ON THE MICROSTRUCTURE PROPERTIES CORRELATION OF THE RECYCLED ALUMINIUM ALLOY

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B. ENG. (HONS.) MANUFACTURING ENGINEERING

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SUPERVISOR'S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Bachelor of Engineering in Manufacturing.

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STUDENT'S DECLARATION

I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

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ABSTRACT

This study relates with recycled aluminium alloy. Aluminium is the third most abundant element on earth. It is widely used in aerospace and automobile industry. However, aluminium used mostly in industry are recycled aluminium. This is because recycled aluminium only needs 5% of energy needed compared to energy needed to produce aluminium from its ore. Unfortunately, recycling of aluminium generates secondary aluminium which is high in Fe content. Presence of Fe lowers ductility and tensile strength on aluminium. Iron increases the porosity in aluminium alloy. This is due to the presence of brittle β-Al_5FeSi Needle structure in high Fe content recycled aluminium alloy. The motive of this study is to reduce the presence of brittle β-Al_5FeSi Needle structure by inoculation method. The innoculation elements are Nickel and Chromium. The objective of this study is to conduct melting and casting experiments of recycled aluminium, to study the effect of heat treatment on aluminium alloy, to study the microstructure properties of aluminium alloy by innoculation and to study the tensile strength of aluminium alloy. From the result of this study, 1.0% of Ni is the best innoculation percentage for as-cast alloy, 2.0% of Ni is the best innoculation percentage for heat treated alloy, 2.0% of Cr is the best innoculation percentage for as-cast alloy and finally 2.0% of Cr is the best inoculation percentage for heat treated alloy.

ABSTRAK

Kajian ini berkaitan dengan aloi aluminium yang dikitar semula. Aluminium adalah unsur yang paling banyak yang ketiga di bumi. Ia digunakan secara meluas dalam aeroangkasa dan industri automobil. Walau bagaimanapun, aluminium yang digunakan kebanyakannya dalam industri adalah aluminium yang dikitar semula. Ini kerana aluminium yang dikitar semula hanya memerlukan 5 % daripada tenaga yang diperlukan berbanding dengan tenaga yang diperlukan untuk menghasilkan aluminium daripada bijihnya.

Malangnya, aluminium yang dikitar semula menjana aluminium kategori kedua yang tinggi dengan kandungan Fe. Kehadiran Fe merendahkan kemuluran dan kekuatan tegangan pada aluminium. Iron meningkatkan keliangan dalam aloi aluminium. Ini adalah disebabkan oleh kehadiran rapuh struktur bentuk jarum β - Al5FeSi yang tinggi dalam kandungan kitar semula aluminium aloi. Motif kajian ini adalah untuk mengurangkan kehadiran rapuh struktur β - Al5FeSi jarum dengan kaedah inokulasi. Unsur-unsur innoculation adalah nikel dan kromium. Objektif kajian ini adalah untuk menjalankan lebur dan pemutus eksperimen aluminium yang dikitar semula , untuk mengkaji kesan rawatan haba ke atas aloi aluminium, untuk mengkaji sifat mikrostruktur aloi aluminium dengan innoculation dan mengkaji kekuatan tegangan daripada aloi aluminium. Dari hasil kajian ini , 1.0 % daripada Ni adalah peratusan innoculation terbaik aloi as- cast, 2.0% daripada Ni adalah yang terbaik innoculation peratusan bagi haba yang dirawat aloi, 2.0% daripada Cr adalah yang terbaik innoculation peratusan bagi as- cast aloi dan akhirnya 2.0% daripada Cr adalah peratusan inokulasi terbaik haba yang dirawat aloi.

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CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

Aluminium is a silvery white, ductile and soft metal. It is found to be the third most abundant element on earth. It has low density and good corrosion resistance. However, it has weak tensile strength. Due to this, aluminium is mostly alloyed with other elements to enhance its properties. Aluminium alloys are widely used in electrical conductors, transportation, packaging, building and architecture. Aluminium alloy due to its high strength-to- weight ratio and good corrosion resistance is widely used in aerospace and automobile industries. Aluminium alloy is used to make body frames, structural components, engine casting and other compartments. The manufacturing of aluminium is done by electrolysis. Electrolysis need to be done to extract aluminum from bauxite ore which needs high electrical capacity. High electrical capacity cost is expensive, therefore aluminium is need to be recycled. 95% of energy are saved by recycling of aluminium instead of producing it[1]. However, recycling of aluminium tend to increase the iron content in the aluminium. Probably due to handling of the scrap, iron occurs to be the most common impurity in aluminium. High iron content of aluminium can adversely affect the mechanical properties of aluminium. To overcome this problem, aluminium is normally alloyed with other elements to react with the iron content [3].

As to this, this research is done to study the microstructure properties of aluminium alloy. This research is to study the effect of alloying aluminium with other elements on the microstructure of aluminium alloy and also to study the heat treatment influence on aluminium alloy.

1.2 PROBLEM STATEMENT

There is a huge increase in the usage of aluminium alloy in many industries today especially in aerospace and automobile industry. Due to this, aluminium are mostly recycled to save the energy and to lower the cost of production. However, recycling of aluminium generates secondary aluminium which is high in iron content. High iron content in aluminium causes ductility and decreasing its tensile strength of aluminium. Furthermore, high content of iron causes porosity in the aluminium. Thus, to overcome this problem should be tested.

1.3 PROJECT OBJECTIVE

The main objective of this project is:

a) To conduct melting and casting experiments of recycled aluminium.
b) To study the effect of heat treatment on aluminium alloy.
c) To study the microstructure properties of aluminium alloy by inoculation.

1.4 PROJECT SCOPE

This research is focused on carrying out microstructure studies of aluminium alloy that able to reduce the iron content in aluminium alloy and analyze the tensile mechanical properties of Ultimate Tensile Strength (UTS) or in other words, tensile strength. The microstructure study is done by optical microscope and scanning electron microscopy (SEM). The tensile strength is tested by using Universal Testing Machine (UTM) with an American Society of Testing and Materials (ASTM) standard.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter gives a review of the past research efforts related to the microstructure study on the aluminium alloy; its mechanical method and procedure and the properties of microstructure of aluminium alloy. Review of other related research studies are also provided. These are organized orderly to give an understanding on how the past research efforts have set up the foundation for subsequent studies, including the present research effort. The reviews are detailed so that the present research effort can be properly fitted to add to the present body of literature as well as to justify the scope and direction of the present research effort.

2.2 ALUMINIUM

Aluminium is found to be third most abundant element on earth. Aluminium is a silvery-white, non-magnetic, soft, ductile metal, and light in weight. It has high strength to weight ratio and good corrosion to resistance. It's density of 2.70 g/cm^3. Aluminium has good corrosion resistance due to presence of strong protective oxide layer which prevents corrosion of the base material. Aluminium is brittle and soft but it can be strengthened by alloying with other elements like magnesium ,copper , vanadium or nickel[2].

Aluminium is made by chief ore bauxite. The process of making aluminium commercially is called Hall-Heroult Process. The general procedure for Hall-Heroult Process are:

1) Aluminium oxide is separated from the iron oxide in bauxite in a concentrated sodium hydroxide solution.
   (Soluble complex ion is formed when aluminum ions with hydroxide ions but iron ions do not)

2) After the filtration of insoluble iron oxide from the solution, $Al(OH)_3$ is precipitated from the solution by adding acid.
   (Addition of acid is to lower the pH to about 6)

3) After that, heating process is done to produce dry Al_2O_3 (alumina).

4) Electrolysis process is done using alumina to obtain aluminium metal.

5) Aluminium metal is collected at the cathode.

2.3 RECYCLING OF ALUMINIUM

Aluminium could be recycled without losing any of its superior characteristics. Recycling of aluminium only uses 5% of energy compared to producing a new aluminum from raw materials. Recycling of aluminium is cheaper and more environmental friendly as it releases only 4% of CO_2 compared to producing a new aluminium. This is because aluminium has been in the metallic state already, therefore, all energy needed in purifying the ore and reducing it to the metal is saved when aluminium is recycled. The aluminium are to be melted to be reused only. Aluminium has low melting point which is 660º C, and it requires only 26 kJ/mol to melt. However, recycling of aluminium increases the content of iron in the aluminium. This is due to the pickup from material handling system during recycling of aluminium and scrap addition that contains high iron level than primary level[1].

2.4 IRON

Iron is the highest impurity in aluminium[1]. Iron is an alloying addition that improve the process ability of alloy and strength of final wrought product. Iron has low solubility in solid, therefore it combines with other elements to form intermetallic phases. In the absent of Si, iron combines with aluminium to form Al_3Fe and Al_6Fe. However, when Si is present, it forms dominant phase α-Al_8Fe_2Si phase and monoclinic β-Al_5FeSi phase.

β-phase contain a platelet form in three-dimensions and needles like structure when observed in two-dimensions. Iron influence on cast ability and mechanical properties in aluminium alloy is due to the difference in iron-containing intermetallic phases. Another reason of influence of iron in cast ability and mechanical properties of aluminium is the time or temperature of solidification of different phases.

Intermetallic particles that form earlier than solidification of aluminium dendrite grain network are very large in size compared to particles that form during or after the period of Al-Si eutectic solidification. This is because of the large liquid space available for growth to occur at the beginning stages. However, the larger the particle, the more adverse its effect on properties and process ability. This shows that high Fe content and increase in cooling rate causes the risk of forming large particles. Large particles forms by high cooling rate when the increase in length of time available for unconstrained growth [3].

Iron is mainly categorized as harmful impurity due to the brittle AlFeSi intermetallic compounds, which appear as needles or platelets in the microstructure. This needles microstructure can grow very large. However, for pressure die-casting alloys, iron is also beneficial which helps in prevention of the molten alloys from soldering to the casting die. There are many types of AlFeSi particles which are divided into three different morphologies ; Chinese script, polyhedral crystals, or thin platelets[4].

When Fe increases from 0.5 to 1.2 wt% in an Al-13 wt % Si casting alloy reduces the mechanical properties due to platelet phase formation. The platelet phases, which behaves as stress raisers causes brittleness of material. These structures aid in prevention of flowing of liquid metal through the feeding channels. Furthermore, intermetallic compounds in as-cast aluminium alloys face porosity effect due to high iron content. Compounds of AlFeSi and AlFeMnSi type causes formation of shrinkage porosity by blocking the interdendritic feeding channels of hypoeutectic aluminium-silicon alloys.

These problems can be overcome by adding other elements into aluminium alloy that can reduce iron content in the aluminium alloy. Example of other elements that can be added are nickel, chromium, vanadium and manganese. These elements are iron modifiers These elements can replace or neutralize the iron content in the aluminium. In this research, we are going to concentrate on nickel, chromium and vanadium elements only.

2.5 EFFECT OF INOCULATION ELEMENTS ON THE MICROSTRUCTURE AND MECHANICAL PROPERTIES OF RECYCLED ALUMINIUM ALLOY

Nickel is an effective iron neutralizer. It changes brittle plate-like β-Al_5FeSi intermetallic into elongated form of Al_9FeNi phase The change in microstructure of A356 aluminium alloy before and after nickel addition for as –cast condition and heat treated condition in shown in Figure 2.3. Al_9FeNi is also brittle and this causes nucleation of fatigue cracks. This reduces the creep resistance of the aluminium alloy. Other than that, nickel causes reduction of yield strength and ultimate tensile strength. When a load being applied, local stresses around coarse polygonal Al_3Ni and Al_9FeNi compounds which increases leads to these intermetallic to break which leads to further intercrystalline cracks that occurs within the brittle phases. The steep increase at the local stresses around the eutectic Si particles and intermetallic in the remaining eutectic areas leads to lower the ultimate tensile strength. However, this detrimental effect on mechanical properties caused by nickel can be overcome by heat treatment process. Heat treatment causes the nickel based aluminium alloy to have better mechanical properties(Casari, el al.,2014).

