FABRICATION & PROPERTIES OF ALUMINIUM-ALUMINIUM OXIDE (Al/Al_2O_3) COMPOSITE MATERIAL

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Report submitted in partial fulfillment of the requirements
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“In the Name of Allah, the most Beneficent, the Most Merciful”

Special dedication to my beloved parents:

Mohammad Azmi Bin Masiral

&

Mudznah Binti Esmin

My respected supervisor:

Assc. Prof. Dr. Dewan Muhammad Nuruzzaman

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ABSTRACT

A composite is a material come from two or more material with different chemical properties. Metal matrix composites have a metal matrix and the fiber includes carbon and silicon carbide. In composites if the matrix is metal it is termed metal matrix composites. In this project, the metal matrix used is aluminium and the fiber material is aluminium oxide. The main objective of this project is to study the behavior of Al-Al2O3 composite in different volume fraction under various sintering temperature. In this project used powder metallurgy method. The steps of this method are mixing, compaction and sintering. Firstly, the mixing begin with prepar ing powder which is various in weight percentage 95% Al + 5% Al2O3, 90% Al + 10% Al2O3 and 85% Al + 15% Al2O3. Secondly, the mixed powders were pressed through compaction process by using the hydraulic press machine with 20 ton compaction load. Lastly, sintered in a furnace with different sintering temperature which is 500°C, 550°C and 580°C. The specimens are characterized and the microstructures of the composites were studied by using the optical microscope. Besides, the hardness was studied by using Vickers Micro Hardness testing machine. The different ceramic composition with different sintering temperature influences in the Al-Al2O3 composite material and affect the density before and after sintering process, hardness test and microstructure in Al-Al2O3 composite material.

ABSTRAK

Komposit adalah bahan datang dari dua atau lebih bahan dengan perbezaan ciri-ciri kimia. Logam matrik komposit mempunya logam matrik dan gentian termasuk karbon dan silicon karbida. Dalam projek ini, logam matrik komposit adalah aluminium dan bahan gentian adalah aluminium oksida. Objektif utama dalam projek ini adalah mempelajari kelakuan Al-Al2O3 komposit dalam perbezaan pecahan isipadu dibawah pelbagai suhu pensinteran. Dalam projek ini menggunakan kaedah pemprosesan serbuk. Langkah kaedah adalah pencampuran, pemadatan and pensinteran. Pertama, pencampuran bermula dengan menyediakan serbuk yang terdiri daripada pelbagai peratus berat 95% Al + 5% Al2O3, 90% Al + 10% Al2O3 dan 85% Al + 15% Al2O3. Kedua, serbuk campuran telah ditekan melalui proses pemadatan dengan menggunakan mesin hidraulik dengan 20 beban pemadatan. Terakhir, pensinteran dengan menggunakan relau dengan perbezaan suhu sinteran adalah 500°C, 550°C and 580°C. Specimen yang mempunyai ciri-ciri dan mikrostrutur bagi komposit telah diuji dengan menggunakan mikroskop optik. Disamping itu, kekerasan komposit telah diuji menggunakan mesin ujian Vickers Micro Kekerasan. Perbezaan komposit seramik dengan perbezaan suhu sinteran mempengaruhi dalam Al-Al2O3 bahan komposit dan kesan padat sebelum dan selepas proses sinteran, ujian kekerasan dan mikrostruktur dalam Al-Al_2O_3 bahan komposit.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

mol	Molecule
g	Mass
cm	Centimetre
ton	Mass or Volume
F	Force
D	Diameter
ρ	Density
V	Volume

LIST OF ABBREVIATIONS

PM	Powder Metallurgy
MMC	Metal Matrix Composite
Al_2O_3	Aluminium Oxide
HV	Hardness Value
Al	Aluminium

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

There was higher involvement to develop of metal matrix composites (MMCs) with the previous three decades. This is given it offers two or three one of kind mechanical properties such as low density, high strength, high hardness, high wear resistance along with the other properties. Nowadays a lot part in automobile industry like pistons, connecting rods, cylinder liners, control devices, train part and brake pads made from MMCs materials (Torralba, J.M et al, 2003).

A material made from two or more constituent materials with different chemical properties or physical that was a composite material when combine will be produce a material with characteristics different from the individual components. The matrix is the monolithic material into which the reinforcement is embedded and completely continuous while the reinforcement material is embedded into a matrix. The most common reinforcing materials are alumina and silicon carbide. This project will be combine aluminium-aluminium oxide composite by using powder metallurgy method. The advantages using this method because parts have good chemical homogeneity and the time taken to take a part from concept to production using powder metallurgy often quite short which has economic benefits.

1.2 PROBLEM STATEMENT

Aluminium is low in its hardness and the strength low same goes to its melting point. Thus the Aluminium oxide is added to improve since aluminium oxide have high hardness, high strength and high melting point.

1.3 OBJECTIVES

The objectives of this project are:

a. To fabricate the Al-Al_2O_3 composite by using powder metallurgy method.
b. To study the mechanical properties and characterization of Al-Al_2O_3 composite.

1.4 SCOPES

The method used for this project is powder metallurgy process which is was three main processes mixing used by mortar, compaction in cylindrical die and sintering with different temperature will be sintered. Before to characterization the specimen will set go through steps of metallographic. After that, the specimen was characterized the distribution of Al-Al_2O_3 composite using an optical microscope and for hardness using Vickers hardness tester.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The objective of this chapter is to provide the finding and the literature for evidence from previous study, which is related to the fabrication and properties of Aluminium – Aluminium Oxide. A review from the other relevant studies to this project is included in this chapter.

2.2 COMPOSITE MATERIALS

A composite is a material come from two or more material with different physical or chemical properties. Although most metallic alloys and metal ceramics have multiple phases they are not fit this definition because they are materialize as a result of natural phenomena. Many composite materials are comprised of just two phases which is one is known the matrix, which continuously called the dispersed phase. The example properties of component phase are volume fraction, shape and size of particle, distribution and orientation. Considering type and shape of reinforcement used in fabricating the final material composites can be classified to three main categories. It is consisting of particle-reinforced, fiber-reinforced and structural composites. Each group includes a minimum of two subdivisions. Equated dispersed phase is the main characteristic of particle-reinforced composites example particle dimensions are nearly the same in all directions whereas the dispersed phase of fiber-reinforced composites has the geometry of a fiber example a large length to diameter ration. Structural composites are mixtures of composites and homogenous materials (William and David, 2007).

