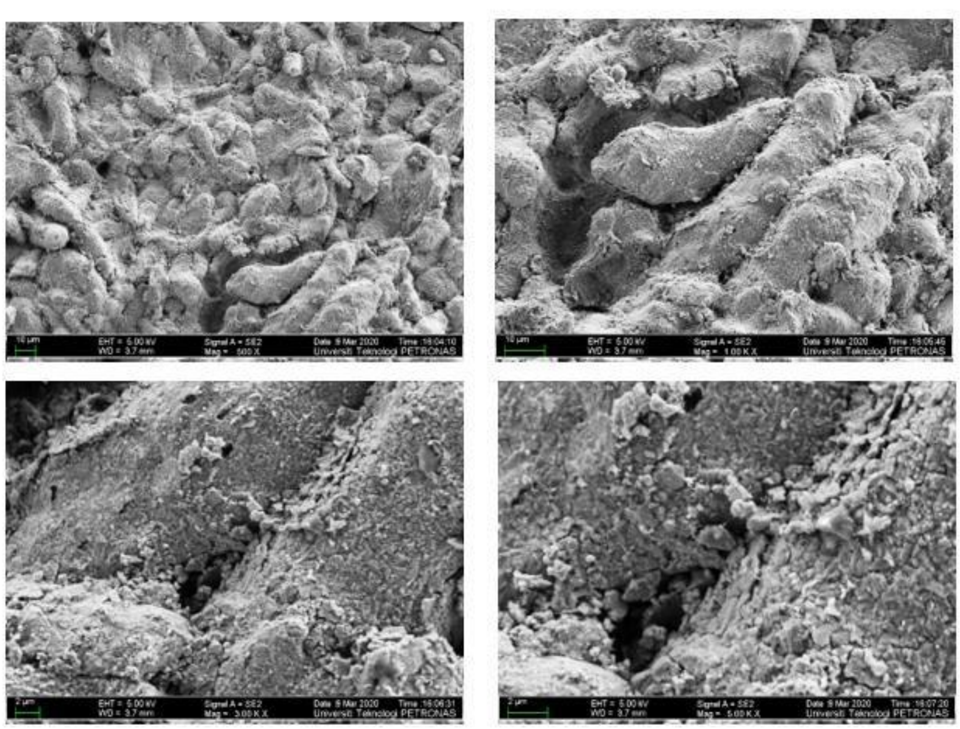


Figure 4.3: SEM image of Pure Aluminum.