Addition of vanadium in aluminium alloy refines the α-Al dendrites which is in columnar dendritic form to cellular morphology form. Furthermore, vanadium aid in overcoming Fe effect on aluminium alloy by modifying coarse plate-like Fe-rich phases by forming complex intermetallic with Fe which are equaled in all directions in morphology. During heat treatment, eutectic silicon morphology changes from needle-like to spheroidal form. Vanadium influences in periodization of eutectic silicon and other Fe-rich phases[6]. According to [5], addition of vanadium is an effective method for grain refinement. This is due to addition of vanadium forms trialuminides which enhance grain refinement. Grain refinement increases the yield strength and ultimate tensile strength of aluminium alloy [5]. Vanadium also prevents dislocation movement and increases dislocation multiplication. Diffusivity of aluminum is higher than vanadium self-diffusion at any temperature. This leads to pile-up dislocations were strongly pinned at the sub grain boundaries which results in high multiplication rate of dislocations. This behaves as barriers to further dislocation movement, leading to an enhanced work hardening effect. According to [7], vanadium influence is highest with 0.03-0.05% V then 0.11-0.15% V and lastly 0.19% V addition[7].

Addition of chromium can neutralize the negative effect of iron by transforming β-AlFeSi phase to α-Al (Fe, Cr) Si phase. This occurs due to the ability of transition elements Fe, Cr, and Mn can exchange with each other so that they can exist at the same time in Fe-bearing intermetallic compounds. However, at high temperature, addition of chromium decreases ultimate tensile strength. This is because conversion of a harder phase of β-AlFeSi to α-Al(Fe,Cr)Si [8] [9].

2.6 EFFECT OF HEAT TREATMENT ON RECYCLED ALUMINIUM ALLOY

Heat treatment process influences the mechanical properties and microstructure of aluminium alloy. Heat treatment improves the tensile strength of eutectic Al-SI piston alloys(PENG, el al., 2011) . Solution treatment is done for long period of time for few reasons. First is to get homogeneity and maximum solubility of the alloying element in the matrix, then to obtain solution strengthening and precipitation strengthening in α-Al and to modify the acicular morphology of the eutectic silicon to be less detrimental. During the solution treatment , eutectic Si is spheroid zed which prevents cracks from propagating and reducing the stress concentration[8].

Heat treatment process homogenize the α-Al dendrites to improve the mechanical properties of aluminium alloy. Studies have been done on grain size with variation of section size by (Akhil el al., 2014). It shows at as-cast condition, microstructure is fine at smaller section size but coarse for large section size whereas at heat treated condition, microstructure is much refined and uniform in all section size. The variation of microstructure phase is due to cooling rate. Larger section size has shorter cooling rate.

The mechanical properties such as hardness, impact strength, ultimate tensile strength of aluminium alloy in as cast condition increases as the section size decreases. This is caused by grain refinement in smaller section size due to fast cooling rate. However, the mechanical properties of aluminium alloy at aged condition and heat treated was improved compared to as-cast condition. Furthermore, the mechanical properties are almost constant with variation in section size. This is due to higher grain refinement in aged condition and heat treated condition irrespective to section size[10].

Solution treatment is the first step in heat treatment process. Its objective is to eliminate the consequences of micro segregation and also increase the mechanical properties of casting. Solution treatment is done by heating the specimen above the aluminium alloy solvus temperature. The temperature will be usually 100 ºC above its solvus temperature. The process is heating specimen and putting them into the furnace that have been heated to a specific temperature and wait until the required time is met.

The next step is quenching. Quenching is a process of cooling the heated specimens rapidly to room temperature drop should be minimized. In this process, delay which result in temperature drop should be avoided. The medium used for quenching is water at room temperature. The process starts with taking heated specimens out from furnace and put it into the water medium.

The third step is aging. Aging was done to obtain a uniform distribution of small precipitates or grain refinement which gives a higher strength. Aging is a process of re-heating specimens. However, the re-heating temperature is usually lower but the period of heating is longer. Aging time usually determine the tensile properties of material. Too short or too long cycle can result in poor tensile strength properties. Artificial aging is more popular because of the ability to lock the peak properties that occur prior to over aging [11].

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter will discuss about the methods used in this research. Basically, this research was done to study the microstructure properties correlation on aluminium alloy. Aluminium alloy is taken from recycled automotive scrap. This research is focused to study the effect of various alloying element addition and heat treatment on the morphological changes on the Fe-rich intermetallic in the aluminium alloy and the ultimate tensile strength of the aluminium alloy which has different alloying element.

The experiment starts with melting, inoculation, casting and heat treatment of aluminium alloy. Then, specimen, both as cast and heat treated obtained is examined through metallographic method using optical microscopy and scanning electron microscopy (SEM). The as cast and heat treated specimen is also tested for ultimate tensile strength test using universal tensile testing machine. Lastly, the results obtained from the recorded sample and the best composition that influences the melt-inoculations on the morphology of the Fe-bearing intermetallic in aluminium alloy and the sample with highest ultimate tensile strength is determined.

3.2 FLOWCHART

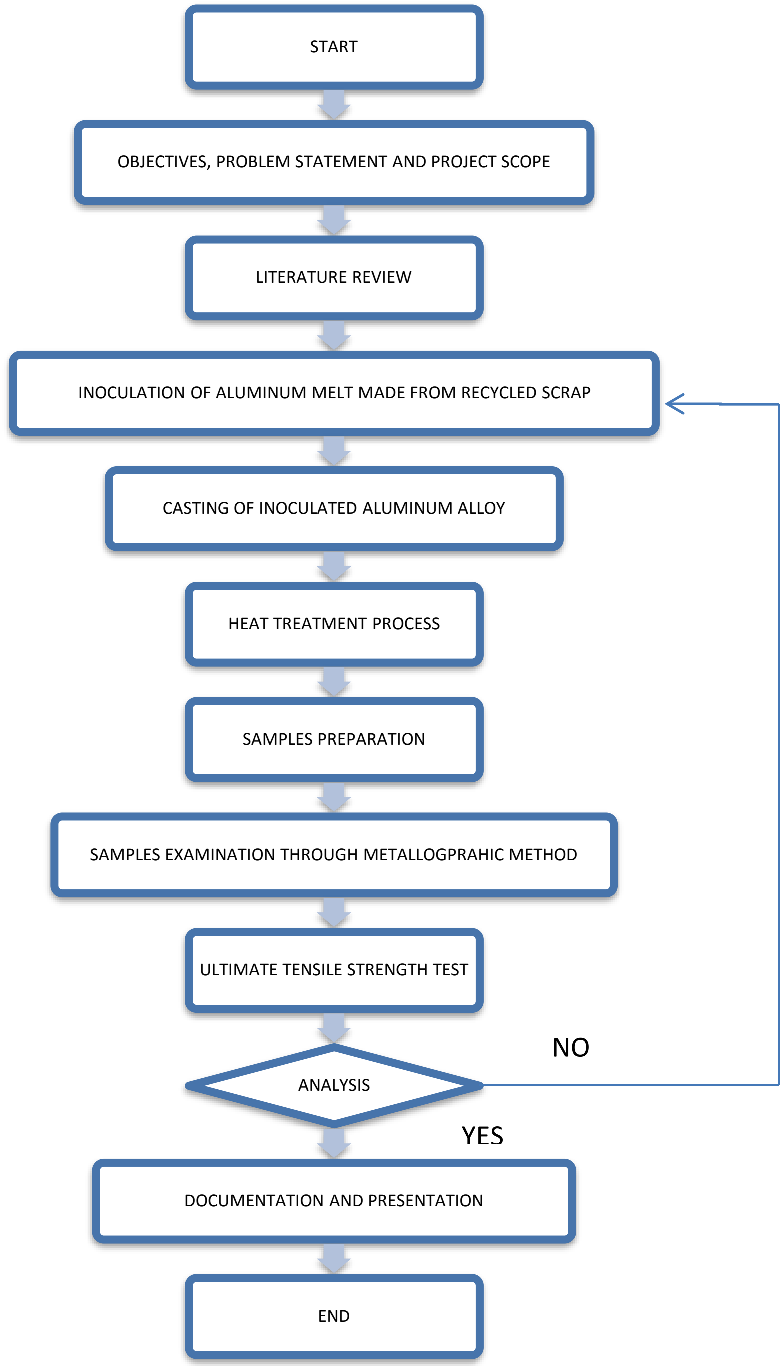


Figure 3.1: Methodology Flow Chart

3.3 MELT-INOCULATION OF ALUMINIUM MADE FROM RECYCLED ALUMINIUM SCRAP

Smaller pieces of aluminium are cut from recycled aluminium blocks by using vertical band saw machine. These recycled aluminium blocks are samples used as raw material for automobile industry. Then, weight the pieces to approximately about 1 kg by using weighing scale.

Next, aluminum is to be placed inside an A4 size crucible which will be then placed inside a furnace for melting process. During melting process, aluminium will be completely become a liquid at its liquidus temperature which is 650 ºC. However, in order to ensure that the aluminium is completely melted, the furnace must be heated up until 750 ºC. Other than that, the furnace must be heated until 750 ºC to ensure that the molten aluminium will not solidify during the early pouring of molten aluminium into the mold opening for casting process.

Then after melting process, the crucible will be taken out from the furnace, and the aluminium will be melt-inoculated. Inoculate is a process of adding other elements into the melted aluminium. Small quantity of other elements like chromium, vanadium and nickel will be inoculated into the melted aluminium.

3.4 CASTING OF MELT-INOCULATED ALUMINIUM

Before starting casting process, the steel made mold need to be graphite coated to prevent the solidified inoculated aluminium to stick to the mold. For this casting process, split mold will be used. After the split mold has been coated with graphite, the split mold will be clamped together with G-clamp. After that, molten inoculated aluminium will be poured into the mold opening and leave for a time until it is completely solidified. After it is completely solidified, the clamp will be opened and the solidified inoculated aluminium will be taken out from the mold. Table 3.4.1 and Table 3.4.2 shows the calculations for the weight of innoculants to be added into the molten aluminium.

Table 3.4.1: Calculation of Weight of Innoculants Needed for Nickel

INOCULATION PERCENTAGE (%)	CALCULATION	WEIGHT (g)
0.2%	$\frac{0.002(1209.7)}{0.2 - 0.002}$	12.219
0.5%	$\frac{0.005(1196.80)}{0.2 - 0.005}$	30.687
1.0%	$\frac{0.010(1206.85)}{0.2 - 0.010}$	63.518
2.0%	$\frac{0.020(1195.25)}{0.2 - 0.020}$	132.806

Table 3.4.2: Calculation of Weight of Innoculants Needed for Chromium

INOCULATION PERCENTAGE (%)	CALCULATION	WEIGHT (g)
0.2%	$\frac{0.002(1204.45)}{0.8-0.002}$	3.0187
0.5%	$\frac{0.005(1206.10)}{0.8-0.005}$	7.586
1.0%	$\frac{0.010(1204.75)}{0.8-0.010}$	15.250
2.0%	$\frac{0.020(1200.60)}{0.8-0.020}$	30.785

3.5 HEAT TREATMENT PROCESS

After the process had been done, sample preparation need to be done. Specimen were cut into a size of 1cm X 1cm. Specimens are separated as as-cast and heat treated. For heat treated specimen, specimens are cleaned and grinded to make sure smooth surface was produced.

Specimens are solutionized for 4 hours at 550 ºC in the furnace. After 4 hours, specimens are quenched in water at room temperature for 30 seconds to cool the specimens. Then, specimens were aged at 150 ºC for 2 hours and then quenched at room temperature for 30 seconds. Table 3.5.1 shows the heat treatment process in scheduled manner.

Table 3.5.1: Heat Treatment Process

Process	Time	Temperature
Solutionizing	4 hours	550 ºC
Rapid Quenching	30 seconds	Room temperature
Aging	2 hours	150 ºC
Rapid Quenching	30 seconds	Room temperature

3.6 SAMPLES PREPARATION

3.6.1 Mounting

Resin and hardener are mixed with ratio of 2:1 and inserted inside a mold. Then, place the specimen inside the mixture and let it for a certain period of time until mixture is completely solidified. After solidification, take mixture out from the mold.

3.6.2 Polishing

Sand paper is used to do polishing. Grinding process is done onto the specimen and the process is repeated from coarsest to finer sandpaper. After that, use cloth to replace sandpaper and repeat the process. At first, polishing is done by using cloth with alumina solution. Then, diamond polishing is done. Few drops of ethanol on cloth is needed to prevent structure of cloth from being damaged.

3.7 MICROSTRUCTURAL CHARACTERIZATION

The samples after preparation will be examined through metallographic method. Different types of microstructural and phase analysis technique will be used. Example of techniques that will be used are:

1. Optical microscopy
2. Scanning Electron Microscopy (SEM)

3.7.1 Optical microscopy

Microstructure of specimen is observed by optical microscopy. Microstructure picture will have captured and saved. Different magnification power is used to observe and capture the microstructure of the specimen. Change in porosity size and number of porosity is calculated on the specimens by using image analyzer. Figure 3.2 shows the optical microscopy that will be used for this study which is OLYMPUS BX 51M.

