STUDY OF MICROSTRUCTURE AND HARDNESS OF Al-Si-Mg-Be ALLOY IN T6 CONDITION

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Dissertation submitted in partial fulfillment of the requirements for the degree of

BACHELOR OF ENGINEERING

Branch: METALLURGICALENGINEERING

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DEPARTMENT OF METALLURGICAL ENGINEERING

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Bona fide record of work done by

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SYNOPSIS

In this study, Al7Si0.6Mg0.04Be alloy is produced by stir casting route for studying the microstructure and mechanical properties. This alloy is strengthened by precipitation hardening, through T6 condition, which consists of solution annealing and artificial aging. The optimum level of strength and ductility attained after thermal treatments is attributed to changes in Si particle characteristics resulting from the solution treatment and to the formation of Mg-Si precipitates resulting from the aging process. For the experimental studies, two samples with 0.4% Magnesium and without beryllium, and another one with 0.6% Magnesium and with beryllium are prepared through stir casting process. Then they are heat treated under T6 condition. The samples are solutionized at 550°C and water quenched. The samples are then artificially aged at different temperatures to determine the suitable temperature for enhanced properties. The samples are characterized by hardness testing and optical microscopy. Finally, samples are compared based on the results obtained. The eutectic Si particles are larger in alloys with higher Mg content. The addition of Mg and Be increases the strength and hardness while decreasing ductility. The formation of the finer Mg-Si precipitates (β) during the aging process could be the reason for the increased hardness.

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CHAPTER 1

INTRODUCTION

An aluminium alloy is an alloy in which aluminium (Al) is the predominant metal. The typical alloying elements are copper, magnesium, manganese, silicon, tin, nickel and zinc. There are two principal classifications, namely cast alloys and wrought alloys, both of which are further subdivided into the categories heat-treatable and non-heat-treatable. About 85% of aluminium is used for wrought products, for example rolled plate, foils and extrusions. Cast aluminium alloys yield cost-effective products due to the low melting point, although they generally have lower tensile strengths than wrought alloys. The most important cast aluminium alloy system is Al–Si, where the high levels of silicon (4–13%) contribute to give good casting characteristics. Aluminium alloys are widely used in engineering structures and components where light weight or corrosion resistance is required.

Aluminium 357 alloy is a high-strength aluminium alloy that is commonly used in various industries due to its excellent combination of mechanical properties, corrosion resistance, and castability. It belongs to the aluminium-silicon-magnesium (Al-Si-Mg) alloy family, which are known for their lightweight properties and high strength-to-weight ratio. Aluminium 357 alloy is typically composed of aluminium (Al), silicon (Si), magnesium (Mg), and small amounts of other elements such as copper (Cu), manganese (Mn), and zinc (Zn). The specific composition may vary depending on the manufacturer or application requirements. One of the key features of aluminium 357 alloy is its exceptional strength, making it suitable for demanding applications where high mechanical performance is required. It exhibits excellent tensile strength, yield strength, and hardness, making it ideal for applications that require lightweight and strong components, such as aerospace and automotive industries. Moreover, aluminium 357 alloy also offers good corrosion resistance, making it suitable for use in harsh environments where exposure to moisture, chemicals, or saltwater is a concern. This makes it ideal for marine, automotive, and other corrosive environments. In addition, aluminium 357 alloy is known for its good castability, allowing for complex shapes and designs to be easily achieved through various casting methods, such as sand casting, die casting, and investment casting. This makes it a popular choice for manufacturing complex components and parts. Overall, aluminium 357 alloy is a high-strength aluminium alloy with excellent mechanical properties, corrosion resistance, and castability, making it suitable for a wide range of applications across various industries.

The **microstructure** of aluminium 357 (A357) alloy typically consists of primary aluminium dendrites and eutectic phases, which are formed during solidification. The specific microstructure may vary depending on the processing conditions, such as casting method, cooling rate, and heat treatment. The primary aluminium dendrites are the first solidified phase during the solidification process of A357 alloy. They form a branched, tree-like structure that grows inward from the Mould walls. The size and shape of the primary aluminium dendrites depend on the cooling rate during solidification, with slower cooling rates typically resulting in larger dendrites. The eutectic phases in A357 alloy typically consist of two main phases: aluminium-silicon (Al-Si) eutectic and aluminium-magnesium-silicon (Al-Mg-Si) eutectic.

The Al-Si eutectic phase typically forms lamellar structures, where aluminium and silicon alternate in layers. The Al-Mg-Si eutectic phase, on the other hand, usually forms as small, dispersed particles within the microstructure. Apart from the primary aluminium dendrites and eutectic phases, A357 alloy may also contain other secondary phases or intermetallic compounds, such as magnesium-containing phases (e.g., Mg_2Si) and copper-containing phases (e.g., $CuAl_2$). These phases may form due to the specific composition and processing conditions of the alloy. The microstructure of A357 alloy plays a crucial role in determining its mechanical properties, such as strength, ductility, and toughness. Heat treatments, such as solution heat treatment and precipitation hardening, can be employed to modify the microstructure and further enhance the mechanical properties of A357 alloy for specific applications.

Heat treatment: Heat treatment of A357 alloy typically involves a combination of solution heat treatment (also known as homogenization) and precipitation hardening (also known as aging). These heat treatment processes are used to modify the microstructure and improve the mechanical properties of the alloy for specific applications.

Solution Heat Treatment (Homogenization): The solution heat treatment is typically the first step in the heat treatment process for A357 alloy. It involves heating the alloy to a temperature above its solvus temperature, which is the temperature at which all the alloying elements dissolve in the aluminium matrix, typically around 500-550°C. The alloy is then held at this temperature for a sufficient time to allow for a uniform distribution of the alloying elements within the aluminium matrix, typically ranging from 1 to 8 hours, followed by a quenching process, such as water quenching or air quenching, to rapidly cool the alloy to room temperature. This results in a supersaturated solid solution of alloying elements in the aluminium matrix.

Precipitation Hardening (Aging): After solution heat treatment, the alloy is aged, or precipitation hardened, to form fine precipitates of alloying elements within the aluminium matrix. The alloy is typically heated to a lower temperature, typically around 150-200°C, and held at this temperature for a specific period of time, typically ranging from a few hours to several days, depending on the desired properties. During aging, the alloying elements that were dissolved during the solution heat treatment start to precipitate out of the solid solution, forming fine particles or precipitates. These precipitates act as barriers to the dislocation movement, leading to an increase in strength and hardness, while maintaining good ductility. The specific temperature, time, and quenching conditions used in the heat treatment of A357 alloy may vary depending on the specific requirements of the application and the desired mechanical properties. Heat treatment parameters need to be carefully controlled to achieve the desired microstructure and properties, as excessive or insufficient heat treatment can result in undesirable effects, such as over-aging or under-aging, which can affect the mechanical properties of the alloy.

Overall, the heat treatment of A357 alloy involving solution heat treatment and precipitation hardening is a common process used to improve the mechanical properties, such as strength and hardness, of the alloy for specific applications where high performance is required. It is important to consult the specific heat treatment guidelines provided by the alloy manufacturer or a qualified metallurgist to ensure proper heat treatment for A357 alloy.