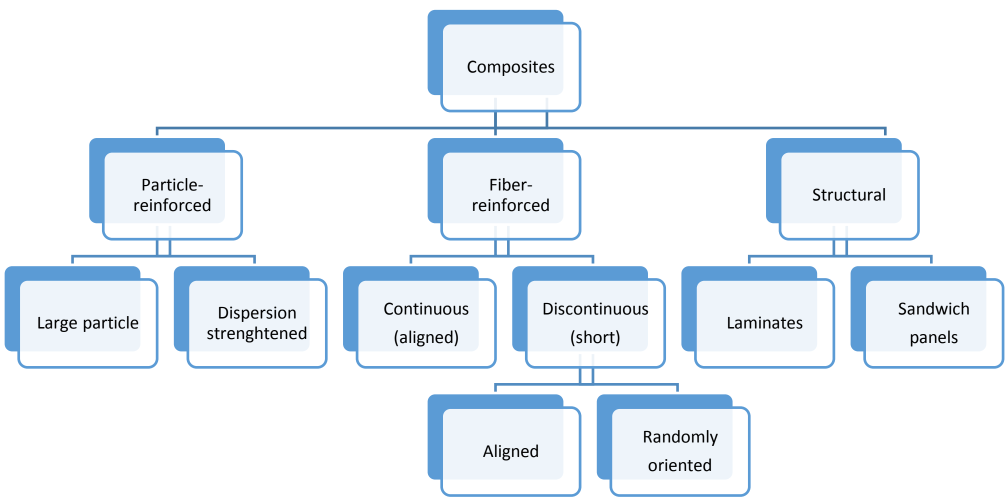


Figure 2.1: Classification for various composite

2.3 PARTICLE REINFORCED

Particle-reinforced composites are composing of two sub-divisions can be found as either large-particle or dispersion-strengthened composites. These two categories are distinguished by strengthening mechanism that is used to form the composite. When the particle-matrix relations is not to be discussed on the atomic or perhaps molecular level the term large-particle is used. The major of composites in this category consist of harder particulate phases than matrix material. The strengthening particles detain movement of the matrix phases in the neighborhood of each particle. In fact, a portion utilized stress is conveyed to the particles by matrix. Robust bonding at the matrix-particle interface plays an important role in improvement of mechanical behavior of composites. Among large-particle composites will be concrete which is constituted regarding cement this matrix in to sand and to gravel this is the particulates (K.U.Kainer, 2006).

2.4 FIBER REINFORCED

Reinforcing fibers can be made of metals, ceramics, glasses, or polymers that have been turned into graphite and known as carbon fibers. Fibers increase the modulus of the matrix material. The strong covalent bonds along the fiber’s length give them a very high modulus in this direction because to break or extend the fiber the bonds must also be broken or moved. Fibers are difficult to process into composites which makes fiber-reinforced composites relatively expensive. Fiber-reinforced composites are used in some of the most advanced, and therefore most expensive, sports equipment, such as a time-trial racing bicycle frame which consists of carbon fibers in a thermoset polymer matrix. Body parts of race cars as shown in figure 2.2 and some automobiles are composites made of glass fibers in a thermoset matrix (Tuttle, 2004)

Figure 2.2: Application for fiber reinforced composites

Source: Iran Composites Association

2.5 STRUCTURAL COMPOSITES

The properties of structural composites depend on constituents and geometrical design. Common structural composites types are laminar and sandwich panels. Laminar means composed of two dimensional sheets or panels that have a high strength direction and the layer are stacked and cemented together. Example for complex structure is modern ski and plywood (William and David, 2012).

Sandwich panels combined from two strong outer sheets known as face sheets who carry most of the loading and stresses and made of aluminum alloys, fiber reinforced plastics, titanium alloys and steel. Core may be a honeycomb structure has less density than the face sheets and resists perpendicular stresses and provides shear rigidity. Roofs, floors, walls of building and part of aircraft was a applications for sandwich panels (William and David, 2012).

2.6 METAL MATRIX COMPOSITES (MMCs)

Metal matrix composites, as the name implies, have a metal matrix. Examples of matrices in such composites include aluminum, magnesium and titanium. The typical fiber includes carbon and silicon carbide. Metals are mainly reinforced to suit the needs of design. For example, the elastic stiffness and strength of metals can be increased, while large co-efficient of thermal expansion, and thermal and electrical conductivities of metals can be reduced by the addition of fibers (Autar K. Kaw, 2005).

In composites if the matrix is metal it is termed a metal matrix composites. Many scholars link the expression metal matrix composites while using term light metal matrix composites. Metal matrix composites tend to be characterized by this reinforcement particle-reinforced metal matrix composites, small fiber or whisker reinforced metal matrix composites as well as continuous fiber or even layer metal matrix composites (K.U Kainer, 2006).

Aluminum is the dominant choice of matrix material for majority of the metal matrix composites. However, it must not be considered as the only one for instance titanium alloys are employed in metal matrix composites for some specific applications. These titanium alloys have enhanced strength to weight ratios as well as improved strength retentions at 400-500˚C than those of aluminum alloys. Titanium metal matrix composites are applied in applications where performance is challenged regardless of cost efficiency (M. Rosso, 2006).

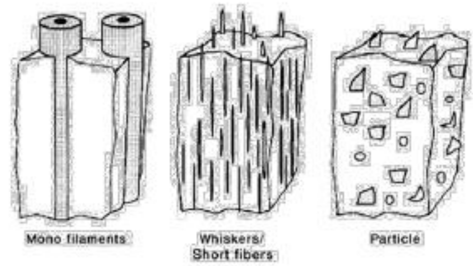


Figure 2.3: Schematic illustration of three types of MMCs materials.

Scource: Kalpakjian and Schmid, (2010).

2.7 MATRICES

The role of matrix in a fiber-reinforced composite is to transfer stress between the fibers, to provide a barrier against an adverse environment and to protect the surface of the fibers from mechanical abrasion. The matrix plays a major role in the tensile load carrying capacity of a composite structure. The binding agent or matrix in the composite is of critical importance. Four major types of matrices 8 have been reported: Polymeric, Metallic, Ceramic and Carbon. Most of the composites used in the industry today are based on polymer matrices. Polymer resins have been divided broadly into two categories Thermosetting and Thermoplastics.

2.8 REINFORCEMENT

The reinforcement material is embedded into a matrix does not always serve a purely structural task but is also used to change physical properties. The reinforcement can be either continuous or discontinuous who can be isotropic and can be worked with standard metalworking techniques.

2.9 POWDER METALLURGY

Powder Metallurgy is mostly used for the production of discontinuously reinforced MMCs and has four main process which is powder production, mixing or blending, compaction and the last sintering. The powder metallurgical was introduced to cut the problems of wetting and interfacial reactions often encountered with liquid processing with has benefit to improved distribution of particulates in discontinuously reinforced MMCs (Stone and Tsakiropoulos, 1993).