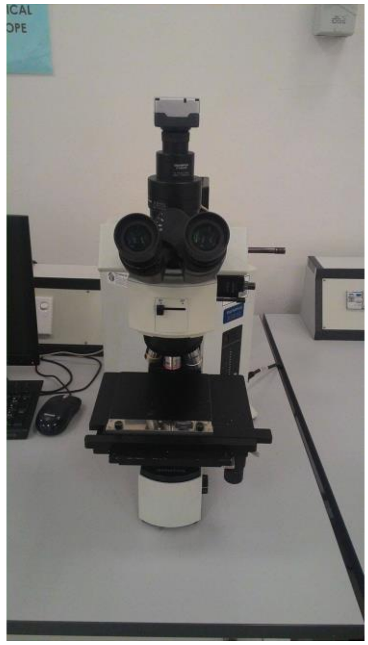


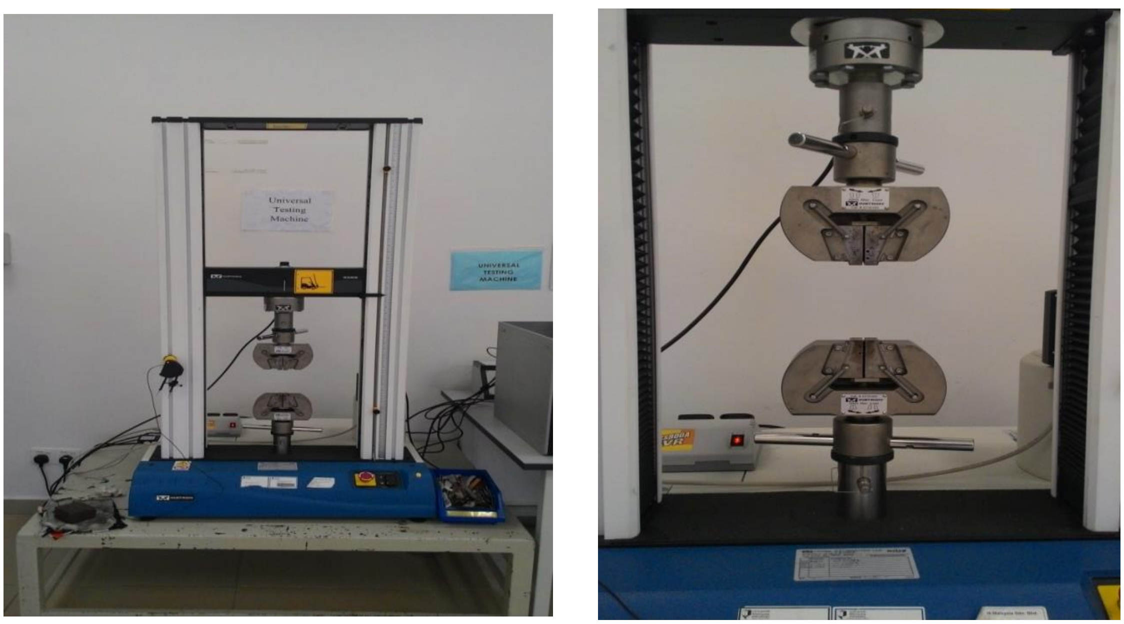
Figure 3.2: Optical Microscopy OLYMPUS BX 51M

3.7.2 Scanning Electron Microcopy (SEM)

The specimen is cleaned and dried. Then is it placed in the scanning electron microscopy. The process of scanning will proceed. The microstructure of specimen will then be saved.

3.8 ULTIMATE TENSILE STRENGTH TEST

The specimen is prepared according the ASTM standard. The specimen is cut in dog-bone shape by using milling machine and wire cut machine. The specimen is then clawed at the jaw and under the process of pulled on a machine. The machine we using is called Instron Universal Testing Machine to perform the tensile test. The measurement unit for this machine is kN and the maximum load that can be applied by this machine is 50kN. Figure 3.3 shows ultimate tensile strength machine.



(a) (b)

Figure 3.3: (a) Instron Universal Testing Machine (b) Jaw for clawing

3.9 ANALYSIS

Lastly, analysis was done based on the results obtained and phase diagrams need to done to investigate the influence of melt-inoculations on the morphology of the Fe-bearing intermetallic in recycled alloys and influence in ultimate tensile strength of aluminium alloy which have additional elements.

3.10 BUDGET PLAN

No.	Item	Resource	Price (RM)
1	**Aluminium A356 Alloy**	**UMP**	**0**

CHAPTER 4

RESULT AND DISCUSSION

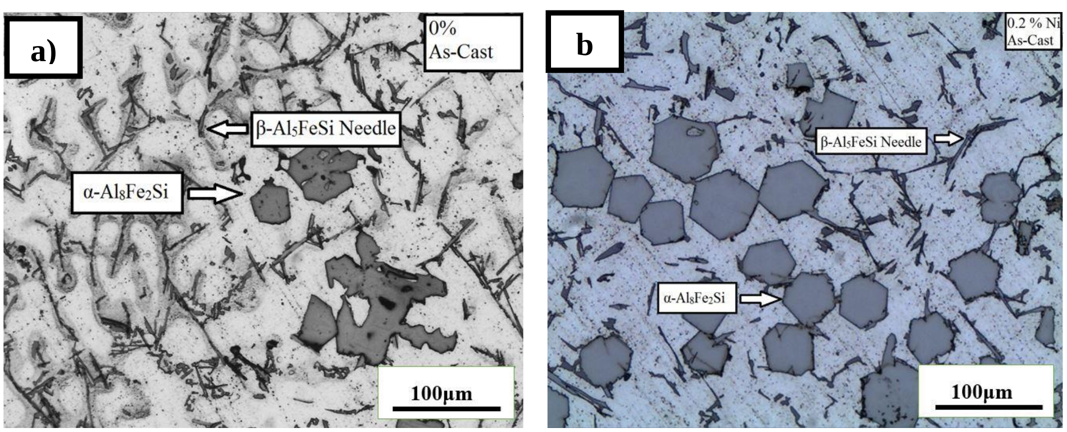
4.1 INTRODUCTION

This chapter will discuss about results obtained by sample examination through optical microscopy and results from tensile strength test for percentage of elongation and maximum tensile strength of innoculated recycled aluminium.

4.2 RESULTS

4.2.1 Effect of Nickel on the Microstructure (As-Cast)

Figure 4.1 shows optical microstructure of As-Cast Recycled Aluminium Alloy with addition of 0%, 0.2%, 0.5%, 1.0%, 2.0% Nickel. Figure 4.1 (a), (b), (c) shows there are two structures formed which are α-Al_8Fe_2Si polyhedral structure and β-Al_5FeSi Needle structure. Figure 4.1(d) shows there are new structures formed which are Eutectic silicon and Chinese Script besides α-Al_8Fe_2Si polyhedral structure and β-Al_5FeSi Needle structure. Figure 4.1 (e) shows structures formed are Chinese Script, Al_8Fe_2Si polyhedral structure and β-Al_5FeSi Needle structure.



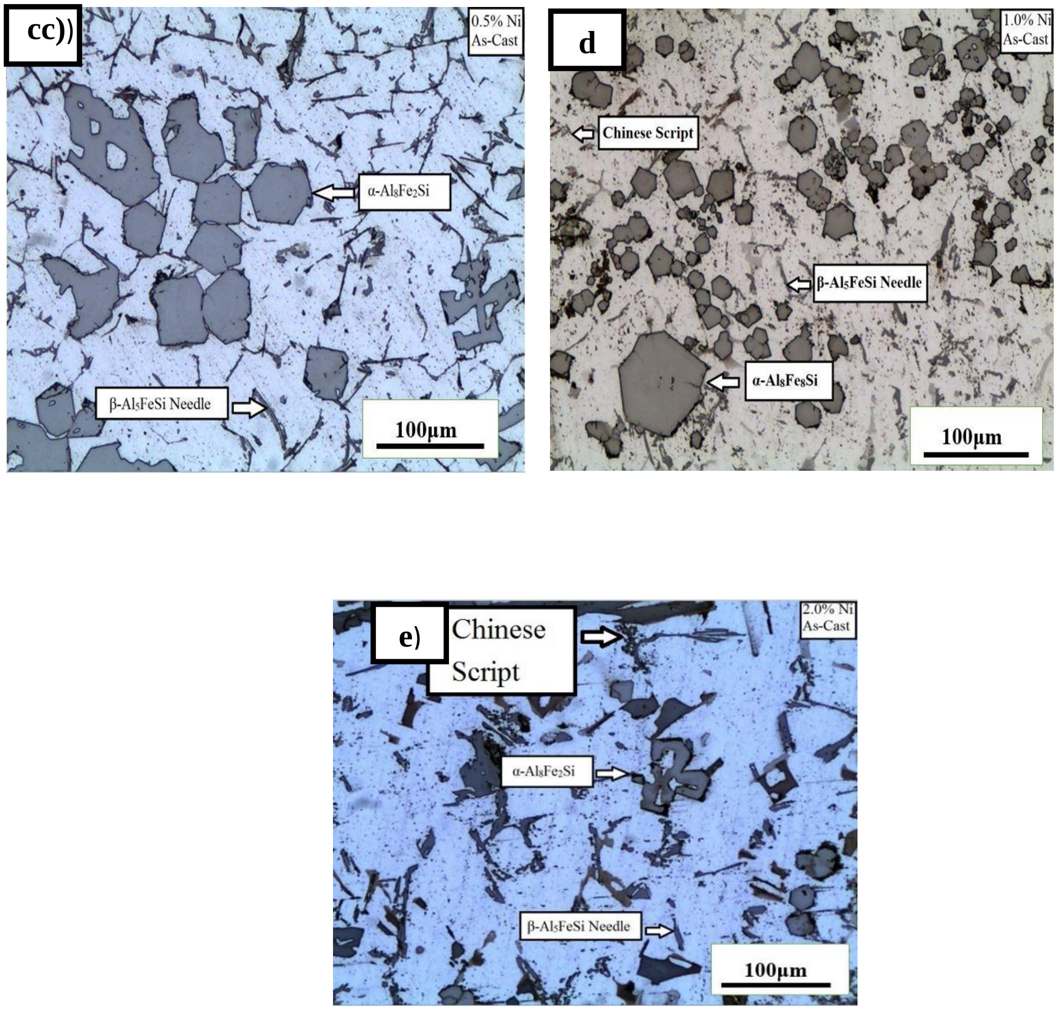
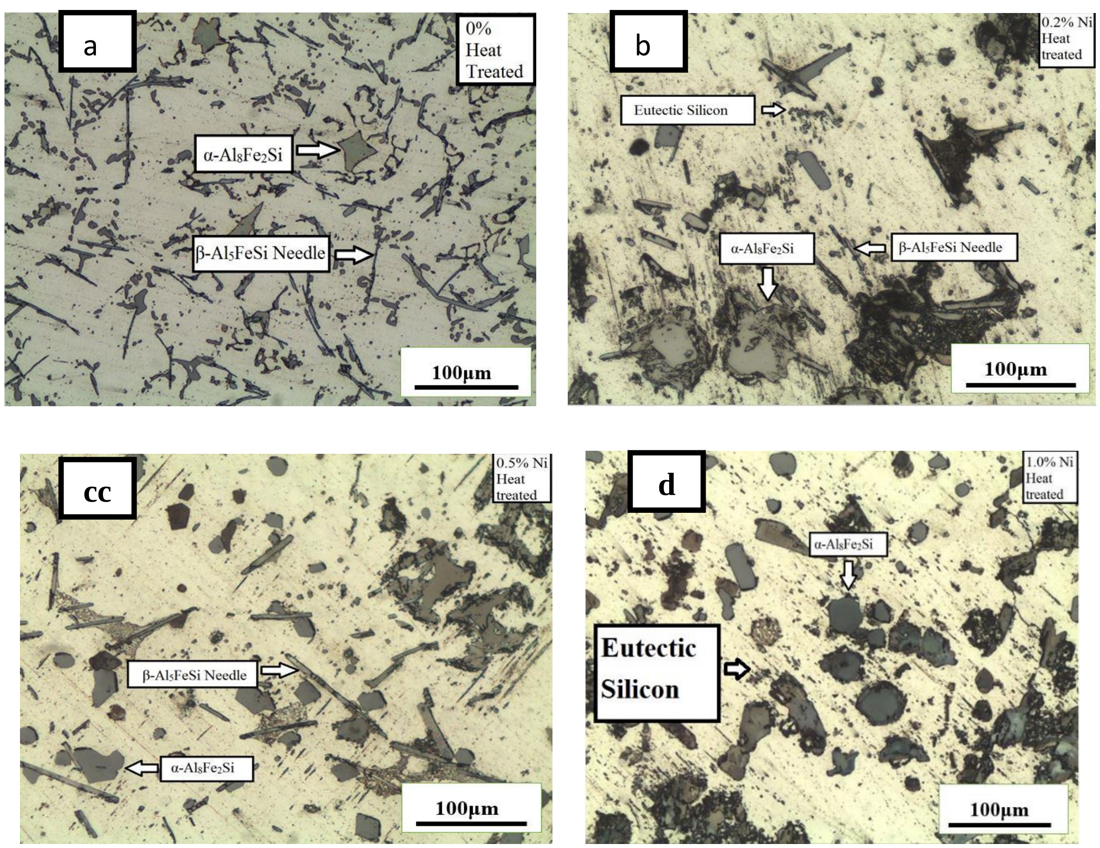