Phase Diagram:

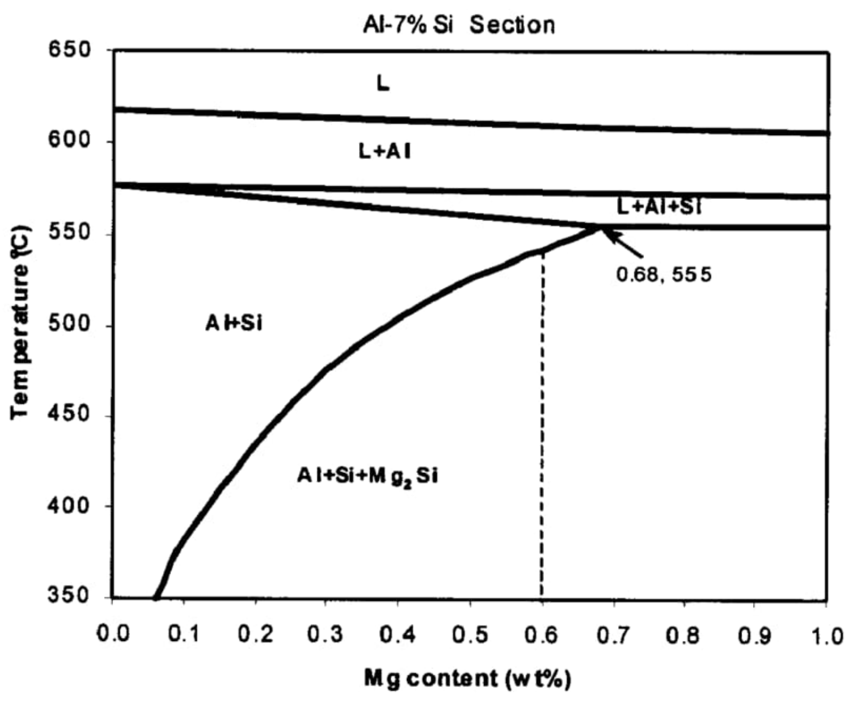

Fig 1.1: Phase diagram of Al-Si-Mg alloy

The phase diagram of A357 alloy consists of three main phases: solid solution (α-Al), eutectic phase (Al-Si), and intermetallic compounds (Al_2CuMg and Al_7Cu_2Fe). The phase diagram typically includes temperature (T) on the y-axis and composition (wt.%) on the x-axis.

Solid Solution (α-Al): At low temperatures and aluminum-rich compositions, A357 alloy is in the solid solution phase, where aluminum (Al) atoms are dissolved in the matrix. This phase is characterized by a single-phase solid solution of aluminum with a face-centered cubic (FCC) crystal structure.

Eutectic Phase (Al-Si): As the temperature increases, a eutectic reaction occurs in A357 alloy, leading to the formation of a eutectic phase composed of aluminum (Al) and silicon (Si). This phase has a lamellar structure and consists of alternating plates of aluminum and silicon. The eutectic composition of A357 alloy is typically around 6-7 wt.% Si.

Intermetallic Compounds (Al_2CuMg and Al_7Cu_2Fe): At elevated temperatures, A357 alloy forms intermetallic compounds, including Al_2CuMg and Al_7Cu_2Fe , which are precipitation-hardening phases. These phases form during heat treatment or solidification and provide the alloy with improved strength and hardness. The phase diagram of A357 alloy is complex and may vary depending on the specific composition, processing conditions, and heat treatment. Understanding the phase diagram is important in determining the appropriate processing and heat treatment conditions to achieve desired mechanical properties in A357 alloy casting.

CHAPTER 2
LITERATURE SURVEY

2.1 Al-Mg-Si ALLOYS:

About 90% of all shaped Al castings are made from Al-Si based alloys because they combine good casting properties with acceptable mechanical properties. Si improves the fluidity and improves wear resistance. By adding Mg, Al-Si alloys become age hardenable through the precipitation of Mg_2Si particles.

Excellent castability, corrosion resistance and high strength-to-weight ratio (which increases performance and fuel economy) have made cast Al–Si–Mg alloys suitable candidate materials for various applications in the automotive industry, such as engine blocks and cylinder heads.[8]

The main limitations of Al-Si-Mg cast components are due to the considerable influence of the solidification conditions on the final microstructure. The final cast component inevitably contains a certain number of defects such as oxide films, shrinkage and gas porosity, which significantly affect the mechanical properties and in particular the fatigue behaviour.[10]

2.2 STIR CASTING PROCESSING

Stir casting is a suitable processing technique to fabricate Al alloys as well as aluminum matrix composites. It is an economical process and preferred for mass production. The first step of stir casting involves melting of aluminum using an electric resistance type furnace. Figure 2.1 shows the schematic diagram of a stir casting equipment.

Stir casting is a type of casting process in which a mechanical stirrer is introduced to form vortex to mix reinforcement in the matrix material. It is a suitable process for production of metal matrix composites due to its cost effectiveness, applicability to mass production, simplicity, almost net shaping and easier control of composite structure.[5]

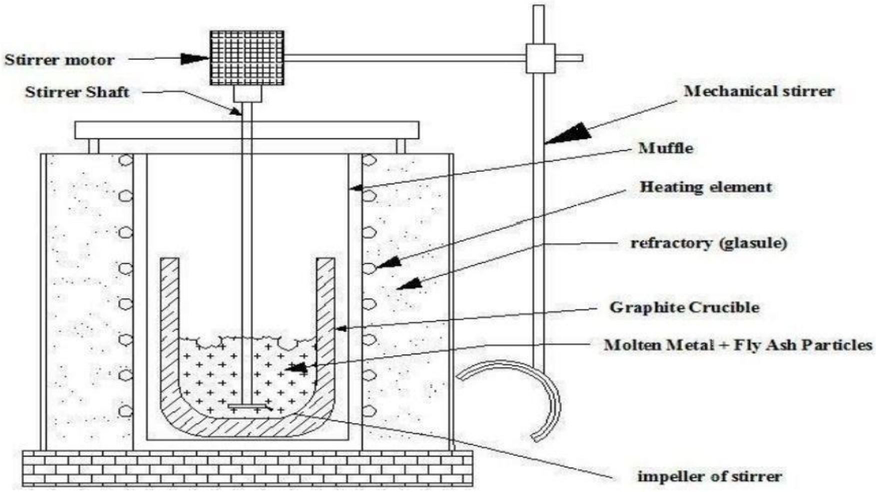

Fig 2.1 A schematic diagram of a stir casting unit.

Stir casting setup as, consist of a furnace, reinforcement feeder and mechanical stirrer. The furnace is used for heating and melting of the materials. The bottom poring furnace is more suitable for the stir casting as after stirring of the mixed slurry instant poring is required to avoid the settling of the solid particles in the bottom crucible. The mechanical stirrer is used to form the vortex which leads to the mixing of the reinforcement material which are introduced in the melt. Stirrer consists of stirring rod.