Figure 2.4: Process of Powder Metallurgy

The reason powder metallurgy route is most popular to manufacture of MMCs because of some advantages compare to others method which is lower temperature, decreased possibility of chemical reaction between matrix and reinforcements. Also, long term reliability through close control of dimensions and physical properties (Gheorghe and Rack, 2000).

2.9.1 Mixing

The mixing or blending process is an important stage in the preparation of MMCs. This process controls the distribution of the reinforcing particles and the green density of the pressed compacts which is affects the mechanical properties of the MMCs (Liu and Lim 1993).

2.9.2 Compaction

After the powder mixing compaction process will be apply pressurize bond the particles to form a cohesion among the powder particles. Compaction is carried out by pouring a measured amount of powder into the die cavity and will be applying pressure. This creates a solid part called a green compact and can be broken apart by hand but is also strong enough to be handled. This process to create the desired shape, control of dimensional, control porosity and to impart adequate strength for handling (C.A Mitchell, 2002).

During compaction a lubricant is usually used mixed with the powder and applied to the walls of the die to reduce friction between the powder and the tooling surfaces. Some clearance between the punch and die must in order for the punch to easy move within the die. The requisite compacting pressure depends on the specific characteristics and initial shape of the particle, the method of blending and the application of lubricants.

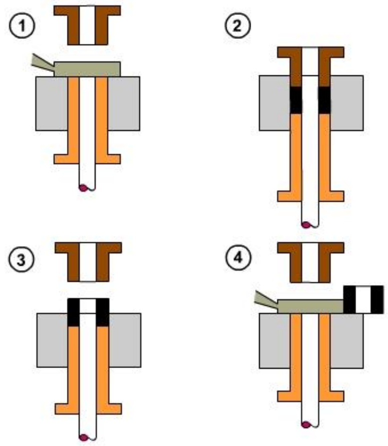


Figure 2.5: Compacting process cycle

Source: Russo (2014)

2.9.3 Sintering

During this stage the green compact is heated in furnace with a suitable temperature which is below the melting point of the metal to a certain level and keeping it at that temperature for a certain amount of time. This will cause bonding mechanisms to occur between powders particles pressed together in the compact and sintering greatly strengthens the part.

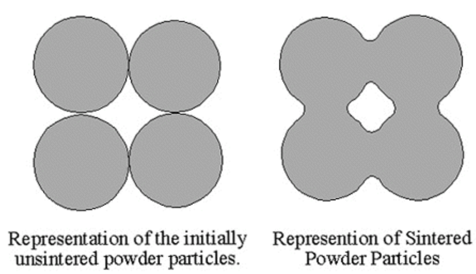


Figure 2.6: Schematic for sintered process

Source: Kalpakjian and Schmid, (2010).

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter will discuss regarding the method used to fabricate which powder metallurgy. Then, guides about the preparing of specimens step by step to achieve the aims of this project.

3.2 POWDER METALLURGY PROCESS

As mention before powder metallurgy have four main processes which is powder production, mixing or blending, compaction and sintering. So, in this project will following process flow as shown in Figure 3.1.

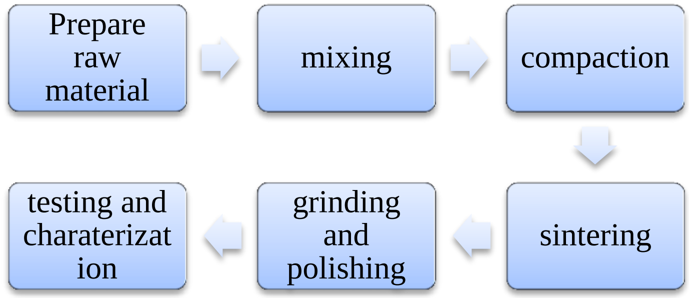


Figure 3.1: Flowchart of Powder Metallurgy

3.3 PREPARE RAW MATERIAL

The aluminium and alumina powders will be weighed with different composition by used the digital weight balance as shown in Figure 3.2. Molecular weight for Aluminium is 26.98 g/moles while the alumina 101.96 g/mol. After that, the powders will save with different container.

Figure 3.2: Digital weight balance for weighing powder

Three compositions of the powder mixtures were used. The compositions varied with the volume fraction as shown in the table below.

Aluminium	Aluminium oxide
95%	5%
90%	10%
85%	15%

Table 3.1: Percentage of composition

3.4 MIXING POWDERS

The Aluminium and alumina powder were thoroughly mixed together firstly. The mixture by used pastel mortar for about 1 hours until the uniform distribution for both of powder but not to be longer than needed. In this process mixing is to combining and homogeneously distributing particles of different materials. Over mixing can decrease particle size, alter particle shape and work harden particles. During mixing atmosphere must be controlled to avoid contamination such as the forming of oxides on particle surfaces.

Figure 3.3: Mixing process by used pastel mortar

3.5 COMPACTION PROCESS

In this process, the mixed are pressed into the cylindrical steel die shapes using hydraulic press machine and the pressure used is 20 ton. This pressure was enough to hold the powder together. The pressed powder is called green compact which means not yet fully processed and the specimens not strong enough. During process the die surface should be thoroughly cleaned by using Meguiar's Mold Release Wax and also smeared by a little bit of alumina.

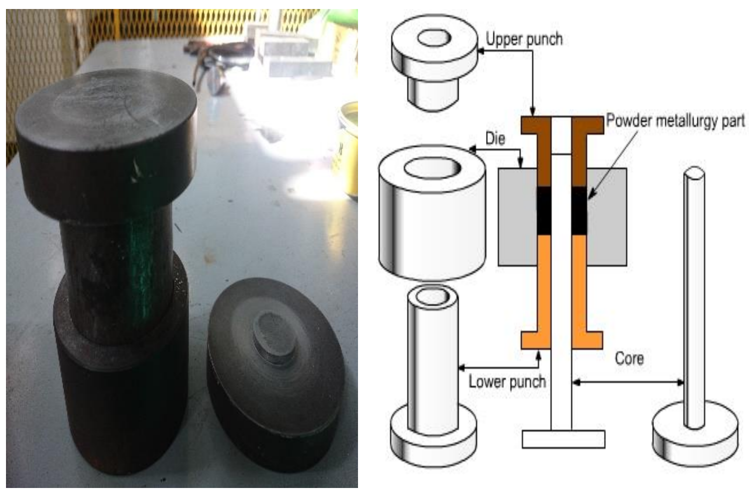


Figure 3.4: Cylindrical steel die

Figure 3.5: Meguiar's Mold Release Wax

Figure 3.6: Hydraulic Press machine

3.6 SINTERING

Sintering is the process reduces the porosity and increased the strength this will cause bonding mechanism to occur between powder particles compressed together in the compact. After all the specimen compacted continue with sintering with different temperature which is 500°C, 550°C and 580°C. There are started with the 30°C and stopped at 400°C this is the first cycle and holding process around 30 minutes. After first cycle finish continue with second cycle which is start from 400°C and stopped at 500°C, 550°C or 580°C and holding time 1 hour and 30 minutes.