Figure 4.1: Optical Microstructure at 20x Magnification of As-cast Recycled Aluminium Alloy with Nickel Addition (a) 0% (b) 0.2% (c) 0.5% (d) 1.0% (e) 2.0%

4.2.2 Effect of Nickel on the Microstructure (Heat Treated)

Figure 4.2 shows optical microstructure of Heat Treated Recycled Aluminium Alloy with addition of 0%, 0.2%, 0.5%, 1.0%, 2.0% Nickel. Figure 4.2 (a) and (c) shows there are two structures formed which are α-Al_8Fe_2Si polyhedral structure and β-Al_5FeSi Needle structure. Figure 4.2(b) shows there are new structure formed which is Eutectic silicon besides α-Al_8Fe_2Si polyhedral structure and β-Al_5FeSi Needle structure. Figure 4.1 (d) and (e) shows only Al_8Fe_2Si polyhedral structure formed.



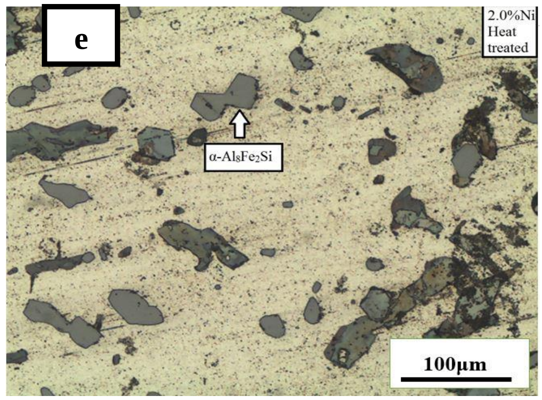


Figure 4.2: Optical Microstructure at 20x Magnification of Heat Treated Recycled Aluminium Alloy with Nickel Addition (a) 0% (b) 0.2% (c) 0.5% (d) 1.0% (e) 2.0%

4.2.3 Effect of Chromium on the Microstructure (As-Cast)

Figure 4.3 shows optical microstructure of As-Cast Recycled Aluminium Alloy with addition of 0%, 0.2%, 0.5%, 1.0%, 2.0% Chromium. Figure 4.3 (a) and (b) shows there are two structures formed which are α-Al_8Fe_2Si polyhedral structure and β-Al_5FeSi Needle structure. Figure 4.3 (c) and (d) shows there are new structure formed which is Chinese Script besides α-Al_8Fe_2Si polyhedral structure and β-Al_5FeSi Needle structure. Figure 4.1 (e) shows structures formed are Chinese Script, Al_8Fe_2Si polyhedral structure and β-Al_5FeSi Needle structure and a new structure which is Eutectic Silicon.

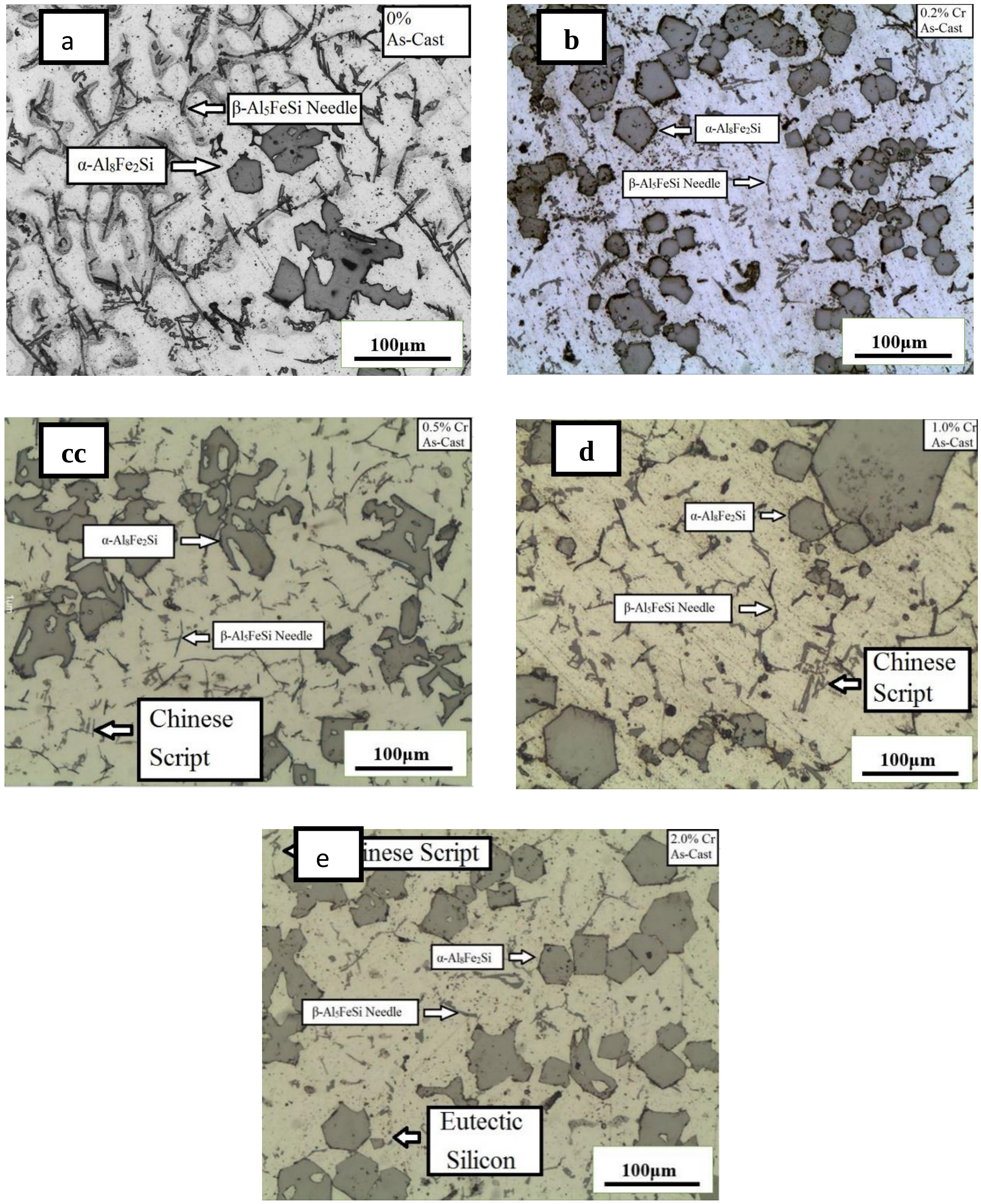
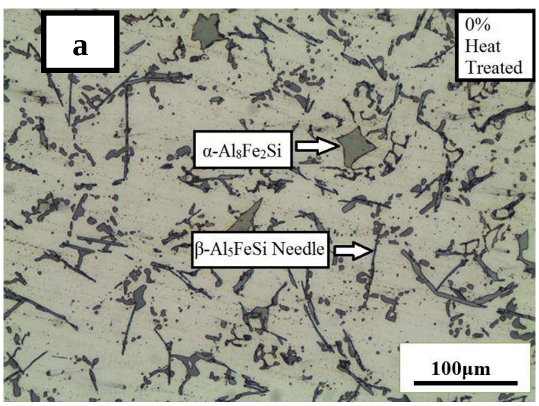
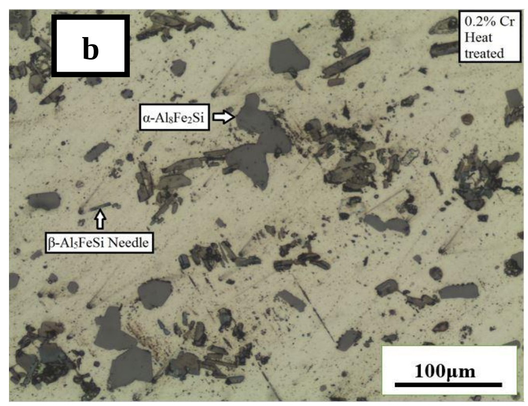


Figure 4.3: Optical Microstructure at 20x Magnification of As-cast Recycled Aluminium Alloy with Chromium Addition (a) 0% (b) 0.2% (c) 0.5% (d) 1.0% (e) 2.0%

4.2.4 Effect of Chromium on the Microstructure (Heat Treated)

Figure 4.4 shows optical microstructure of Heat Treated Recycled Aluminium Alloy with addition of 0%, 0.2%, 0.5%, 1.0%, 2.0% Chromium. Figure 4.4 (a),(b),(c) and (d) shows there are two structures formed which are α-Al_8Fe_2Si polyhedral structure and β-Al_5FeSi Needle structure. Figure 4.4(e) shows there are new structure formed which is Eutectic silicon besides α-Al_8Fe_2Si polyhedral structure and β-Al_5FeSi Needle structure.





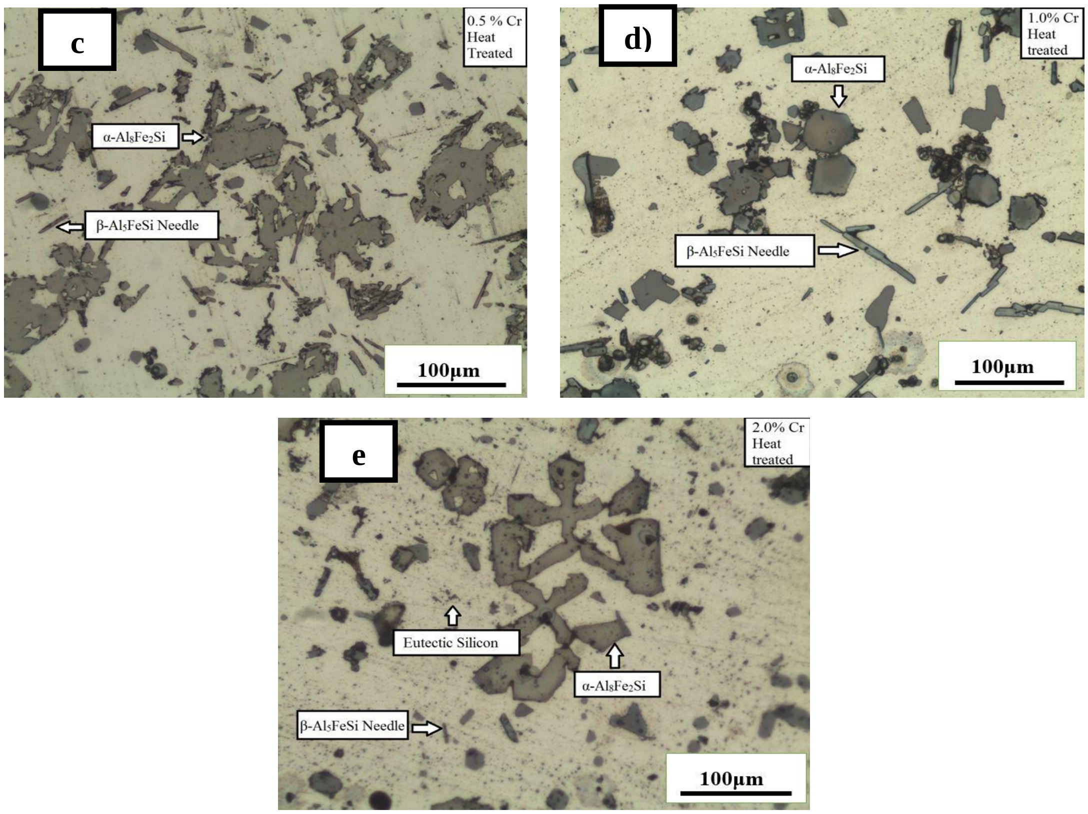


Figure 4.4: Optical Microstructure at 20x Magnification of Heat Treated Aluminium Alloy with Chromium Addition (a) 0% (b) 0.2% (c) 0.5% (d) 1.0% (e) 2.0%

4.2.5 Effect of Nickel As-Cast and Heat Treated on the Percentage of Elongation of Recycled Aluminium

According to the graph in the figure 4.5, the Percentage of Elongation of Recycled Aluminium is highest for 1.0% Ni for As-Cast and 0.2 % Ni for Heat Treated. 1.0% Ni for As-Cast has 3.755 % of Elongation of Recycled Aluminium. 0.2 % Ni for Heat Treated has 3.439 % of Elongation of Recycled Aluminium.