The stirrer is connected to the variable speed motors, the rotation speed of the stirrer is controlled by the regulator attached with the motor. Further, the feeder is attached with the furnace and used to feed the reinforcement powder in the melt. A permanent mold, sand mold or a lost-wax mold can be used for pouring the mixed slurry.

In this process, the matrix material are kept in the bottom pouring furnace for melting. Simultaneously, reinforcements are preheated in a different furnace at certain temperature to remove moisture, impurities etc. After melting the matrix material at certain temperature, the mechanical stirring is started to form vortex for certain time period then reinforcements particles are poured by the feeder provided in the setup at constant feed rate at the center of the vortex, the stirring process is continued for certain time period after complete feeding of reinforcements particles. The molten mixture is then poured in preheated mold and kept for natural cooling and solidification. [5]

2.3 MICROSTRUCTURE OF A357:

A typical microstructure of the cast A357 alloy consists of the Al matrix and the Si particles, with the Si particles being somewhat fibrous. It consisted of α-Al plus several morphologically distinct intermetallic constituents as well as Si phase. They were observed in the α-Al interdendritic regions.

By a combination of morphology, EPMA analysis and etching characteristics, these intermetal- lic phases were identified as ß (Al_5FeSi), π ($Al_8Si_6Mg_3Fe$) and (Mg_2Si). The ß (Al_5FeSi) phase generally appeared with a platelet morphology. [10]

2.4 HEAT TREATMENT OF A357:

The heat treatment of age hardenable aluminum alloys involve solutionizing the alloys, quenching, and then either aging at room temperature (natural aging) or at an elevated temperature (artificial aging). The optimum degree of strength can be achieved by heat treatment, consisting of a solution heat treatment close below the eutectic temperature, followed by quenching and, eventually, natural or artificial ageing [10]

The enhancement in mechanical properties after thermal treatment has largely been attributed to the formation of non-equilibrium precipitates within primary dendrites during aging and the changes occurring in Si particles characteristics from the solution treatment.[2]

The age hardening response depends on the fraction size, distribution and coherency of precipitates formed. Al-Si-Mg alloys generally have a high age hardening response.[2]

A357 is strengthened by precipitation hardening particularly T6 heat treatment which consists of solutionizing at high temperature, subsequent water quenching and final artificial ageing.

The optimum castability of such alloy is provided by Si presence which increase the fluidity and hot cracking resistance, while the Mg presence improves the mechanical properties after T6: during heat treatment Mg and Si form Mg_2Si which precipitates from α-Al solid solution and strengthens the alloy precipitation hardening.[2]

2.5 APPLICATIONS OF A357:

Among Al–Si–Mg alloys, A357 or AlSi7Mg 0.6 is a cast alloy extensively used in aerospace applications such as turbo frames and aircraft bodies (Figure 2.2).[6] They are also used in structural automotive applications such as blocks, cylinder heads, suspension system etc. since its very good castability and the specific strength, good corrosion and fatigue resistance.[8]

A357 is typically used in situations where high strength combined with high corrosion resistance and/or pressure tightness are required. It is commonly used to make parts; including structural, machine, impellers, housings, pump and valve components, tools, frames, and brackets.[1]

Aluminum in many forms has been used in aircraft since the early beginning. This is because aluminum alloys can be heat-treated to relatively high strengths, while maintaining low weight. It is easy to bend and machine, and cost of material is low. Because of these advantages, it is the most common material used in aerospace today.[7]

Because of affordability, the use of castings has also been used. However, the use of castings has been limited because of design factors and the limited ductility of castings. Typically casting alloys such as A356, and A357 are used. Applications of castings are simple, non-flight critical applications, such as door handles and avionics cabinets.

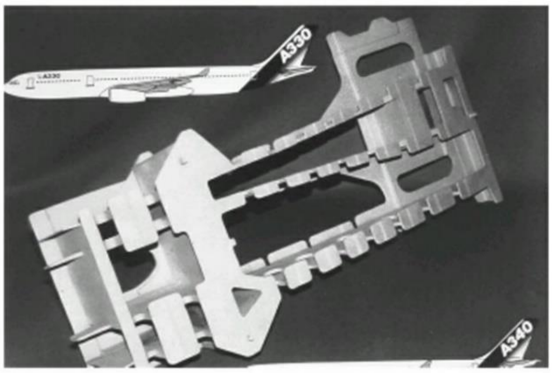

Fig 2.2

Fig 2.3

Figure 2.2 and 2.3: A357 alloys used in inner turbo frame for the Airbus family of aircraft and another aircraft cast component.

CHAPTER 3

OBJECTIVES AND SCOPE OF PROJECT

3.1 OBJECTIVES

- To produce Al-Si-Mg alloy with Mg and Be content using Stir-casting set-up.
- To study the mechanical properties and microstructural characteristics of A357 alloys under As-cast and Heat-treated conditions.

3.2 SCOPE

- To compare the microstructure and mechanical properties of Al-Si-Mg alloy with and without Be in both As-cast and T6 condition.