Figure 3.7: Furnace

Figure 3.8 and 3.9 show the heating curve from the cycle to the second cycle of heating. There are started at 30°C and stopped until 400°C and holding about 30 minutes. After holding around that time the specimen continue sintering process at the second cycle of heating. When the temperature stopped at on what temperature set and undergoes the holding time for 1 hour.

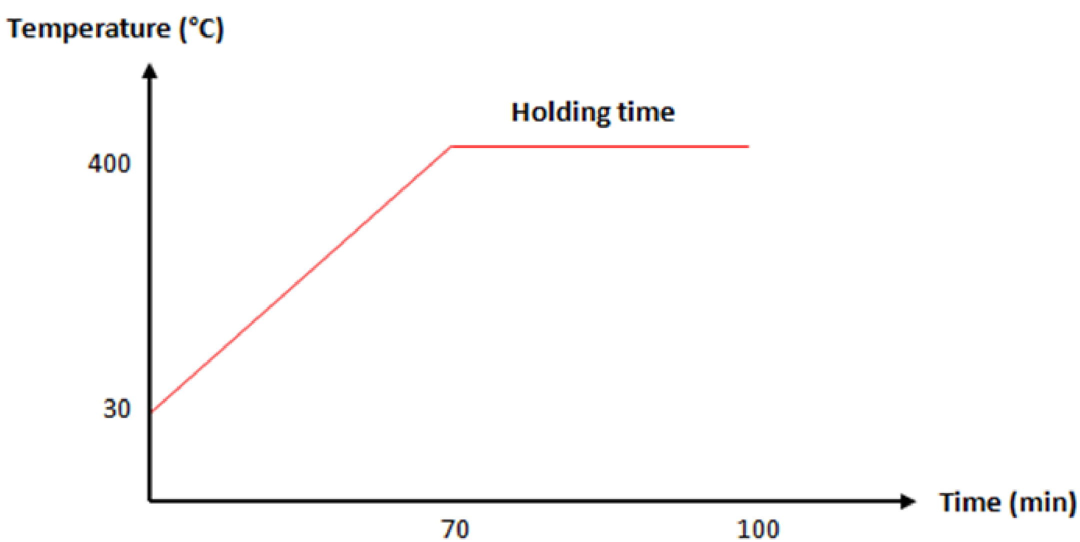


Figure 3.8: First cycle of heating curve

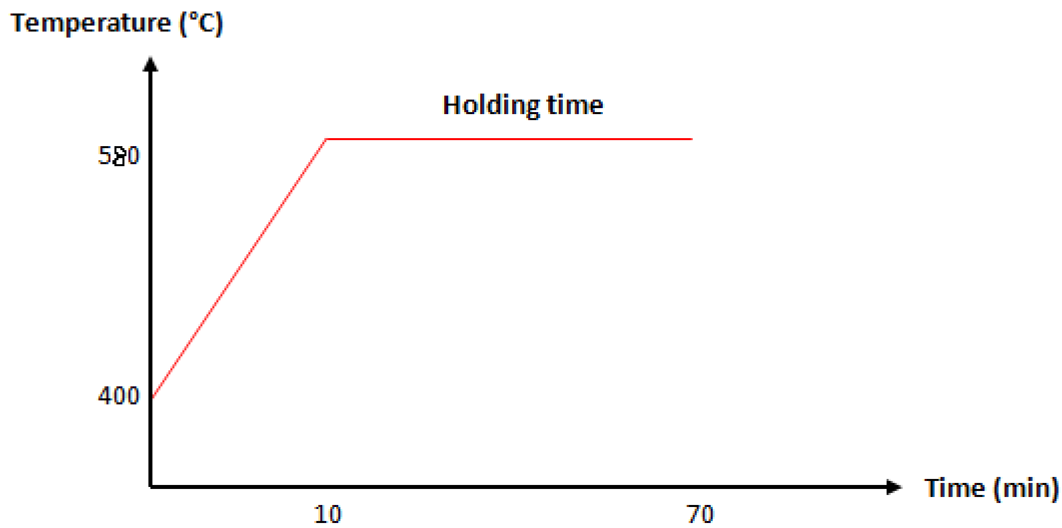


Figure 3.9: Second cycle of heating curve

3.7 MOUNTING AND GRINDING

In order to characterize the specimen was set to go through several step of metallographic sample preparation in order to study the microstructure and hardness test. The equipment use for microstructure is optical microstructure and for hardness test used by Vickers micro hardness tester. In this project the metallographic specimen preparation is carried out by mounting and grinding.

1. Mounting
   Mounting of specimen actually to be handled easily and also minimizes the amount of damage. A mounted specimen should have a thickness about half its diameter to prevent rocking during grinding and polishing and to avoid damage during grinding or polishing recommended the edges should be rounded.

2. Grinding
   After mounted, the specimen is grinded with six different grit roughness's which are 180, 240, 400,600, 800, and 1200 SiC to produce a fine surface by using grinding

machine. The grit paper was used start 180 till 1200 with the speed 300 rpm. However, the grit paper need to be changed for every time of grinding.

3.8 MICROSTRUCTURAL ANALYSIS

The microstructure can be analysis by capturing the image of the specimen after polishing by used optic microstructure. The microstructure of specimens is studied at magnification of 10X.

Figure 3.10: Optical Microscope

3.9 HARDNESS ANALYSIS

Hardness of the composite specimens was measured by using Vickers hardness tester to study the strength or mechanical behaviour of the composite. For each specimen at least 15 measurements had been taken at equivalent positions on the sample. The Vickers hardness test uses a square-base diamond pyramid as the indenter.

Figure 3.11: Vickers Micro Hardness

CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter includes all the results obtained from the fabrication. In this chapter data were be collected data before and after process fabrication of the specimen which are aluminium and aluminium oxide. The specimen with different composition but all the specimen has same compaction load is 20 ton but from the sintering process has three different temperatures which is 500°C, 550°C and 580°C.