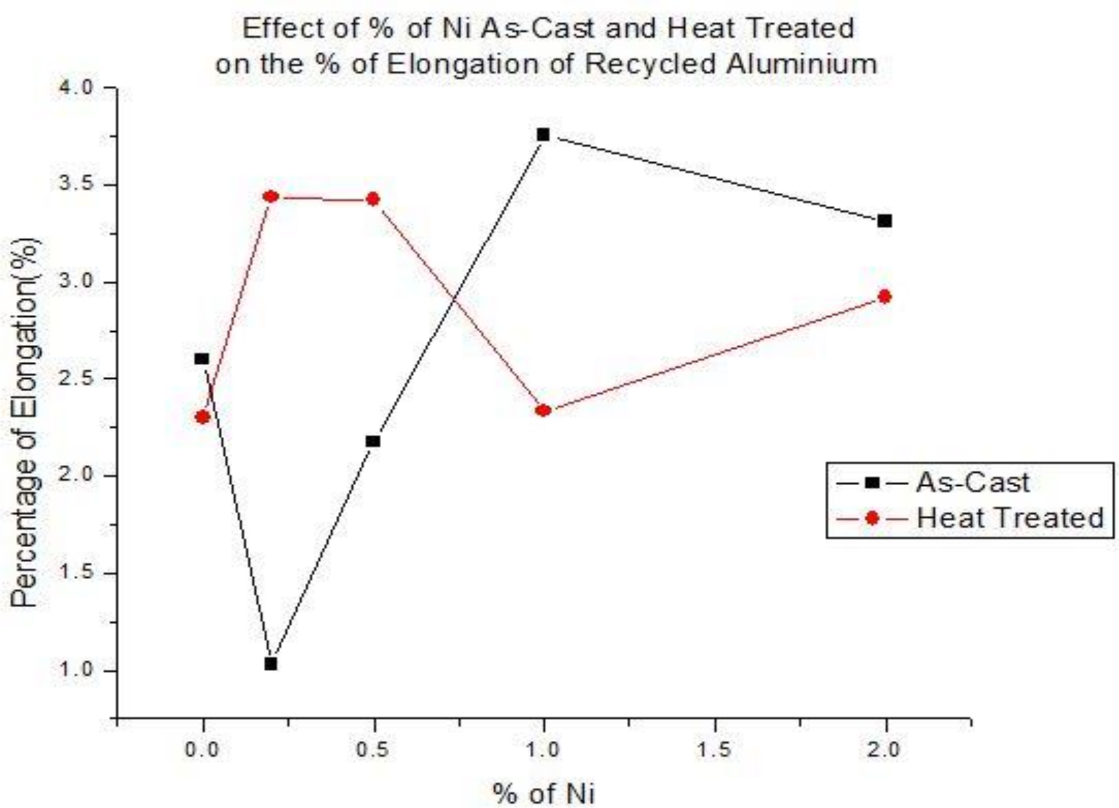


Figure 4.5 : Effect of Nickel As-Cast and Heat Treated on the Percentage of Elongation of Recycled Aluminium

4.2.6 Effect of Chromium As-Cast and Heat Treated on the Percentage of Elongation of Recycled Aluminium

From the graph in the figure 4.6, the Percentage of Elongation of Recycled Aluminium is highest for 2.0% Cr for As-Cast and 1.0 % Cr for Heat Treated. 2.0% Cr for As-Cast has 4.802% of Elongation of Recycled Aluminium. 1.0 % Cr for Heat Treated has 3.704 % of Elongation of Recycled Aluminium.

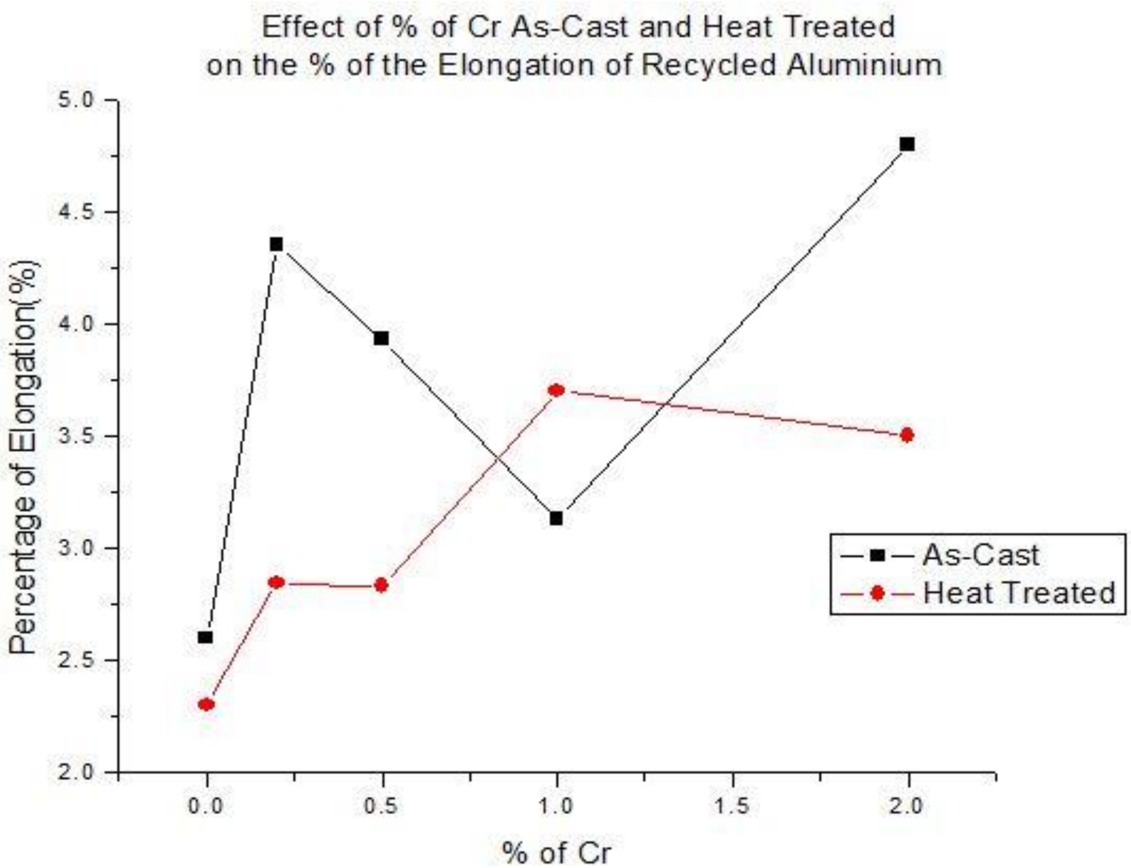


Figure 4.6 : Effect of Chromium As-Cast and Heat Treated on the Percentage of Elongation of Recycled Aluminium

4.2.7 Effect of Nickel As-Cast and Heat Treated on the Tensile Stress at Maximum Load (MPa) of Recycled Aluminium

According to the graph in figure 4.7, Tensile Stress at Maximum Level (MPa) is highest for 0.5% Ni for As-Cast and 2.0% Ni for Heat Treated. 0.5% Ni for As-Cast has 138.53 MPa of Tensile Stress at Maximum Load (MPa).2.0% Ni for Heat Treated has 151.73 MPa of Tensile Stress at Maximum Load (MPa).

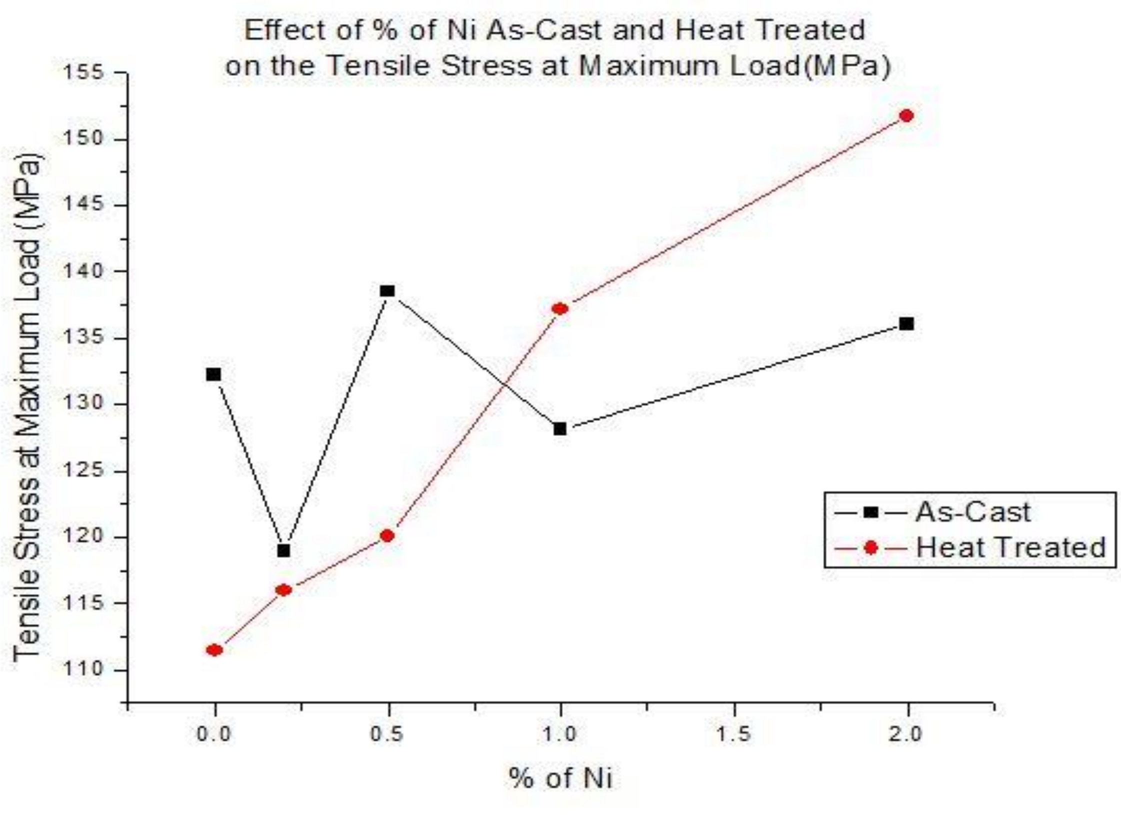


Figure 4.7 : Effect of Nickel As-Cast and Heat Treated on theTensile Stress at Maximum Load (MPa) of Recycled Aluminium

4.2.8 Effect of Chromium As-Cast and Heat Treated on the Tensile Stress At Maximum Load (MPa) of Recycled Aluminium

From the graph in figure 4.8, Tensile Stress at Maximum Level (MPa) is highest for 2.0% Cr for As-Cast and 0.5% Cr for Heat Treated. 2.0% Cr for As-Cast has 154.33 MPa of Tensile Stress at Maximum Load (MPa). 0.5% Cr for Heat Treated has 163.01 MPa of Tensile Stress at Maximum Load (MPa).