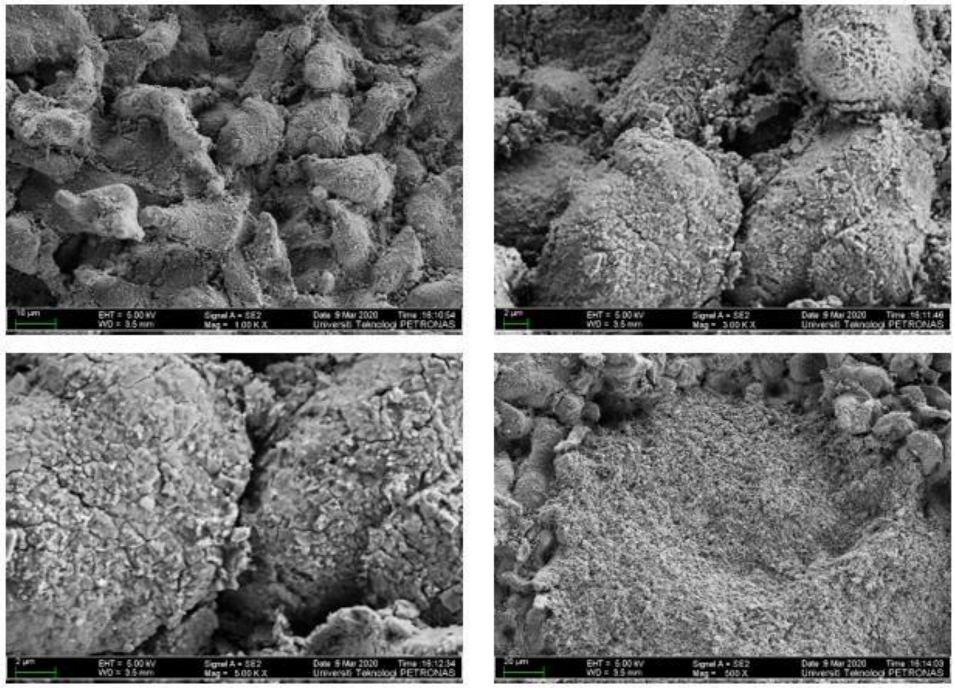


Figure 4.4: SEM images of Pure aluminum with 3% of TiC & 0.5% graphite

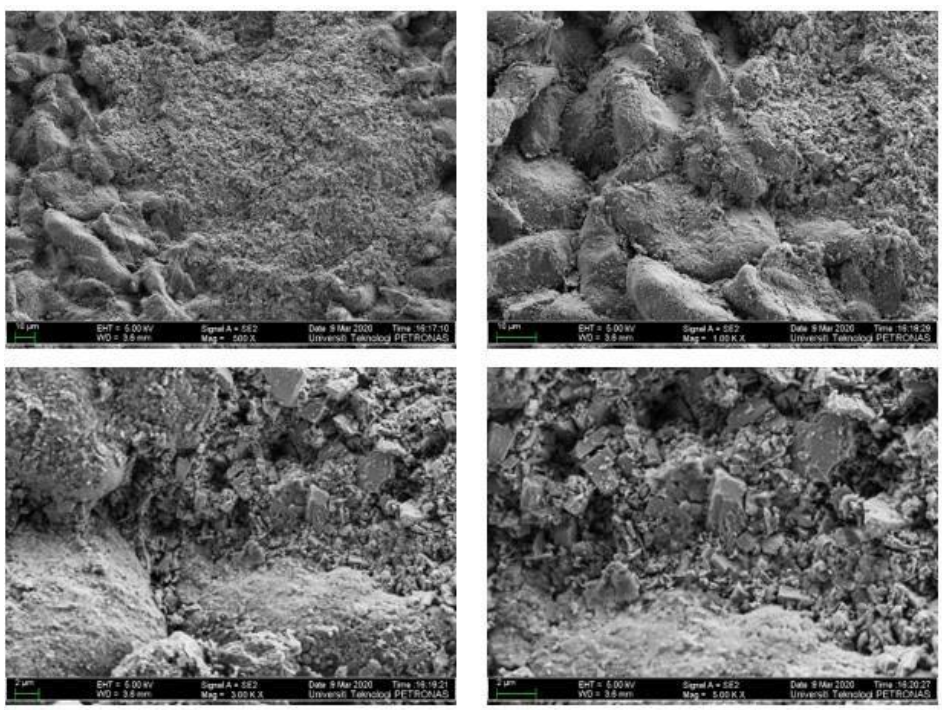


Figure 4.5: SEM images of Pure aluminum with 5% of TiC & 0.5% graphite.