4.2 SINTERING RESULT

Sintering is a forth process fabricated Al-Al2O3 by used powder metallurgy method composites material to reduce the porosity and increased the strength and also hardness. As mentioned in previous chapter, this sintering process has three different temperatures which is 500ºC, 550ºC, and 580ºC but compacted with the same load which is 20 ton. Before and after sintering will collected data such as weight, thickness and diameter. Thickness and diameter measured by using vernier calipers and digital weight for weight. Table 4.1 shows the data recorded in 500ºC, 550ºC, 580ºC of sintering.

Table 4.1 500ºC of Sintering Temperature

Specimen (%)	Before sintering			After sintering		
	Weight (g)	Thickness (mm)	Diameter (mm)	Weight (g)	Thickness (mm)	Diameter (mm)
95Al + $5Al_2O_3$	4.65	2.6	30.0	4.62	2.5	30.1
90Al + $10Al_2O_3$	4.70	2.7	30.0	4.67	2.6	30.1
85Al + $15Al_2O_3$	4.81	2.8	30.0	4.78	2.7	30.1

Table 4.2 550ºC of Sintering Temperature

Specimen (%)	Before sintering			After sintering		
	Weight (g)	Thickness (mm)	Diameter (mm)	Weight (g)	Thickness (mm)	Diameter (mm)
95Al + 5Al_2O_3	4.80	2.7	30.0	4.75	2.6	30.2
90Al + 10Al_2O_3	4.95	2.8	30.0	4.89	2.7	30.1
85Al + 15Al_2O_3	5.23	2.9	30.0	5.18	2.8	30.1

Table 4.3 580ºC of Sintering Temperature

Specimen (%)	Before sintering			After sintering		
	Weight (g)	Thickness (mm)	Diameter (mm)	Weight (g)	Thickness (mm)	Diameter (mm)
95Al + $5Al_2O_3$	4.89	2.8	30.0	5.24	2.8	30.3
90Al + $10Al_2O_3$	5.24	2.9	30.0	5.34	2.8	30.2
85Al + $15Al_2O_3$	5.35	3.0	30.0	5.59	2.9	30.2

4.3 DENSITY

Table 4.4 shows the density variations of different sintering temperature of Al-Al_2O_3 composite materials specimens before and after the sintering process. These specimens were sintered 500ºC, 550ºC and 580ºC then using 20 ton compacting load. The different of thickness influenced the density of specimens.

From the graph, Figure 4.1, 4.2 and 4.3 show the graph of the density versus the Al-Al_2O_3 percentage. The graph showed there are increases in each value of density after the sintering process. The existence of Al_2O_3 make higher in the density of the material as long as the reinforcements are uniformly distributed in the aluminium matrix. Theoretically, as the aluminium oxide percentage higher, the density differentiates after sintering will increased.

Table 4.4 Density variations of different sintering temperature

Specimen (%)	Before sintering			After sintering		
	500ºC	550ºC	580ºC	500ºC	550ºC	580ºC
95Al + $5Al_2O_3$	2.53	2.52	2.47	2.60	2.55	2.59
90Al + $10Al_2O_3$	2.46	2.50	2.55	2.52	2.54	2.66
85Al + $15Al_2O_3$	2.43	2.55	2.52	2.49	2.60	2.69