3.3 METHODOLOGY

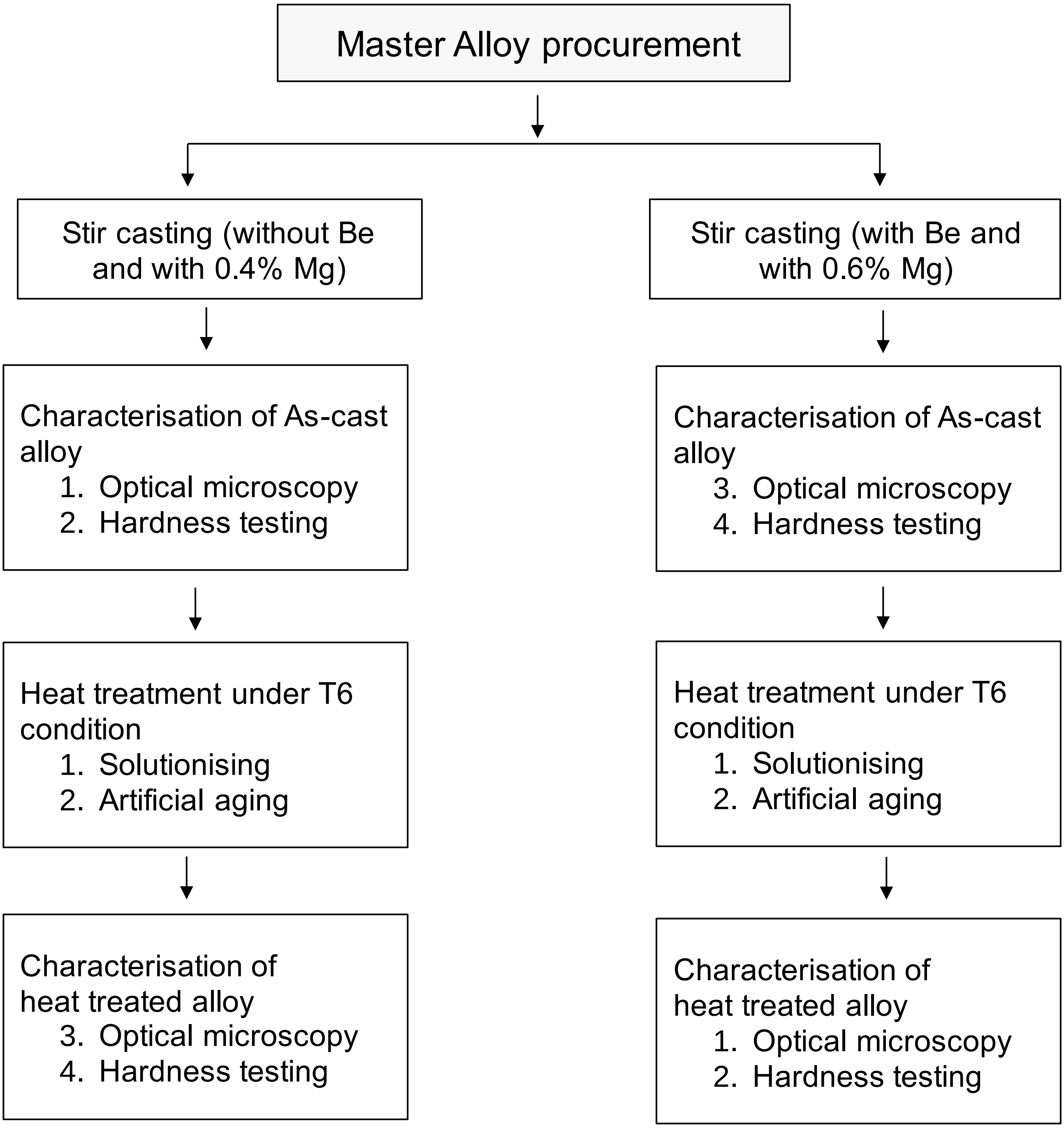

Fig 3.1: Flowchart of the present work

CHAPTER 4

EXPERIMENTAL WORKS

4.1 CASTING OF Al-Si-Mg ALLOY WITHOUT Be

4.1.1 PROCUREMENT OF RAW MATERIALS: -

The base alloy LM 24 alloy is tested in OES to know the chemical composition. The OES result is given in tables 4.1,4.2,4.3.

Table 4.1: Chemical composition of LM24 alloy

Si	Mg	Ti	Al
8.629%	0.135%	0.037%	89.65%

The master alloys i.e., Al 20 Mg and Al TiB were purchased due to the low Mg and Ti content in the base alloy. The composition of both the master alloys were given below.

Table 4.2: Chemical composition of Al-TiB 5:1 alloy

Ti	B	Fe	Al
5%	1%	0.3%	Remaining

Table 4.3: Chemical composition of Al 20 Mg alloy

Mg	Fe	Al
20%	0.5-1%	Remaining

4.1.2 CHARGE CALCULATION: -

The charge calculation is done by a formula as shown below:

Charge calculation =

*[(existing comp-required comp)/ efficiency] * total weight of the liquid metal*

Using above equation, required amount of raw materials were calculated and reported below

The charge calculation was made for aim composition as shown in table 4.4.

For 1kg cast,

Al - 8.2 Si = 800g

Pure Al = 250g

Al – 20 Mg = 20g

Ti – B = 20g

Required composition:

Table 4.4: Aim composition of Al-Si-Mg alloy

Si	Mg	Ti	Fe	Al
6.5 to 7%	0.4%	0.02 to 0.2%	0.3%	89.9%

4.1.3 STIR CASTING PROCESS: -

4.1.3.1 PREHEATING OF THE RAW MATERIALS

The alloys are preheated at 200 degrees Celsius for about 2 hours. Preheating is done to remove all the moisture content from the base alloy and master alloys. Preheating is a mandatory process before stir casting. The semi solid casting furnace is heated to its maximum temperature of 750-degree C. Ar gas is provided inside the furnace at a rate of 1litre/min. Ar gas is provided to avoid oxidation and create an inert atmosphere.

4.1.3.2 MELTING OF Al-Si-Mg ALLOY

Melting was carried out using a furnace type crucible melting furnace with stir facility. The schematic diagram of melting furnace with stirring facility is shown in fig 4.1.

Then the Al-Si alloy is added and melted. The Melting happened after 20 mins of adding the Al-Si. After melting the Al-Si, Al- 20Mg is added and melted. Then by using the graphite stirrer, the stirring action is done to finely mix the alloys. The stirring speed is 580rpm. A small part of cast is taken out and tested for chemical composition. The sample contained 8% Si content which is 2% higher than the required composition. 280g of Pure Al is taken and added into the furnace to dilute the Si content. Then the reinforcement Ti-B is added and again stirring is done.

Fig 4.1 Semi solid casting furnace

4.1.3.3 POURING

After 10 mins, the molten cast is prepared. The cast is poured slowly into the mold and the cast alloy is formed. The cast is cooled in room temperature and weighed. Pouring is shown in the fig 4.2.

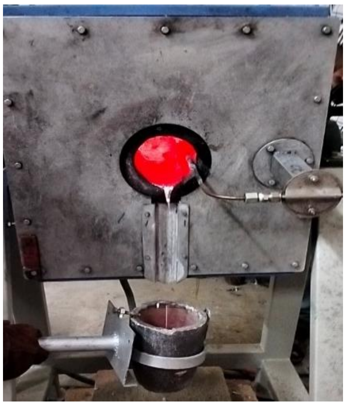

Fig 4.2 Pouring

4.1.3.4 REMOVAL OF THE CAST SAMPLE FROM THE MOLD

The sample is then removed from the mold after cooling on room temperature. Shrinkage defect is observed in this sample. Then the defect part is removed by machining.

Fig 4.3 Aluminum cast alloy

4.2 CASTING OF (Al-Mg-Si) ALLOY WITH Be

4.2.1 PROCUREMENT OF RAW MATERIALS: -

The raw materials for 2^{nd} sample is same as in fig 4.1,4.2,4.3, except for the Be master alloy

Table 4.5: Chemical composition of Al-2Be alloy

Be	Fe	Al
2.2%	0.1%	Remaining

4.2.2 CHARGE CALCULATION: -

The charge calculation is done by using the formula as in 4.1.2

For 1kg cast,

Al-8 Si = 600g

Al-20 Mg = 20g

Al-2Be – 15g

Ti-B = 20g

The charge calculation was made for aim composition as shown in table 4.6.

Required composition:

Table 4.6: Aim composition of Al-Si-Mg alloy(with Be)

Si	Mg	Ti	Be	Fe	Al
6.5 to 7%	0.4%	0.02 to 0.2%	0.04 – 0.07%	0.3%	89.9%

4.2.3 STIR CASTING PROCESS: -

Firstly, the preheating of raw materials is done as said before in 4.1.3.1

Then, melting of the raw materials is done as same as 4.1.3.2 but before the addition of Ti-B, the main alloy Al-2Be is added and melted.

CASTING FACTORS:

- Preheating of alloys: 150°C
- Preheating time: 2 hrs
- Max. temperature of casting furnace: 750°C
- Stirring speed: 580 rpm
- Stirring time: 5 mins

Fig 4.4: Pouring

Fig 4.5: Pouring into the mould

Fig 4.6: Cast filled mould

Fig 4.7: Al-Si-Mg cast sample with Be addition

4.3 COMPOSITION ANALYSIS:

The as-cast and heat-treated samples are analyzed for their compositions by OES. The composition is acquired from OES is then compared to the ASTM standard.