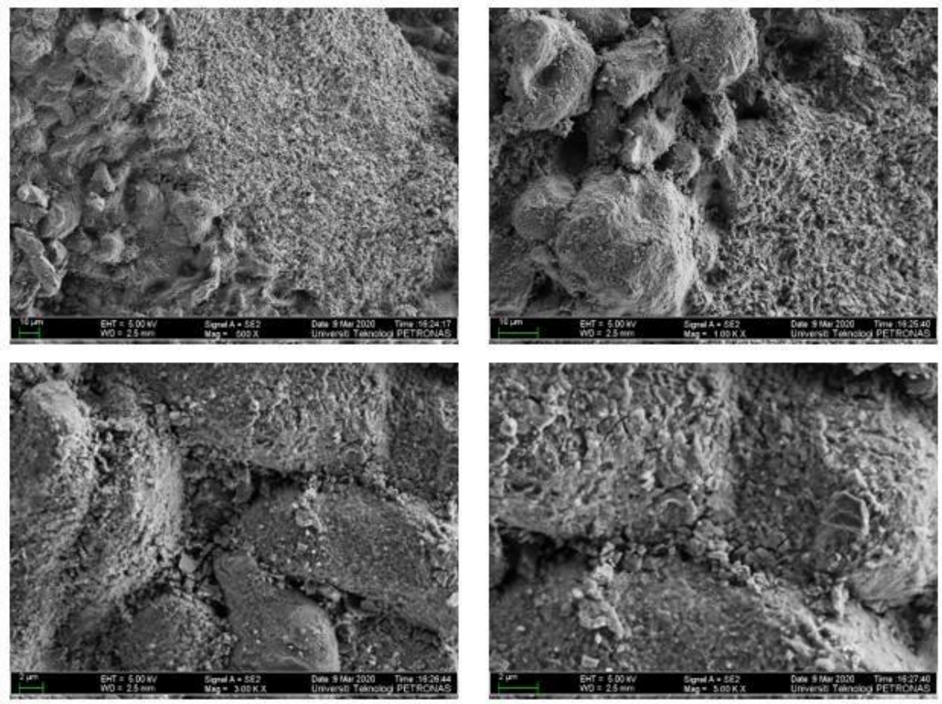


Figure 4.6: SEM images of Pure aluminum with 7% of TiC & 0.5% graphite

CHAPTER 5
CONCLUSION

5.1 Conclusion

Based on the study of hardness and mechanical properties of Aluminum composite reinforced with Titanium Carbide & Graphite, the following conclusions have been arrived. The specimens are pure aluminum, Pure aluminum with 3% of TiC & 0.5% graphite, Pure aluminum with 5% of TiC & 0.5% graphite and Pure aluminum with 7% of TiC & 0.5% graphite successfully developed with powder metallurgy and sintering technique. The SEM images shows the distribution of TiC & graphite are equal and uniform. Measuring the microhardness of the specimen proves that the variation of TiC % presence in the specimen impacts the hardness of the pure aluminum. The highest value of microhardness was obtained in the specimen which has 7% of TiC which is 70.2 HV, while the lowest microhardness was the pure aluminum specimen which has 39.2HV.Clustering and homogenous distribution of TiC & Graphite in Aluminum matrix were clearly observed in the microstructures. The addition of TiC and graphite had clearly increase the mechanical properties of the pure aluminum. The TiC particle had refine the grain structure which had scientifically increase the strength of the composite. Aluminium is a very light in weight metal, adding reinforcement into it will clearly increase the hardness very effectively, where this metal can be applicable in low weight and high strength properties like in automobile and aircraft industries. Lastly, this experiment may be continued by adding different kind of reinforcement which may lead to production of new hybrid composite material. This will provide more investigations in various specimen with various mechanical properties which may change the future of engineering applications. This experiment clearly proves that addition of Titanium Carbide as reinforcement increases the hardness of aluminum metal and was proved clearly with the SEM images of the homogeneous distribution of TiC particles in the pure aluminum composite.

REFERENCES

[1] L. Mahesh, M. Vinyas, J. S. Reddy, and B. Muralidhara, "Investigation of the microstructure and wear behaviour of titanium compounds reinforced aluminium metal matrix composites," Materials Research Express, vol. 6, no. 2, p. 026516, 2018.

[2] C. Saravanan, K. Subramanian, V. Anandakrishnan, and S. Sathish, "Tribological behavior of AA7075-TiC composites by powder metallurgy," Industrial Lubrication and Tribology, 2018.

[3] V. R. Rao, N. Ramanaiah, and M. Sarcar, "Fabrication and investigation on Properties of TiC reinforced Al7075 metal matrix composites," in Applied Mechanics and Materials, 2014, vol. 592: Trans Tech Publ, pp. 349-353.