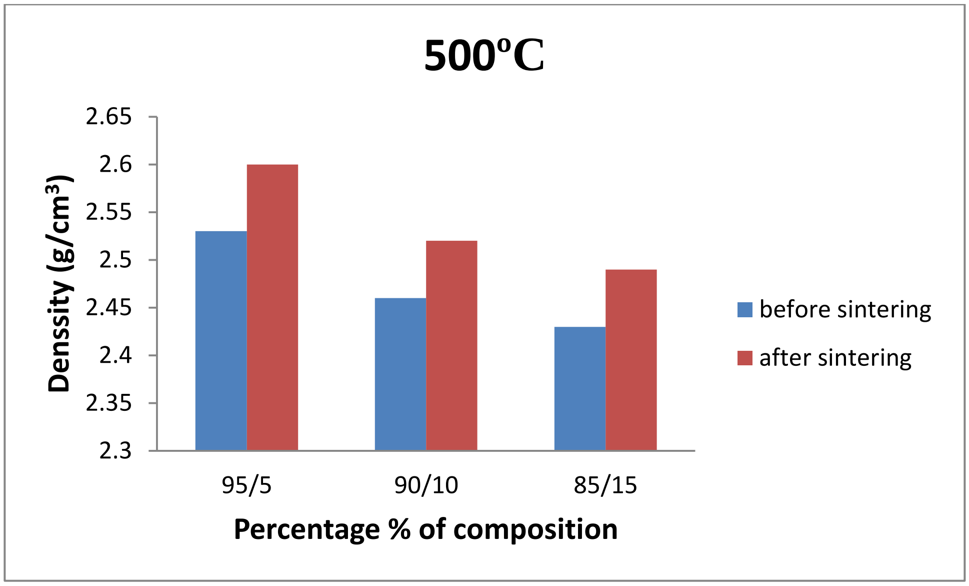


Figure 4.1 Density of 500°C sintering temperature

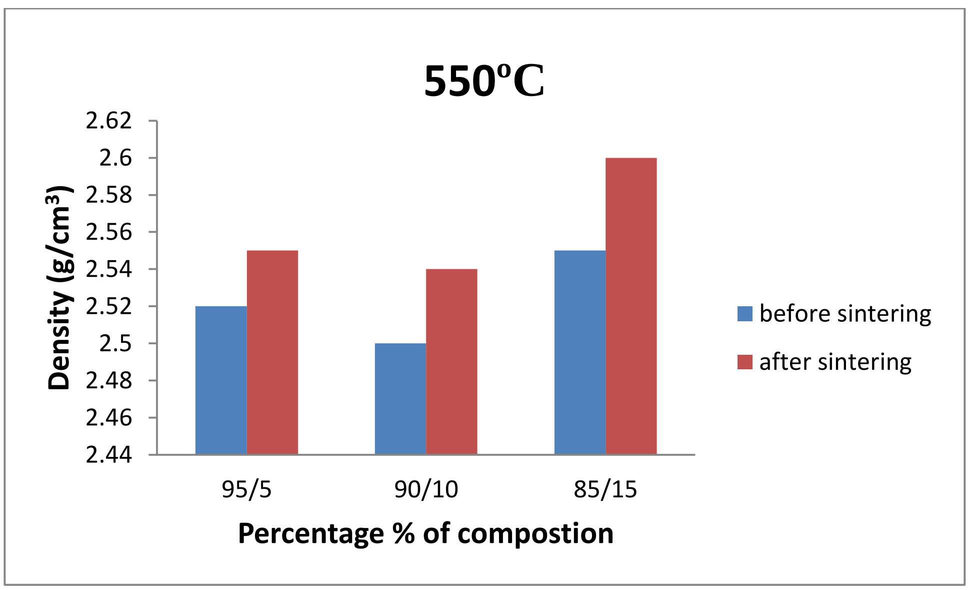


Figure 4.2 Density of 550°C sintering temperature

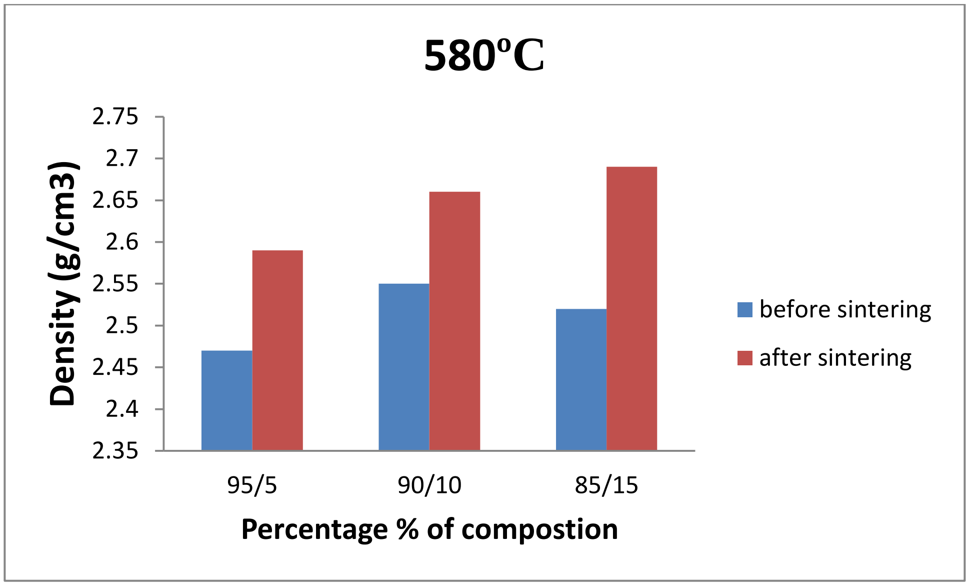
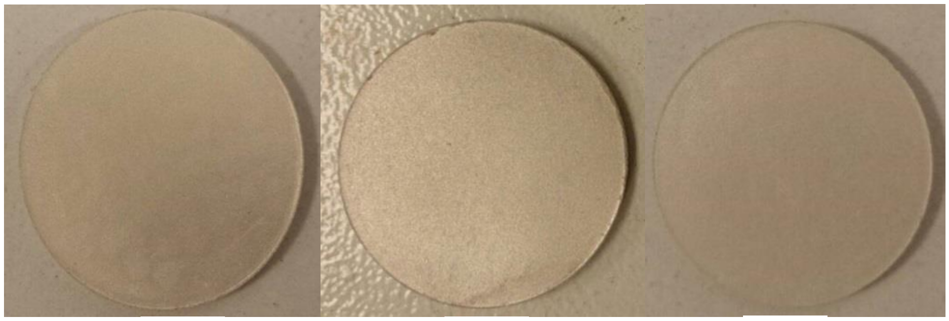


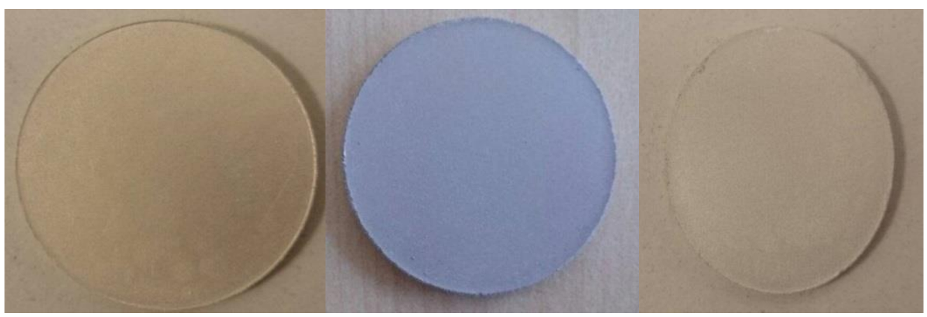
Figure 4.3 Density of 580°C sintering temperature

Figure 4.4 Specimens for 500°C sintering temperature (a) 95% Al + 5% Al_2O_3 (b) 90% Al + 10% Al_2O_3 (c) 85% Al + 15% Al_2O_3



(a) (b) (c)

Figure 4.5 Specimens for 550°C sintering temperature (a) 95% Al + 5% Al_2O_3 (b) 90% Al + 10% Al_2O_3 (c) 85% Al + 15% Al_2O_3



(a) (b) (c)

Figure 4.6 Specimens for 580°C sintering temperature (a) 95% Al + 5% Al_2O_3 (b) 90% Al + 10% Al_2O_3 (c) 85% Al + 15% Al_2O_3

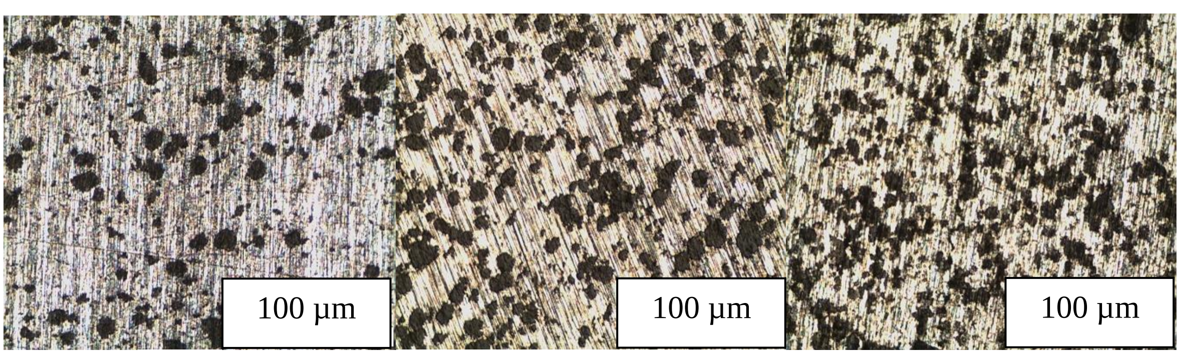
4.4 MIROSTRUCTURE ANALYSIS

The micrograph shows the Al_2O_3 particles are distributed uniformly and agglomerate in the Al matrix. The microstructure of the all specimens were using optical microscope. Before that, the samples were grinding and polished using silicon carbide paper which is 180, 240, 400, 600, 800, 1200 and 1500 grit. The micrograph also showed the different sharpness of the microstructures was because of the different sintering temperature used.