Optical Emission Spectroscopy (OES) is a technique used to analyze the elemental composition of a material. It involves exciting a material with a high-energy source, such as a laser, and measuring the light emitted by the material as a result of this excitation. When an atom or molecule is excited by the energy source, it releases some of its electrons to a higher energy level. When these electrons return to their original energy level, they emit light at a specific wavelength, which is characteristic of the element or molecule being analyzed. By measuring the intensity of the emitted light at different wavelengths, the elemental composition of the material can be determined.

4.4 HEAT TREATMENT:

The sample is cut into small pieces and the markings were given as 1,2,3,4,5 for both melts. The 5 pieces were heat treated under T6 heat treatment condition.

T6 heat treatment is a type of heat treatment applied to aluminum alloys to increase their strength and hardness. The T6 designation refers to the treatment process which involves solution heat treatment followed by artificial aging.

The T6 heat treatment process begins by heating the aluminum alloy to a temperature between 470°C to 540°C for a specific period of time, typically several hours, in order to dissolve the alloying elements in the solid solution. This is known as the solution heat treatment.

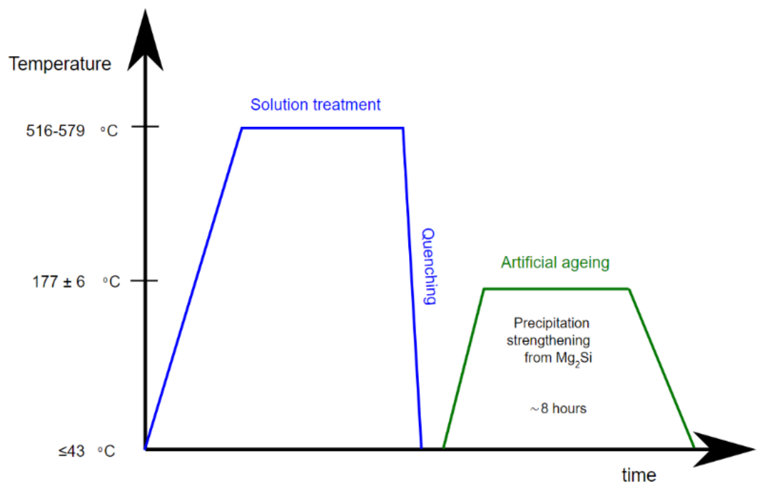

Fig 4.8: Heat treatment of Al-Si-Mg

After this, the material is quenched in water or other appropriate cooling media to prevent the formation of unwanted phases.

Next, the material is artificially aged by heating it to a lower temperature, typically between 120°C to 200°C, for several hours. This process enables the precipitation of the alloying elements that were previously in solution, leading to the formation of fine precipitates that increase the strength and hardness of the material. The mechanical properties reach their highest value at the stage when the precipitates transform from coherent to incoherent particles. Continued aging at too high a temperature for too long a time degrades properties such as strength and hardness as the equilibrium particles grow in size.

The largest precipitates continue to grow whereas the smaller particles disappear, resulting in an increase in the average particle size and a reduction in the number of particles. The softening of an alloy as a result of particle coarsening is called over-aging, and it must be avoided if optimum properties are required.

The samples were solutionised in the muffle furnace at 550^{0}C for 1 hour.

Next, the samples are aged at different temperatures:

(90^{o}C ,120^{o}C,150^{o}C,180^{o}C,200^{o}C) for about 5 hours each.

Solutionizing temperature – 550^{o}C.
Aging temperatures – 90^{o}C,120^{o}C,150^{o}C,180^{o}C,200^{o}C.

4.5 MICROSTRUCTURAL ANALYSIS

Grinding

Mounted or unmounted specimens can be ground either manually (i.e., by hand) or using automated devices. Silicon carbide has been the generally preferred grinding abrasive for aluminium and its alloys and it is quite effective. In the past, specimens were ground through a series of five or more sheets of SiC with increasingly finer abrasive sizes. In the new methods, only one SiC abrasive size is employed. If the specimens have been sectioned with an abrasive wheel designed for metallographic sectioning of aluminium, then the damage introduced is minimal and grinding can commence with a relatively fine grit size, at least 240 (P280) or 320-grit (P400). The surface is water-cooled and the platen is rotated at 240-300 rpm. Loads are slightly lower for Al than for steel, 5 lbs (22N) per specimen, rather than 6 lbs (27N).

Polishing

Polishing is performed today using one or more diamond abrasive sizes followed by final polishing with colloidal silica. MgO is no longer used for final polishing, as it is difficult to use, gives relatively poor results, and its use requires special cloth cleaning procedures due to the formation of magnesium carbonates after the cloth dries (which ruins the cloth). Colloidal silica also has some problems with it use. First, always wash off the cloth thoroughly after use. If the suspension evaporates, the silica will crystallize and ruin the cloth. Colloidal silica is harder to clean off the polished surface than other abrasives. Scrub the surface with a tuff of cotton soaked in a soap solution, rinse with water and dry in the usual manner (displace the water with ethanol and blow dry with warm air). An easy way to simplify cleaning of your specimens is as follows. If you are using an automated polisher, stop adding colloidal silica about 20 s left in the polishing cycle. Then, with about 10 s left, turn the water on and flush the abrasive off the surface. Then, cleaning will be much easier. Colloidal silica is also sold with additives to minimize the crystallization problem. These are often referred to as “non-freezing” suspensions. These are somewhat easier to work with and produce equivalent results.

Etching

With nearly all metals and materials, and aluminium is no exception, it is always best to examine specimens after preparation, prior to etching. Some intermetallic phases are best identified in the as-polished condition, such as Si and Mg_2Si. Fine cracks, voids, or cracks and voids associated with intermetallic particles may be easier to see before etching. Numerous etchants [1, 2] have been developed for revealing the microstructure of aluminum and its alloys. General-purpose etchants are used by swabbing or by immersion. Swabbing is conducting using cotton saturated with the reagent. Hold the specimen with tongs using one hand and swab with cotton, held with tongs, in the other hand. Some metallographers wrap cotton around a small piece of wood, like a “popsicle” stick, others use “Q-tips”. However, for best results, use a good grade of surgical cotton. Cosmetic cotton puffs can contain impurity fragments that may interfere with etching, or they may disintegrate readily in the strong etchants required for aluminum. Immersion is simpler. The specimen is placed in a small beaker containing about 100mL of the etchant, polishing face up, using tongs. Gently swirl the etchant or use the tongs to provide agitation. This promotes uniform etching. Surfaces must be properly cleaned before etching, or etching results will be impaired. Etching is halted when the proper degree of surface dulling is produced. The specimen is removed from the beaker, or swabbing is halted, and rinsed with running water. The specimen is then rinsed with ethanol and blown dry with warm air.