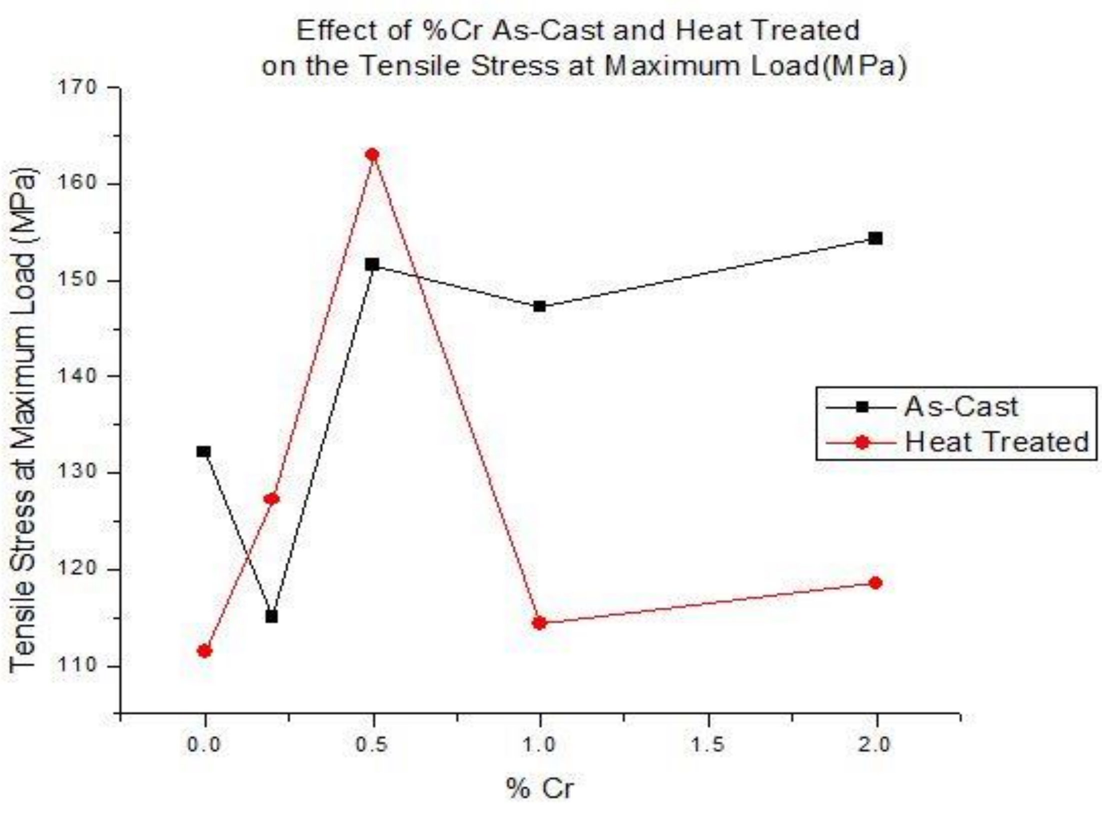


Figure 4.8 : Effect of Chromium As-Cast and Heat Treated on the Tensile Stress at Maximum Load (MPa) of Recycled Aluminium

4.3 DISCUSSION

The aim of this study is to reduce the brittle β-Al_5FeSi Needle structure. Long and sharp edges of β-Al_5FeSi Needle structure break easily, causes brittleness and detrimental effect towards the recycled aluminium alloys. As the addition of innoculation percentage increases, brittle β-Al_5FeSi Needle structure in recycled aluminium alloy decreases. Furthermore, this study is also to increase the Percentage of Elongation and Tensile Stress at Maximum Load (MPa) for recycled aluminium alloys. Addition of inoculation in increasing percentage do affect the Percentage of Elongation and Tensile Stress at Maximum Load (MPa) of recycled aluminium alloy.

4.3.1 Effect of Nickel on the Microstructure (As-cast)

Figure 4.1 shows the optical microstructure of As-Cast Recycled Aluminium Alloy with addition of 0%, 0.2%, 0.5%, 1.0%, 2.0% Nickel. Figure 4.1(a) shows there are two structures present which are α-Al_8Fe_2Si polyhedral structure and β-Al_5FeSi Needle structure. The graph in Figure 4.5 shows that 0% of Ni As-Cast has 2.602% of elongation and the graph in Figure 4.7 shows that 0% of Ni As-Cast has 132.2 MPa of Tensile Stress at Maximum Level.

Figure 4.1(b) shows an increase in inoculation percentage from 0% to 0.2%. This results in β-Al_5FeSi Needle structure becomes thinner in size. However, the α-Al_8Fe_2Si polyhedral structure decomposes into more hexagonal in shape. The Percentage of Elongation drops to 1.028% as shown by graph in Figure 4.5 for 0.2% Ni As-Cast and the Tensile Stress at Maximum Load (MPa) also dropped to 118.94 MPa as the graph shows in Figure 4.7 for 0.2% Ni As-Cast. This shows that increase in percentage of innoculation does not always gives a positive feedback to the recycled aluminium alloy.

Figure 4.1(c) shows an increase in innoculation percentage from 0.2% to 0.5%. It shows that β-Al_5FeSi Needle structure has become shorter and thicker in size. Furthermore, it also shows that α-Al_8Fe_2Si polyhedral structure has also decompose into more hexagonal shape. The Percentage of Elongation by graph in Figure 4.5 shows for 0.5% Ni As-Cast is 2.175% which is higher than the 0.2% Ni As-Cast. The Tensile Stress at Maximum Load (MPa) by graph in Figure 4.7 for 0.5% Ni As-Cast is 138.53 MPa which is also higher than 0.2% Ni As-Cast. This shows that addition of 0.5% Nickel in As-Cast condition brings positive feedback to recycled aluminium alloy.

Figure 4.1(d) shows innoculation percentage increased from 0.5% to 1.0%. There is α-Al_8Fe_2Si polyhedral present in the microstructure. The Percentage of Elongation by graph in Figure 4.5 shows that 1.0% Ni As-Cast has 3.755% of elongation which is higher than 0.5% Ni As-Cast. However, the Tensile Stress at Maximum Load (MPa) by graph in Figure 4.7 for 1.0% Ni As-Cast is only 128.14 MPa which is lower than 0.5% Ni As-Cast. This shows that addition of 1.0% Nickel in As-Cast condition does give positive feedback to recycled aluminium alloy in terms of microstructure properties and Percentage of Elongation but not on Tensile Stress at Maximum Load due to its low grain refinement.

Figure 4.1(e) shows increase in inoculation percentage from 1.0% to 2.0%. There are α-Al_8Fe_2Si polyhedral structure and β-Al_5FeSi Needle structure. However, β-Al_5FeSi Needle structure is thinner and longer in length. This gives a negative feedback to the recycled aluminium alloy as thinner and longer β-Al_5FeSi Needle structure causes brittleness. The Percentage of Elongation by graph in Figure 4.5 shows that 2.0% Ni As-Cast has 3.313% of elongation which is lower than 1.0% Ni As-Cast. On the other hand, the Tensile Stress at Maximum Load (MPa) by graph in Figure 4.7 for 2.0% Ni As-Cast is 136.02 MPa which is higher than 1.0% Ni As-Cast. This shows that 2.0% Ni As-Cast does not give positive feedback to the recycled aluminium alloy in terms of the microstructure and Percentage of Elongation but only on Tensile Stress at Maximum Load.

Therefore, we can conclude that 1.0% Ni As-Cast is the best innoculation percentage for as-cast alloy with microstructure of α-Al_8Fe_2Si polyhedral, Percentage of Elongation of 3.755% and Tensile Stress at Maximum Load of 128.14MPa. This is because it has only α-Al_8Fe_2Si polyhedral microstructure which gives good strength to recycled aluminium alloy. It has also the highest Percentage of Elongation of 3.755%.

4.3.2 Effect of Nickel on the Microstructure (Heat Treated)

Figure 4.2 shows the optical microstructure of heat treated recycled aluminium alloy with percentage of innoculation of 0%, 0.2%, 0.5%, 1.0%, and 2.0% Nickel. Figure 4.2 (a) shows that for 0% Ni Heat Treated, there are α-Al_8Fe_2Si polyhedral and β-Al_5FeSi Needle structure. The β-Al_5FeSi Needle structure is long and thin. The Percentage of Elongation on graph in Figure 4.5 shows 0% Ni Heat Treated has 2.301% of elongation. The Tensile Stress at Maximum Load (MPa) by graph in Figure 4.7 shows for 0% Ni Heat Treated has 111.44MPa.

There is an increase in percentage of innoculation from 0% to 0.2% Ni Heat Treated. The microstructure properties for 0.2% Ni Heat Treated in Figure 4.2(b) shows there are α-Al_8Fe_2Si polyhedral, β-Al_5FeSi Needle structure and there are Eutectic Silicon present. Eutectic Silicon occurs from the breakdown of β-Al_5FeSi Needle structure. The Percentage of Elongation for 0.2% Ni Heat Treated from graph in Figure 4.5 shows that Percentage of Elongation increased for 0.2% Ni Heat Treated to 3.439%. Furthermore, for the Tensile Stress at Maximum Load (MPa) by graph in Figure 4.7 also shows an increase for 0.2% Ni Heat Treated with a value of 115.9MPa. The innoculation percentage of 0.2% Ni Heat Treated gives a positive feedback to the recycled aluminium alloy.

Additionally, the percentage of innoculation was further increased to 0.5% Ni Heat Treated. The microstructure present are α-Al_8Fe_2Si polyhedral and β-Al_5FeSi Needle structure as shown in Figure 4.2(c). The β-Al_5FeSi Needle structure is long and thin. Graph in Figure 4.5 shows the Percentage of Elongation for 0.5% Ni shows a decrease to 3.422 compared to 0.2% Ni Heat Treated. Contrarily, the Tensile Stress at Maximum Load for 0.5% Ni Heat Treated shows an increase to 120.07MPa on graph in Figure 4.7. This shows that 0.5% Ni Heat Treated has negative feedback on recycled aluminium alloy.

Consequently, the percentage of innoculation was increased to 1.0% Ni Heat Treated. The Figure 4.2(d) shows microstructure of this 1.0% Ni Heat Treated have α-Al_8Fe_2Si polyhedral and Eutectic Silicon. The Percentage of Elongation for 1.0% Ni Heat Treated on graph in Figure 4.5 decreased to 2.334%. However, the Tensile Stress at Maximum Level (MPa) on graph in Figure 4.7 shows an increase to 137.19 MPa for 1.0% Ni Heat Treated. This shows 1.0% Ni Heat Treated does give a positive feedback in terms of microstructure and Tensile Stress at Maximum Level to recycled aluminium alloy by changing β-Al_5FeSi Needle structure to Eutectic Silicon. However, it does give a negative feedback to the recycled aluminium alloy in terms of Percentage of Elongation.

The final innoculation percentage is increased to 2.0% Ni Heat Treated. The microstructure present is α-Al_8Fe_2Si polyhedral structure as shown in Figure 4.2(e). There is an improvement in Percentage of Elongation to 2.919% on graph in Figure 4.5 and in terms of Tensile Stress at Maximum Load (MPa) to 151.73 MPa as shown on graph in Figure 4.7 by innoculation of 2.0% Ni Heat Treated. Thus, 2.0% Ni Heat Treated gives a positive feedback to the recycled aluminium alloy.

2.0% Ni Heat Treated is also the best innoculation percentage for heat treated recycled aluminium alloy because the α-Al_8Fe_2Si polyhedral structure is more hexagonal in shape with higher grain refinement . It also has the highest Tensile Stress at Maximum Load(MPa) of 151.73MPa.

4.3.3 Effect of Chromium on the Microstructure (As-Cast)

Figure 4.3 shows the optical microstructure of As-Cast Recycled Aluminium Alloy with addition of 0%, 0.2%, 0.5%, 1.0%, 2.0% Chromium. Figure 4.3(a) shows there are two structures present which are α-Al_8Fe_2Si polyhedral structure and β-Al_5FeSi Needle structure. The graph in Figure 4.6 shows that 0% of Ni As-Cast has 2.602% of elongation and the graph in Figure 4.8 shows that 0% of Ni As-Cast has 132.2 MPa of Tensile Stress at Maximum Level.

The percentage of innoculation was then increased to 0.2% Cr As-Cast. Figure 4.3(b) shows microstructure of 0.2% Cr As-Cast are α-Al_8Fe_2Si polyhedral structure and β-Al_5FeSi Needle structure. The α-Al_8Fe_2Si polyhedral structure is hexagonal in shape and and β-Al_5FeSi Needle structure is shorter in length. The Percentage of Elongation shown on graph in Figure 4.6 for 0.2% Cr As-Cast is 4.355% which is higher than 0% Cr As-Cast. For the Tensile Stress at Maximum Load, 0.2% Cr As-Cast has 115.09 MPa as shown in graph in Figure 4.8 which is lower than 0 % Cr As-Cast. This shows that 0.2% Cr As-Cast gives a positive feedback to the recycled aluminium alloy in terms of microstructure and Percentage of Elongation.