Figure 4.7 shows the microstructure of each composition for 500ºC sintering temperature. The all micrographs show the Al_2O_3 particles are agglomerate and also uniformly distributed in the aluminium matrix. It is because they are properly bonded during the fabrication process. In the micrograph, the whitish is the aluminium particles and the blackish is the Al_2O_3 particles.

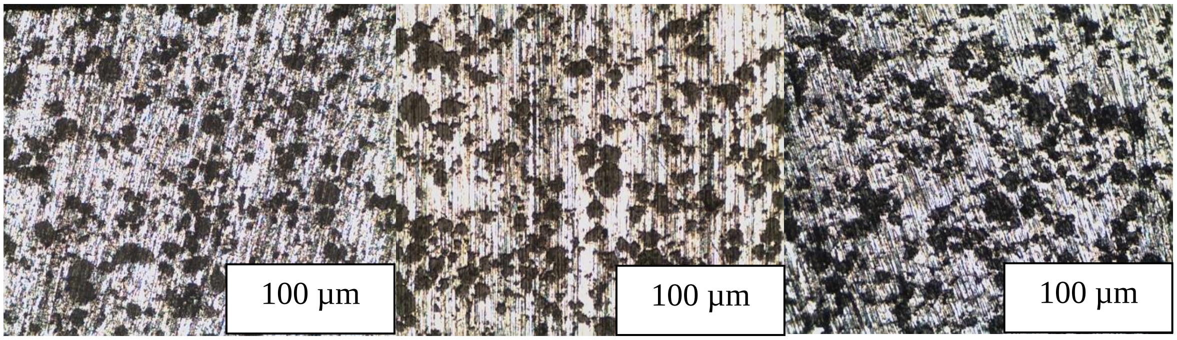
Figure 4.8 shows the microstructure of each composition for 550ºC sintering temperature. The all micrograph shows the Al_2O_3 particles has are not agglomerate in the aluminium matrix. It is because they are not properly bonded during fabrication process which is mixing process. In the micrograph, the whitish is the aluminium particles and the blackish is the Al_2O_3 particles.

Figure 4.9 shows the microstructure of each composition for 580ºC sintering temperature. Micrograph indicates the nearly uniform distribution of the alumina particles in the aluminium matrix even has are not agglomerate. This is effect during fabrication process. As in the micrograph, the whitish is the aluminium particles and the blackish is the Al_2O_3 particles.



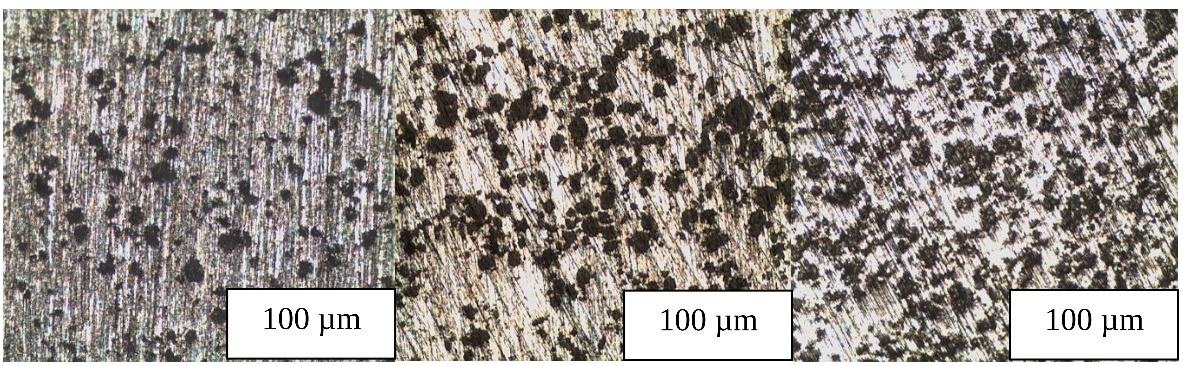
(a) (b) (c)

Figure 4.7 Microstructure of 500ºC (a) 95% Al + 5% Al_2O_3 (b) 90% Al + 10% Al_2O_3 (c) 85% Al + 15% Al_2O_3



(a) (b) (c)

Figure 4.8 Microstructure of 550ºC (a) 95% Al + 5% Al_2O_3 (b) 90% Al + 10% Al_2O_3 (c) 85% Al + 15% Al_2O_3



(a) (b) (c)

Figure 4.9 Microstructure of 580ºC (a) 95% Al + 5% Al_2O_3 (b) 90% Al + 10% Al_2O_3 (c) 85% Al + 15% Al_2O_3

4.5 HARDNESS

Vickers micro hardness measurements were performed on polished the specimens with dwell time 15 second. The average of 10 indentations in each specimen was used to calculate the exact value of the specimens. Results below showed the hardness increased when the temperature sintering increase and also the hardness increased as the increase of Al_2O_3 percentage.

Figure 4.10 shows the graph of different hardness based on different sintering temperature. The hardness of specimens on 580ºC sintering temperature is the highest among three different sintering temperature. We know that when the sintering temperature applied highest so, the hardness will increased.

There are higher value hardness in 85% Al and 15% Al_2O_3 in each graph compare the others this is because more ceramic in the metal matrix composite will caused the hardness increased.

Table 4.5: Hardness variations of different sintering temperature

Specimen	**Vickers Hardness (HV)**		
	500	550	580
95Al + $5Al_2O_3$	21.13	22.55	24.57
90Al + $10Al_2O_3$	22.04	23.48	25.33
85Al + $15Al_2O_3$	23.58	24.81	25.38

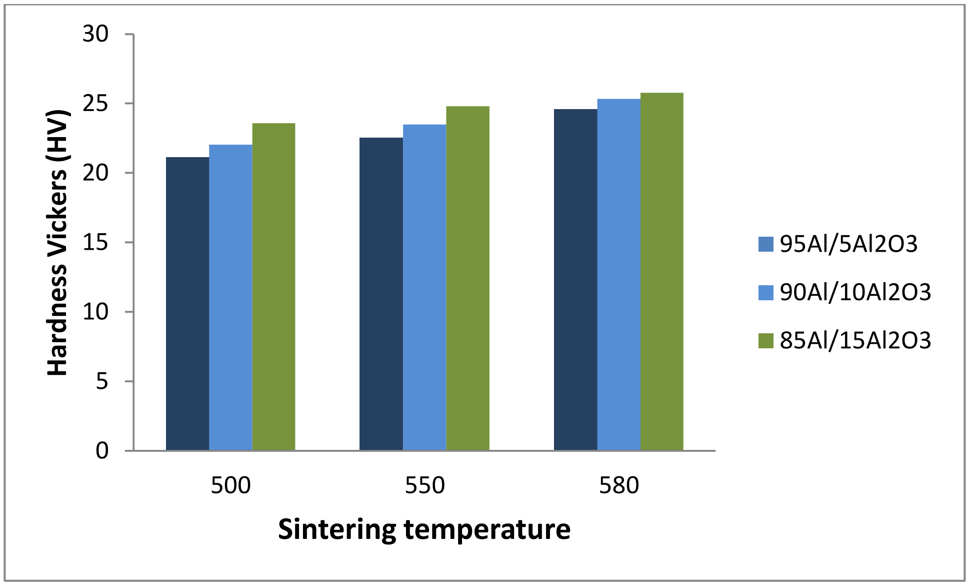


Figure 4.10: Graph of different hardness based on different sintering temperature.