Microstructures

A number of specimens were etched with the following reagents to reveal the grain structure: Keller’s reagent, the caustic NaF reagent, the Graff-Sargent reagent, and Weck’s reagent. The tests showed that Weck’s revealed the grain structure in almost every instance. For 2011-O, only Weck’s produced a rendering of the grains,For 2011-T3, all four revealed the grain structure, but the Graff-Sargent etch appeared to bring up cell boundaries that were much finer in size than the grains. Type 3003 is a very difficult alloy to reveal grain size. Only Weck’s reagent showed the grains, although the results were not as good as desired. Results for 4032-T6 showed that Keller’s and Weck’s could bring up the grain structure, 4147 was quite difficult and again Weck's was the only etch that revealed grains, although the results were not perfect 5083-H321 was tried and Weck's faintly revealed the grain structure, while none of the others revealed any boundaries. 6013-T8 produced good results, except for the Graff-Sargent etch. Results with Weck's reagent are shown in. 6061-T6511 was successfully etched by the caustic NaF reagent and by Weck's,. 6262-T9 was also successfully etched by the caustic NaF reagent and by Weck's. All four reagents revealed the grain structure of 7075-T651 successfully. shows the results after using Weck's reagent. All micrographs were taken in polarized light plus sensitive tint.

4.6 HARDNESS TESTING

A Microhardness test was performed using a Micro-hardness Tester on a Vickers scale with a load of kilogram. The A357 alloy is polished to a mirror finish and then subjected to a diamond pyramid indenter of 136º indenter angle between the opposite faces of the pyramid. Three readings were taken for each specimen in different locations and the average value of Vickers hardness for each specimen was reported.

The hardness of A357 alloy after heat treatment is about 110 HV according to works of literature. In As-cast structure, the hardness measured was 80.

CHAPTER 5

RESULTS AND DISCUSSION

5.1 COMPOSITIONAL ANALYSIS

The Composition of melt without the addition of Be:

Table 5.1: The expected Composition of cast sample without Be

Si	Mg	Ti	Fe	Al
6.5 to 7%	0.4%	0.02 to 0.2%	0.3%	Bal

Table 5.2: The obtained Composition of cast sample without Be

Si	Mg	Ti	Fe	Al
6.93%	0.35%	0.13%	0.32%	bal

The composition of melt with the addition of Be content:

Table 5.3: The expected Composition of cast sample with Be

Si	Mg	Ti	Fe	Be	Al
6.5 -7%	0.4-0.6%	0.02- 0.2%	0.3%	0.04 -0.07%	bal

Table 5.4: The obtained Composition of cast sample with Be

Si	Mg	Ti	Fe	Be	Al
7.1%	0.55%	0.09%	0.2%	0.05%	bal

5.2 MICROSTRUCTURES OF A357 UNDER DIFFERENT CONDITIONS

5.2.1 Microstructures of Al-Si-Mg without Be

Microstructure in as-cast condition

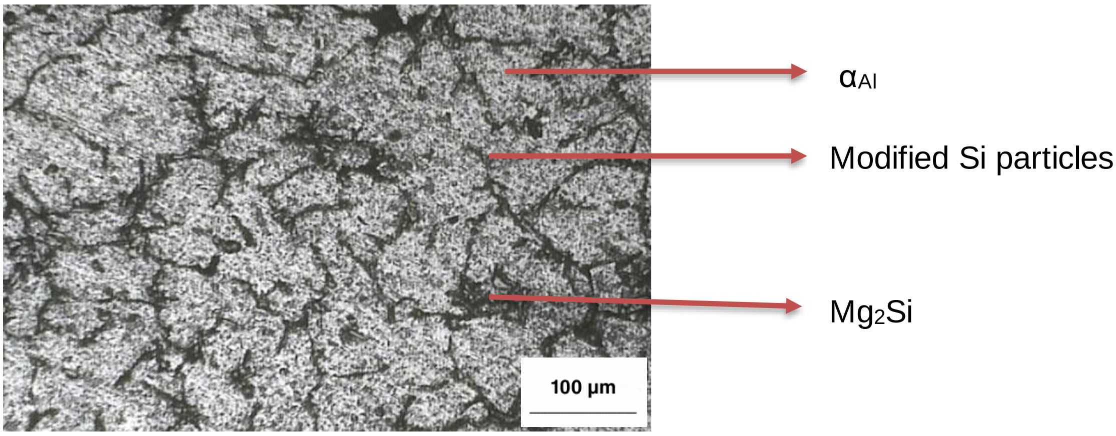

Fig 5.1: Microstructure in as-cast condition

This microstructure has dispersed Si particles and small intermetallic of Mg_2Si.

Microstructure after Solution Annealing

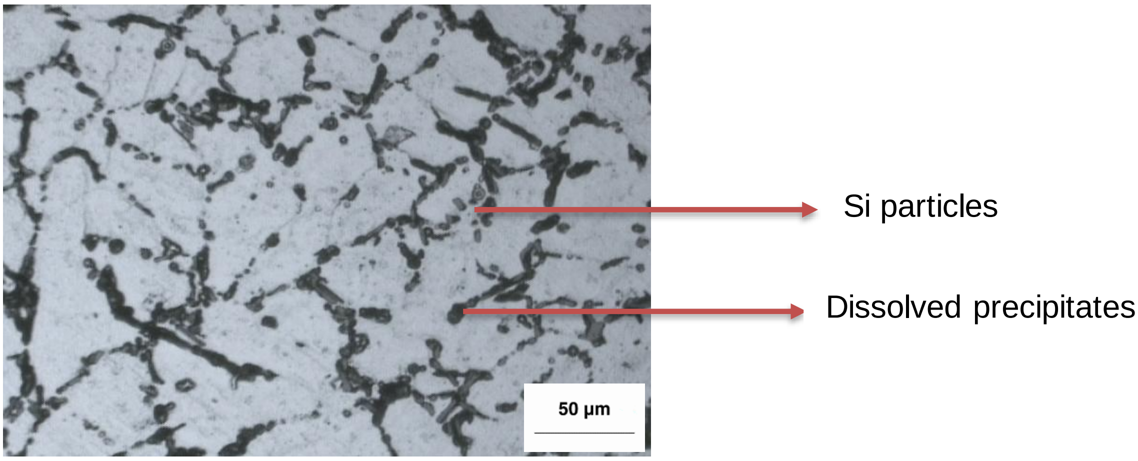

Fig 5.2: Microstructure after Solution Annealing

The specimen shows modified Si particles in the alpha matrix. Hardness after Solutionising is decreased when compared to As-cast. This is because Precipitates got dissolved in Matrix and Supersaturated solid solutions have lower hardness.