[4] V. Sivananth, S. Vijayarangan, and N. Rajamanickam, "Evaluation of fatigue and impact behavior of titanium carbide reinforced metal matrix composites," Materials Science and Engineering: A, vol. 597, pp. 304-313, 2014.

[5] S. M. Sapuan, "Composite Materials," in Composite Materials, 2017, pp. 57-93.

[6] E. Bayraktar, "Composite Materials," in Reference Module in Materials Science and Materials Engineering, 2017.

[7] M. Haghshenas, "Metal–Matrix Composites," in Reference Module in Materials Science and Materials Engineering, 2016.

[8] K. Ravi Kumar, K. Kiran, and V. S. Sreebalaji, "Micro structural characteristics and mechanical behaviour of aluminium matrix composites reinforced with titanium carbide," Journal of Alloys and Compounds, vol. 723, pp. 795-801, 2017, doi: 10.1016/j.jallcom.2017.06.309.

[9] R. J. Syed Ahamed and P. Shilpa, "A LITERATURE REVIEW ON ALUMINIUM-7075 METAL MATRIX COMPOSITES," 2019.

[10] S. Pradeep Devaneyan, R. Ganesh, and T. Senthilvelan, "On the Mechanical Properties of Hybrid Aluminium 7075 Matrix Composite Material Reinforced with SiC and TiC Produced by Powder Metallurgy Method," Indian Journal of Materials Science, vol. 2017, pp. 1-6, 2017, doi: 10.1155/2017/3067257.

[11] Woishnis, W., & Ebnesajjad, 5. (Eds.). (2011). "Fillers as reinforcement, Chemical resistance of thermoplastics (Vol. 1). William Andrew.

[12] V. Verma and A. Khvan, "A Short Review on Al MMC with Reinforcement Addition Effect on Their Mechanical and Wear Behaviour," in Advances in Composite Materials Development: IntechOpen, 2019.

[13] L. Mahesh, J. S. Reddy, and P. Mukunda, "Studies on titanium nitride reinforced aluminium metal matrix composites," International Journal of Mechanical Engineering and Technology, vol. 8, no. 3, 2017.

[14] P. Selvam, R. Sasikumar, and E. Natarajan, "Superior Material Properties of Hybrid Filler Reinforced Aluminium MMC through Double Layer Feeding Technique Adopted in Bottom Tapping Stir Casting," *High Temperature Material Processes: An International Quarterly of High-Technology Plasma Processes*, vol. 22, 2018, doi: 10.1615/HighTempMatProc.2018028877

[15] M. Kiran, H. Govindaraju, T. Jayaraju, and N. Kumar, "Effect of Fillers on Mechanical Properties of Polymer Matrix Composites," Materials Today: Proceedings, vol. 5, no. 10, pp. 22421-22424, 2018.

[16] K. Chawla, "On the applicability of the" Rule-of-Mixtures" to the strength properties of metal-matrix composites," Revista Brasileira de Física, vol. 4, no. 3, pp. 411-418, 1974.

[17] S. N. Trinh and S. Sastry, "Processing and properties of metal matrix composites," 2016.

[18] G. Manohar, A. Dey, K. Pandey, and S. Maity, "Fabrication of metal matrix composites by powder metallurgy: a review," in AIP Conference Proceedings, 2018, vol. 1952, no. 1: AIP Publishing LLC, p. 020041.

[19] M. Meignanamoorthy and M. Ravichandran, "Synthesis of metal matrix composites via powder metallurgy route," Mech Mech Eng, vol. 22, pp. 59-69, 2018.

[20] P. R. B. Mr. Azeem Dafedar, Dr. T. R. Vijayaram, "Processing & Characterization of Titanium Carbide & Titanium Oxide Particulate Reinforced Aluminium Metal Matrix Composite for Aerospace Applications," International Journal of Scientific & Engineering Research, vol. Volume 5, no. Issue 10, October-2014.