4.6 DISCUSSION

1. Because of density of Al_2O_3 is higher than aluminium, the addition of Al_2O_3 leads to an increase the density in the each of specimen in Al-Al_2O_3. After sintering process, the density of each specimen increase in Al-Al_2O_3 composite.
2. The micro hardness test it can be conclude that the hardness of the specimen increased with the increase of Al_2O_3 in Al-Al_2O_3 composite.
3. The increased of sintering temperature leads to the increase of hardness of the Al-Al_2O_3 composite.
4. The microstructural analysis, it can be seen the Al_2O_3 particles are uniformly distributed in aluminium matrix and there has different sharpness of the microstructure possible because of the different sintering temperature used.

CHAPTER 5

CONCLUSION & RECOMMENDATION

5.1 INTRODUCTION

This chapter overall concludes the current research and includes the recommendations for future work. The objectives are also determined in order to find whether the objectives are achievable or vice versa.

5.2 CONCLUSION

In this study, the effects of volume fraction of Al_2O_3 and different sintering temperature on the properties Al-Al_2O_3 composites were investigated. It is observed that density of the each composite specimen increase with a rise of Al_2O_3 percentage in Al-Al_2O_3 composites.

After that, the hardness of the specimen increased with a rise of Al_2O_3 in Al-Al_2O_3 composite. The increased in the sintering temperature will increased the hardness of Al-Al_2O_3 composite. Under 580°C sintering temperature, the hardness of Al-Al_2O_3 composites all of composition is higher than the other hardness which are 500°C and 550°C sintering temperature.

Then, the micrograph show that there are uniformly distribution of Al_2O_3 in the aluminium matrix and also the sharpness of the micrograph can be seen during the microstructural analysis.

Here, all the objective in this project are achieved to understand the effect of volume fraction of Al-Al_2O_3 composite materials under different of sintering temperature.

5.3 RECOMMENDATION

I. Using two different method to know the best method for the improvement of the properties of the composites material.

II. Using a proper powder processing technique in order to produce better specimen with well distributed and agglomerate area during manual mixing and blending process.

III. Using the Rockwell and Brinell hardness test to compare the best testing

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APPENDIX A

SAMPLE CALCULATION OF WEIGHT PERCENTAGE OF ALUMINIUM AND ALUMINIUM OXIDE POWDERS

Before aluminium and silicon carbide powders need to be weighed, the compositions of both materials have been decided with:

Aluminum, Al (%)	**Aluminium oxide, Al_2O_3 (%)**
95	5
90	10
85	15

The molecular weight of aluminium is 26.98 g/mol while for aluminium oxide is 101.96 g/mol.

95% Al – 5% Al_2O_3

$$Al = \frac{95}{100} \times 26.98 = 25.63\ g$$

$$Al2O3 = \frac{5}{100} \times 101.96 = 5.10\ g$$

90% Al – 10% Al_2O_3

$$Al = \frac{90}{100} \times 26.98 = 24.28\ g$$

$$Al2O3 = \frac{10}{100} \times 101.96 = 10.20\ g$$

85% Al – 15% Al_2O_3

$$Al = \frac{85}{100} \times 26.98 = 22.93\ g$$

$$Al2O3 = \frac{15}{100} \times 101.96 = 15.29\ g$$

APPENDIX B

SAMPLE CALCULATION OF SPECIMEN'S DENSITY

The specimen's density has been calculated by using a simple density formula which is:

$$\rho = \frac{m}{V}$$

$$\rho = \text{density}\,, \text{m} = \text{mass}\,, \text{V} = \text{volume}$$

The diameter(cm), thickness(cm) and weight(g) of each Al-Al_2O_3 specimen. Here, is the sample calculation.

$$Volume, V = \pi r^2 h$$

$$= \pi(15^2)(2.8)$$

$$= 1979.20\ mm$$

$$Density, \rho = \frac{m}{V}$$

$$= \frac{4.89}{1979.20}$$

$$= 2.47\ \frac{g}{cm^3}$$

APPENDIX C

Gantt chart FYP1

No	Project Activities		WEEKS													
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
1.	Registration of SV/Panel	**Plan**												PRESENTATION WEEK		
		Actual														
2.	Title Registration/Updates	**Plan**														
		Actual														
3.	Submit FYP Executive Summary	**Plan**														
		Actual														
4.	Milestone 1															
	a) Submit Chapter 1 and Gantt Chart	**Plan**														
		Actual														
5.	Milestone 2															
	a) Submit Corrected Chapter 1	**Plan**														
		Actual														
	b) Submit Chapter 2 and Gantt Chart	**Plan**														
		Actual														
6.	Milestone 3															
	a) Submit Corrected Chapter 2	**Plan**														
		Actual														
	b) Submit Chapter 3 and Gantt Chart	**Plan**														
		Actual														
7.	Milestone 4															
	a) Material/Tool Order	**Plan**														
		Actual														
	b) Submit Final Report (Chapter 1,2,3)	**Plan**														
		Actual														

Gantt chart FYP2

No	Project Activities		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1.	Prepare the specimen														PRESENTATION WEEK	
	a) Mixing and Blending	**Plan**														
		Actual														
	b) Compaction	**Plan**														
		Actual														
	c) Sintering	**Plan**														
		Actual														
2.	Cold mounting, grinding and polishing	**Plan**														
		Actual														
3.	Run mechanical testing and collect data															
	a) Microstructural analysis	**Plan**														
		Actual														
	b) Vickers hardness test	**Plan**														
		Actual														
4.	Comparing data	**Plan**														
		Actual														
5.	Interpret data	**Plan**														
		Actual														
6.	Discuss the result and conclude	**Plan**														
		Actual														
7.	Prepare the final presentation	**Plan**														
		Actual														
8.	Submission of thesis	**Plan**														
		Actual														