Microstructures after heat treatment (Aging)

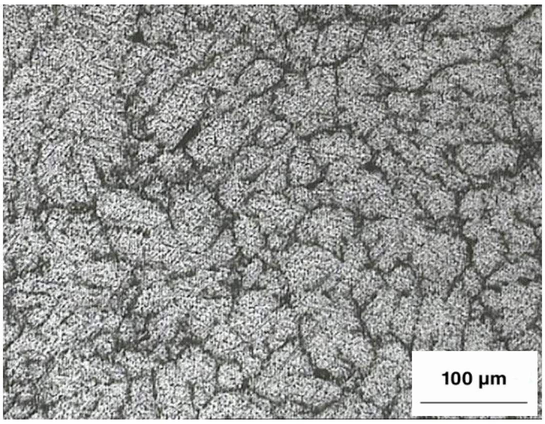

Fig 5.3: Microstructure after Aging at **90°C**

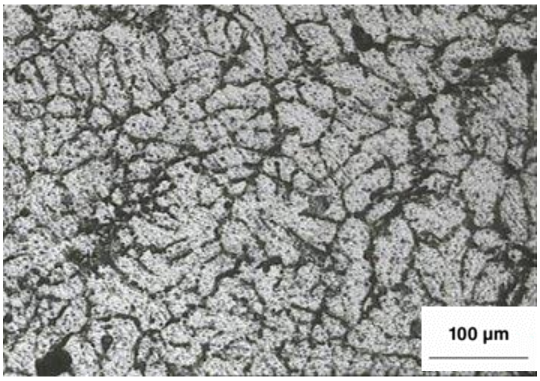

Fig 5.4: Microstructure after Aging at **120°C**

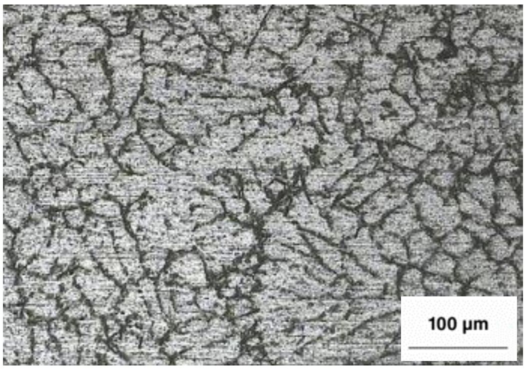

Fig 5.5: Microstructure after Aging at **150°C**

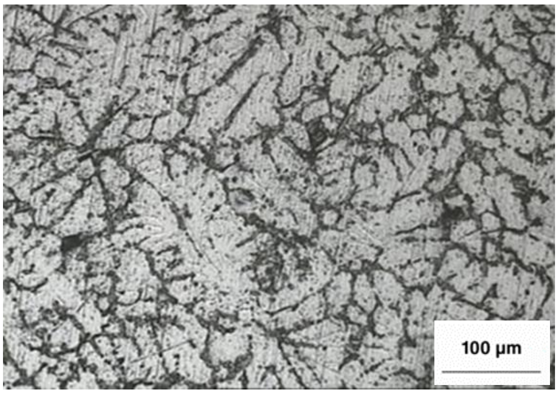

Fig 5.6: Microstructure after Aging at **180°C**

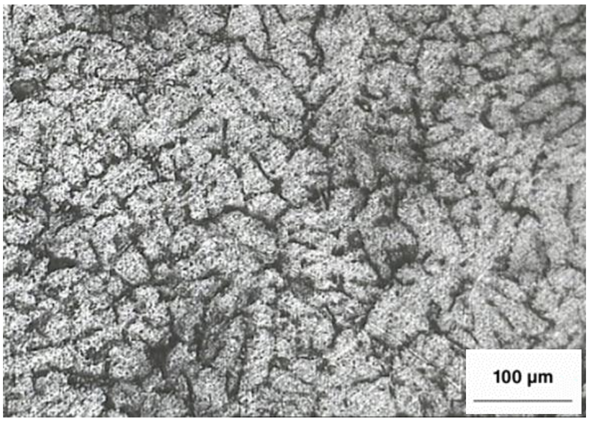

Fig 5.6: Microstructure after Aging at **210°C**

5.2.2 Microstructures of A357 with Be

Microstructure in As-cast condition

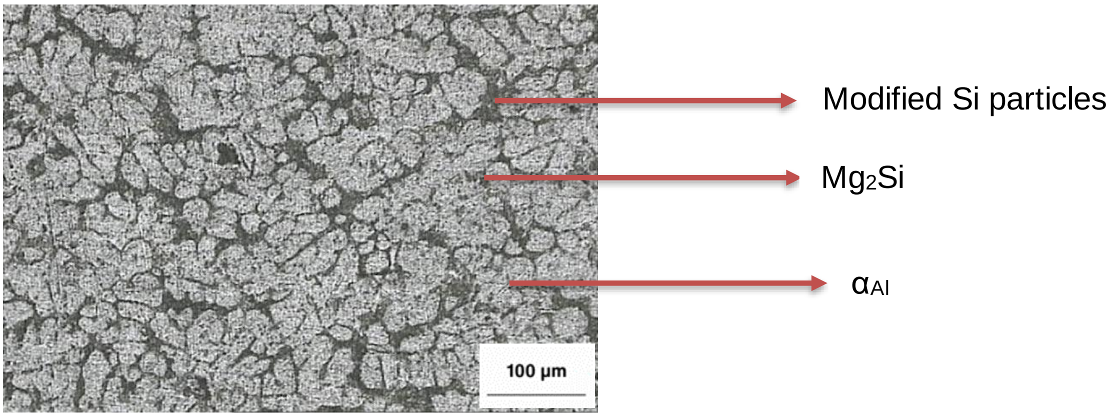

Fig 5.8: The microstructure of A357 with addition of Be content in as-cast condition.

Here, α_{Al} were found as primary phase and Si particles were dispersed in it and some intermetallic of Mg_2Si were found.

Microstructure after Solution Annealing

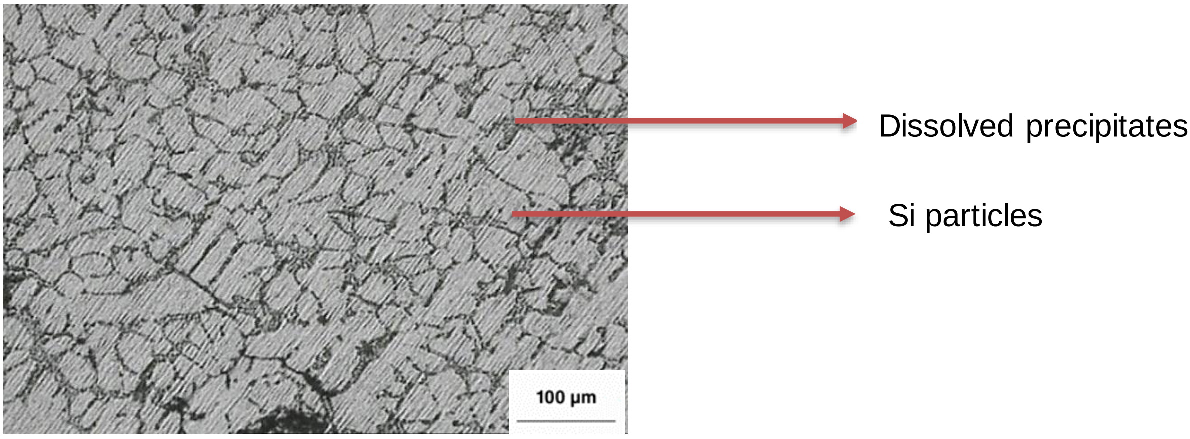

Fig 5.9: Microstructure after Solution Annealing

The thickness of grain boundaries were reduced and the Si particles were dissolved in Primary phase.