Next, the percentage of innoculation was increased to 0.5% Cr As-Cast as shown in Figure 4.3(c). The microstructures present are α-Al_8Fe_2Si polyhedral structure, β-Al_5FeSi Needle structure and Chinese Script. The Chinese Script structure is desirable because it will strengthen the microstructure of aluminium alloy and making it less brittle. The Percentage of Elongation has decreased to 3.936% as shown on graph in Figure 4.6. On the other hand, the 0.5% Cr As-Cast's Tensile Stress at Maximum Load has increased to 151.54 MPa according to graph in Figure 4.8. Thus, 0.5 % Cr As-Cast has poor positive feedback on recycled aluminium alloy.

Subsequently, innoculation percentage was increased to 1.0% Cr As-Cast. Figure 4.3(d) shows microstructures present are α-Al_8Fe_2Si polyhedral structure, β-Al_5FeSi Needle structure and Chinese Script. The α-Al_8Fe_2Si polyhedral structure is in huge hexagonal structure with β-Al_5FeSi Needle structure being very thin. The Percentage of Elongation decreased to 3.133 % as shown on graph in Figure 4.6. Moreover, the Tensile Stress at Maximum Load also decreased to 147.24 MPa as shown on graph in Figure 4.8. As a result, 1.0% Cr As-Cast gives a negative feedback to recycled aluminium alloy.

In the same way, innoculation percentage was increased to 2.0% Cr As-Cast as shown in Figure 4.3(e). The microstructures present are α-Al_8Fe_2Si polyhedral structure, β-Al_5FeSi Needle structure, Eutectic Silicon and Chinese Script. The α-Al_8Fe_2Si polyhedral structures are more blocky in shape and the β-Al_5FeSi Needle structures are short in length.

There is an increase in both, the Percentage of Elongation to 4.802% as shown on graph in Figure 4.6 and for Tensile Stress at Maximum Load to 154.33 MPa as shown on graph in Figure 4.8 for 2.0% Cr As-Cast.

As a result, 2.0% Cr As-Cast is the best innoculation percentage for as-cast recycled aluminium ally with the highest Percentage of Elongation (4.802%) and highest Tensile Stress at Maximum Load (154.33MPa).

4.3.4 Effect of Chromium on the Microstructure (Heat-Treated)

Figure 4.4 shows the optical microstructure of heat treated recycled aluminium alloy with percentage of innoculation of 0%, 0.2%, 0.5%, 1.0%, and 2.0% Chromium. Figure 4.4 (a) shows that for 0% Cr Heat Treated, there are α-Al_8Fe_2Si polyhedral and β-Al_5FeSi Needle structure. The β-Al_5FeSi Needle structure is long and thin. The Percentage of Elongation on graph in Figure 4.6 shows 0% Ni Heat Treated has 2.301% of elongation. The Tensile Stress at Maximum Load (MPa) by graph in Figure 4.8 shows for 0% Cr Heat Treated has 111.44MPa.

The percentage of innoculation was increased further to 0.2% Cr Heat Treated. Figure 4.4(b) shows that 0.2% Cr Heat Treated have microstructures of α-Al_8Fe_2Si polyhedral and β-Al_5FeSi Needle structure. The β-Al_5FeSi Needle structure is short in length. The graph in Figure 4.6 shows that the Percentage of Elongation for 0.2% Cr Heat Treated is 2.849% which is higher than 0% Cr Heat Treated. The Tensile Stress at Maximum Load (MPa) by graph in Figure 4.8 shows for 0.2% Cr has 127.33MPa which is higher than 0% Cr Heat Treated. Therefore, 0.2% Cr Heat Treated has positive feedback on the recycled aluminium alloy.

Next, the percentage of inoculation was increased to 0.5% Cr Heat Treated. Figure 4.4(c) shows that the 0.5% Cr Heat Treated have microstructure of α-Al_8Fe_2Si polyhedral and β-Al_5FeSi Needle structure. The β-Al_5FeSi Needle structure is thin and long in length.

The Percentage of Elongation as shown on graph in Figure 4.6 for 0.5% Cr Heat Treated is 2.832% which is lower than 0.2% Cr Heat Treated. However, there is an increase to 163.01MPa in Tensile Stress at Maximum Load (MPa) as shown on graph in Figure 4.8. Hence, 0.5% Cr Heat Treated does not give positive feedback to recycled aluminium alloy except in terms of Tensile Stress at Maximum Load (MPa).

Similarly, percentage of inoculation was increased to 1.0% Cr Heat Treated. Figure 4.4(d) shows that 1.0% Cr Heat Treated have α-Al_8Fe_2Si polyhedral and β-Al_5FeSi Needle structure. The α-Al_8Fe_2Si polyhedral is more blocky and hexagonal in shape. The Percentage of Elongation of 1.0% Cr Heat Treated has increased to 3.704% as shown on graph in Figure 4.6. Contrarily, the Tensile Stress at Maximum Load (MPa) has decreased to 114.32MPa as shown on graph in Figure 4.8. This shows that 1.0% Cr Heat Treated have positve feedback on recycled aluminium alloy. The reduce in Tensile Stress at Maximum Load (MPa) is due to coarse grain refinement.

Lastly, the percentage of innoculation was increased to 2.0% Cr Heat Treated. The microstructure present are α-Al_8Fe_2Si polyhedral, β-Al_5FeSi Needle structure and Eutectic Silicon. The α-Al_8Fe_2Si polyhedral have star-like blocky shape. Some β-Al_5FeSi Needle structure have broken into Eutectic Silicon. In terms of Percentage of Elongation as shown on graph in Figure 4.6, there is slight decreased to 3.503%. This is due to the present of β-Al_5FeSi Needle structure. The Tensile Stress at Maximum Load(MPa) has increased to 118.56 MPa as shown on graph in Figure 4.8. As a result, 2.0% Cr Heat Treated gives a positive feedback to recycled aluminium alloy.

2.0% Cr is also the best innoculation percentage for heat treated recycled aluminium alloy with the present of Eutectic Silicon and fine grain refinement. It has the second highest Percentage of Elongation (3.503%).

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter summarize the study done based on results and discuss. It also includes the recommendations that could be improved for future studies.

5.2 Conclusion

The purpose of this research is to study the microsturucture properties of recycled aluminium alloy and the effect of innoculation and heat treatment on recycled aluminium alloy. Melting and casting experiments was done by addition of innoculation, which are Nickel and Chromium. The addition level are 0%, 0.2%, 0.5%, 1.0%, and 2.0%. There are two samples prepared for each percentage, the samples were cut into smaller pieces. Then, the samples were grinned and polished. After that, the samples were observed in optical microscopy. The images captured are at 5X, 10X, and 20X magnification. The tensile samples are preapred by machining on milling machine and cut into pieces by wire cut machine. Then they are tested for Percentage of Elongation and Tensile Stress at Maximum Load(MPa) using Instron Universal Testing Machine. The morphological changes observed through optical microscope, Percentage of Elongation and Tensile Stress at Maximum Load (MPa) results are collected and discussed to determine the best innoculation percentage.

The objective of this study is to conduct melting and casting experiments of recycled aluminium, to study the effect of heat treatment on aluminium alloy and to study the tensile strength of aluminium alloy.

The aim of this study is to reduce the detrimental effect on recycled aluminium alloy. The brittle β-Al_5FeSi needle structure is the main cause of this detrimental effect. As the addition of inoculation percentage increases, it has been observed that the brittle β-Al_5FeSi needle structure tend to reduce, Percentage of Elongation increases and Tensile Stress at Maximum Load (MPa) also increases. Other structures that strengthens the recycled aluminium alloy like α-Al_8Fe_2Si polyhedral, Eutectic Silicon and Chinese Script can be seen more clearly. However, not all increase in percentage of innoculation gives a positive feedback, some have caused detrimental effect towards it. 1.0% Ni As-Cast is the best innoculation percentage for as-cast recycled aluminium alloy with innoculated Nickel element as it has only α-Al_8Fe_2Si polyhedral structure and has highest Percentage of Elongation (3.755%). 2.0% Ni Heat Treated is the best innoculation percentage for heat treated recycled aluminium alloy with innoculated Nickel element. 2.0% Ni Heat Treated has α-Al_8Fe_2Si polyhedral structure more hexagonal in shape and β-Al_5FeSi needle structure is thicker. Next, 2.0% Cr As-Cast is the best inoculation percentage for as-cast recycled aluminium alloy inoculated with Chromium element as it has has α-Al_8Fe_2Si polyhedral structure more hexagonal in shape and β-Al_5FeSi needle structure is shorter in length. Moreover, 2.0% Cr As-cast has highest Percentage of Elongation (4.802%) and highest Tensile Stress at Maximum Length (MPa) which is 154.33 MPa. Lastly, 2.0% Cr Heat Treated is the best innoculation percentage for heat treated recycled aluminium alloy innoculated with Chromium element.

In conclusion, this study which is On the Microstructure-Property Correlation of Recycled Aluminium Alloy is a success. All the objectives which are to conduct melting and casting experiments of recycled aluminium, to study the effect of heat treatment on aluminium alloy, to study the microstructure properties of aluminium alloy by inoculation and to study the tensile strength of aluminium alloy have been successfully achieved.

5.3 Recommendations

This study may have some flaws at certain point where it can be improved in upcoming studies. A few recommendations are given in order to have better research study in future. The recommendations are:

5.3.1 Weighing of Innoculants

To achieve better results, weighing of innoculants should be done in careful manner. The weighing should be done on a stable table. The vibration caused by table instability causes weighing of the inoculant weight to be not stable and less accurate.

5.3.2 Casting Process

During casting, the rate of pouring is very important. Pouring should be continuous in order to have uniform pouring rate. This is to reduce the porosity in sample which is caused by not uniform solidification of the sample.

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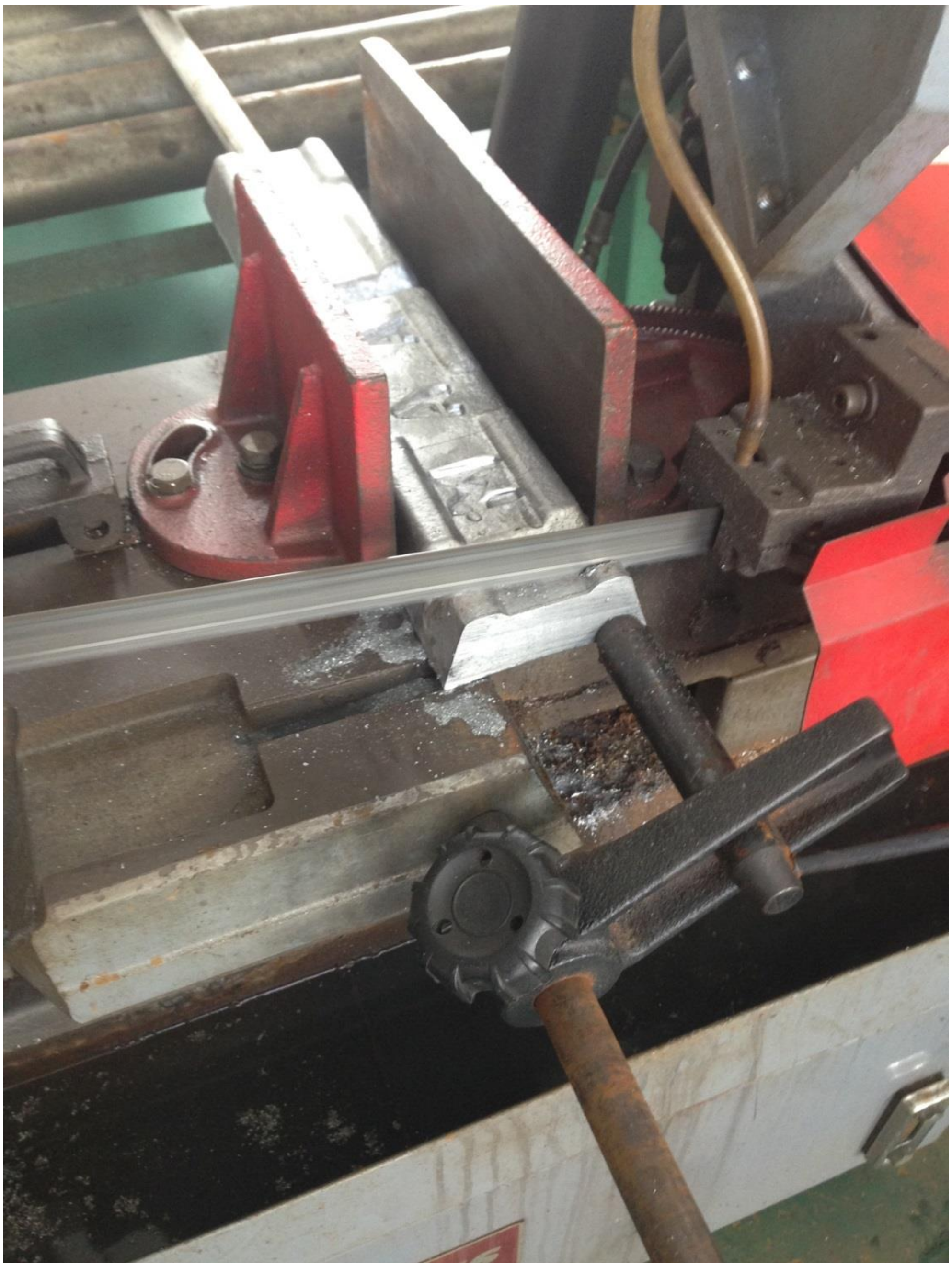
APPENDIX A

Recycled Aluminium Ingot

APPENDIX B

Cutting of Aluminium Ingot Using Horizontal Band saw Machine



APPENDIX C

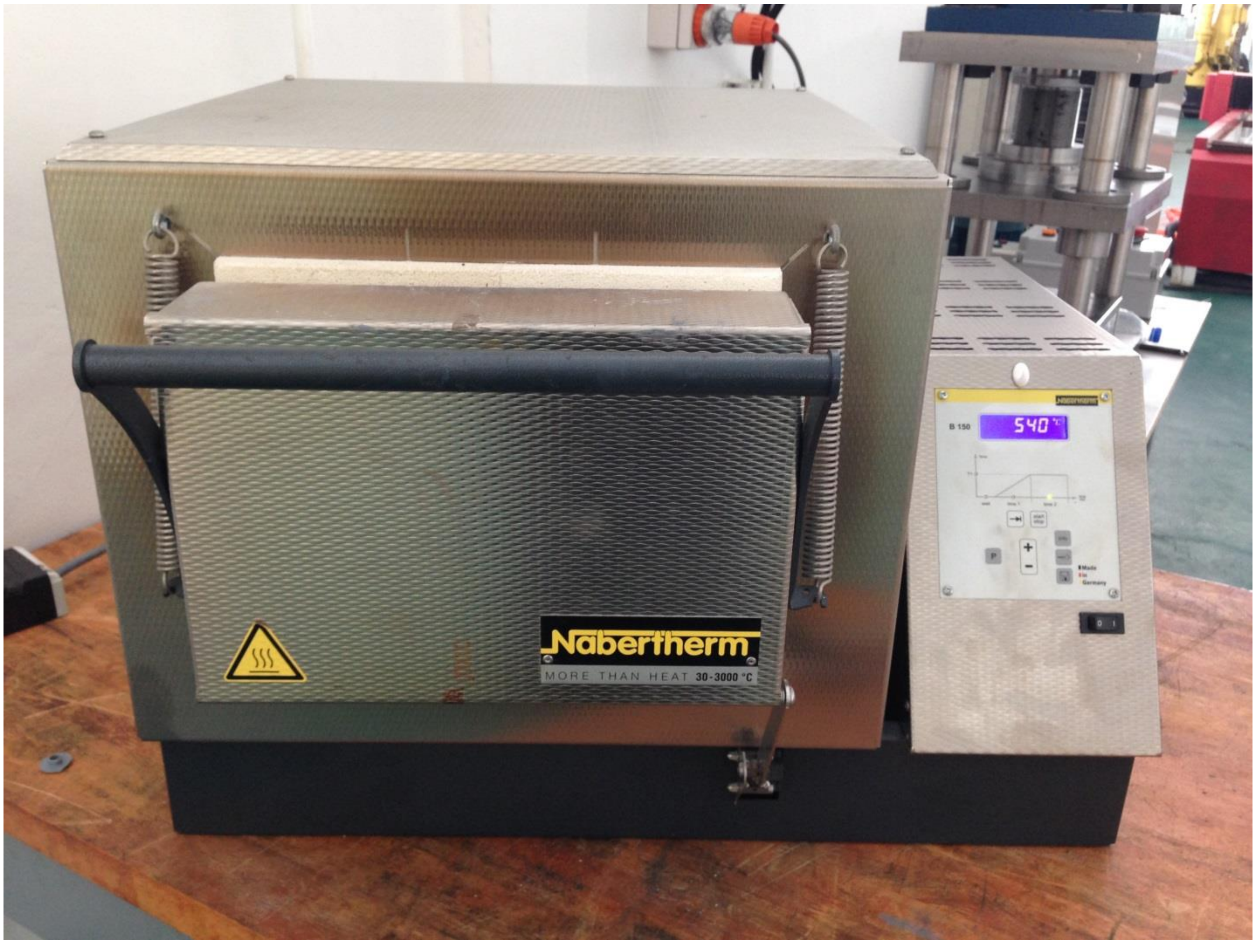
Pieces of Aluminium after Cut

APPENDIX D

Casting Furnace used for Melt and Casting Experiments

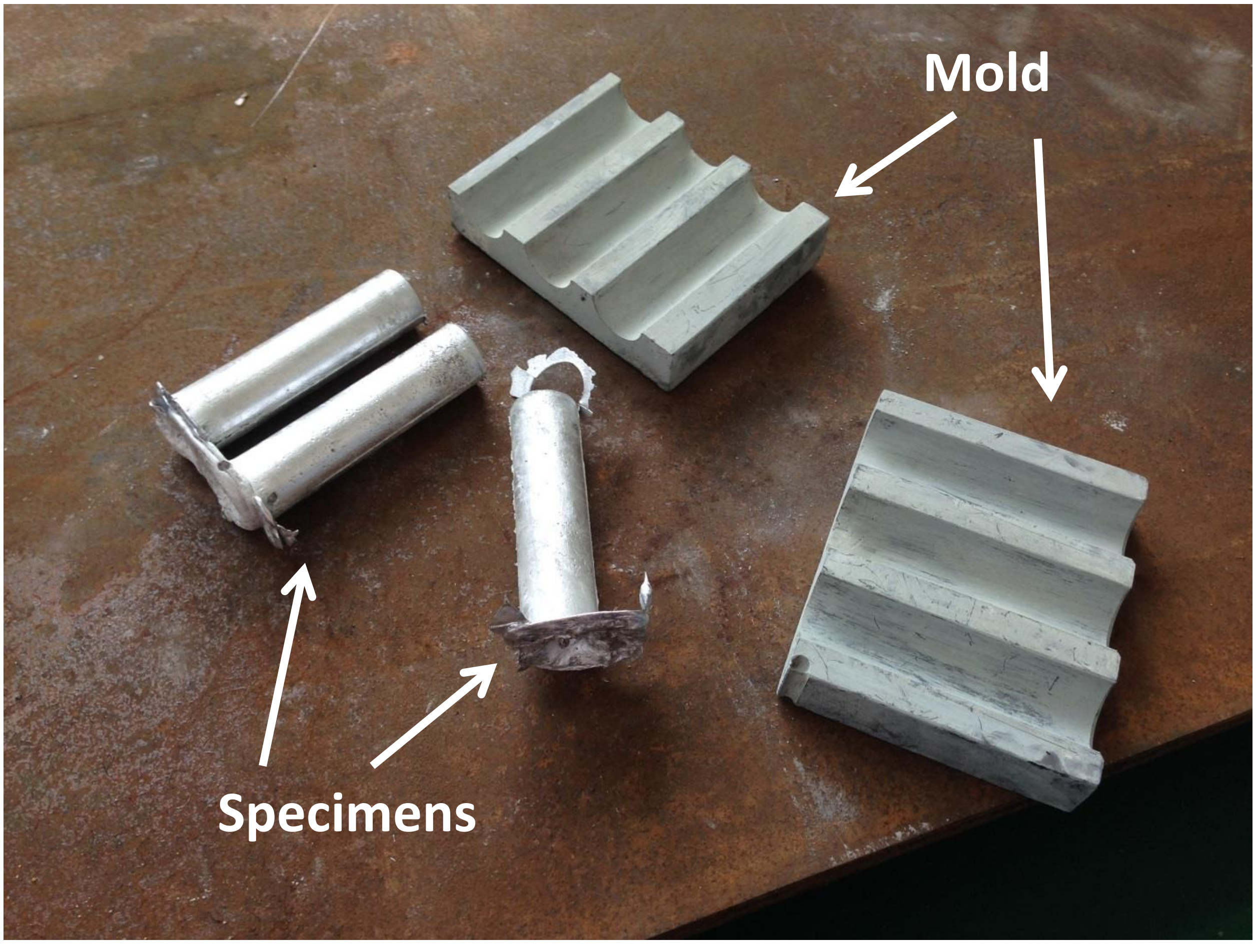
APPENDIX E

Nabertherm Furnace used for Heat Treatment



APPENDIX F

Specimens after Melting and Casting Experiments



APPENDIX G

Metkon Metacut-M-250 Abrasive Cutter

APPENDIX H

Metkon Forcipol 2V Grinder and Polisher

APPENDIX I

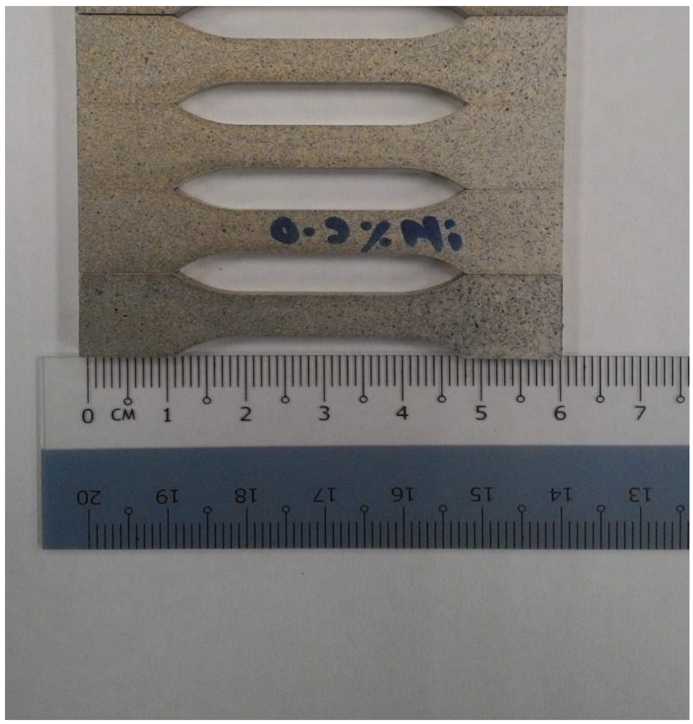
Milling Machine Makino KE55

APPENDIX J

Sodick for Wire Cutting

APPENDIX K

Tensile Sample



APPENDIX L

NO	PROJECT ACTIVITIES		Weeks													
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
	FYP briefing and	Plan														
1	registration of super	Actual														
	Title registration	Plan														
2		Actual														
	Presentation at	Plan														
3	supervisor	Actual														
	MILESTONE 1															
4	Draft of proposal	Plan							Draft of proposal							
		Actual														
	TURN IT IN	Plan									TURN IT IN					
5	result	Actual														
	Presentation	Plan									Presentation slide					
6	side	Actual														
	Presentation	Plan														
7	FYP 1	Actual														
	MILESTONE 2															
8	Summit FYP report a	Plan														
	TURN IT IN result	Actual														

APPENDIX M

FINAL YEAR PROJECT (FYP2)2015-2016																
No.	Project Activities		Week													
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Chapter 4:Results & Discussion															
1.1	Sample Preparation	Plan														
		Action														
1.2	Data collection & Analyzation	Plan														
		Action														
1.3	Discussion	Plan														
		Action														
2	Chapter 5:Conclusion& Recommendation	Action														
2.1	Conclusion	Plan														
		Action														
	Recommendation	Plan														
		Action														
	End of the Project	Plan														
		Action														