Microstructures after heat treatment (Aging)

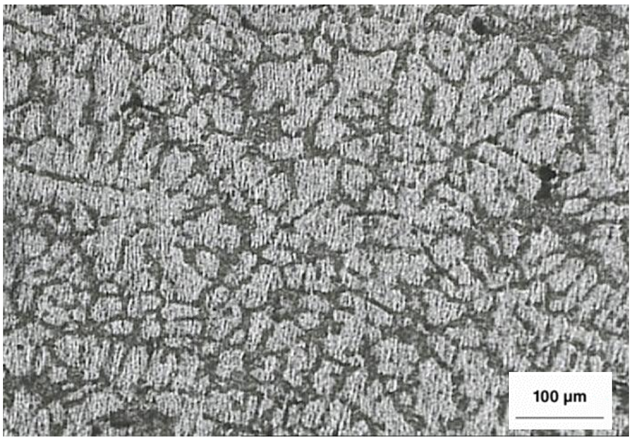

Fig 5.10: Microstructure after aging at 150°

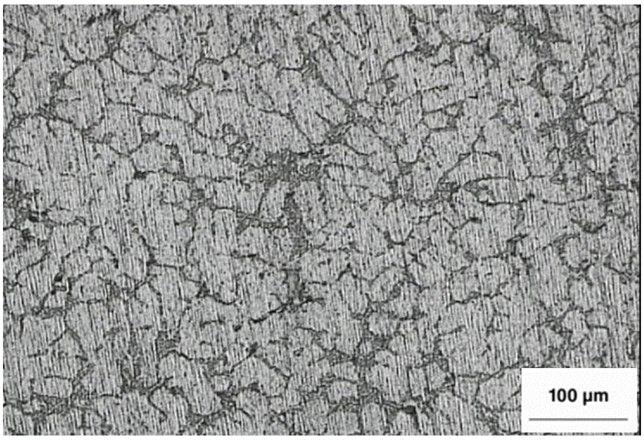

Fig 5.11 Microstructure after aging at 180°C.

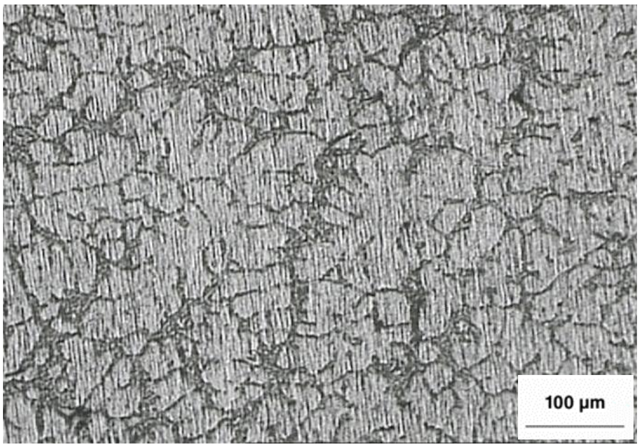

Fig 5.12 Microstructure after aging at 200°C.

5.3 HARDNESS TESTING

5.3.1 Hardness testing of A357 without Be

The hardness testing is done by Vicker's hardness tester and the load is 1 kg. The hardness of as-cast A357 without Be addition is 71.85 HV. The hardness of solution annealed alloy (70.8 HV) is decreased due to the dissolution of precipitates. The hardness of the artificially aged alloy at temperatures 90° C, 120° C,150° C, 180°C and 210°C are 76.4 HV, 88.25 HV, 94.3 HV, 101.83 HV, and 84.05 HV respectively.

The hardness seems to increase to a certain temperature and then decrease due to over-aging. The decrease in hardness could be due to particle coarsening. The peak hardness is 101.83 HV which is observed at 180°C aging temperature. So we can conclude that for this composition, enhanced properties are achieved at 180°C aging temperature.

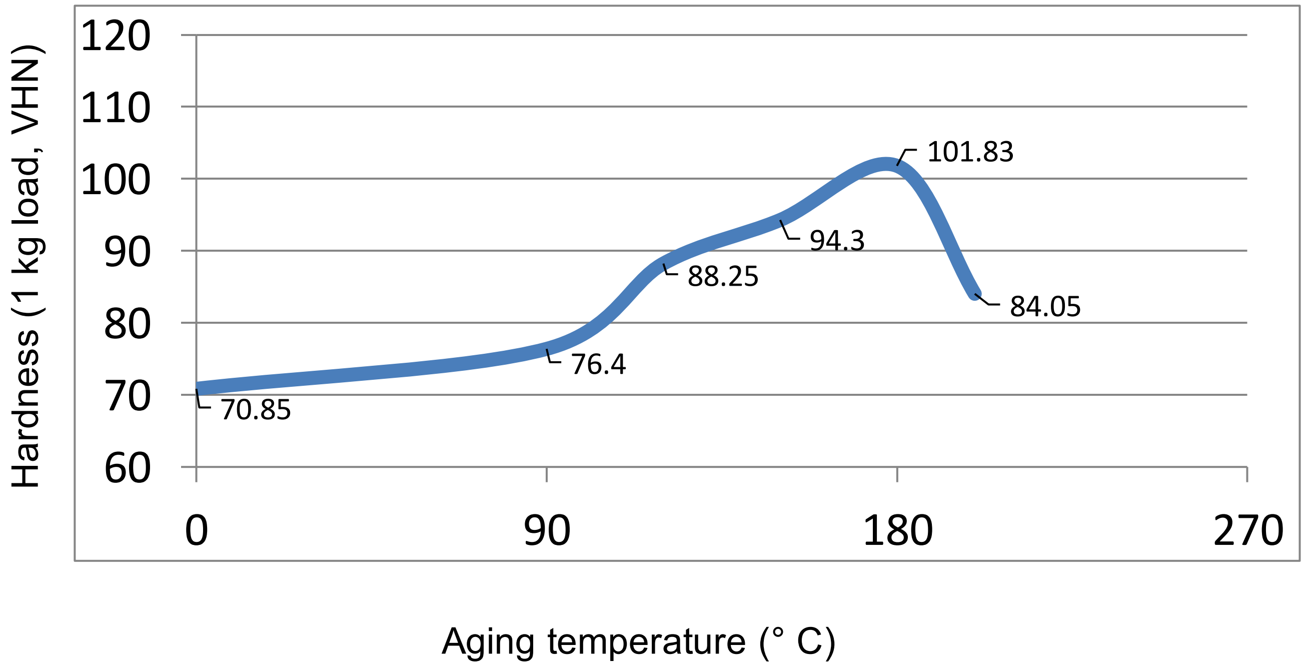

Fig 5.13: Hardness vs Aging temperature Graph

The peak hardness is **102 HV** which is achieved at 180°C.

5.14 Hardness testing of A357 with Be content

The hardness testing is done by Vicker's hardness tester and the load is. The hardness of as-cast A357 without Be addition is 80.25 HV. The hardness of solution annealed alloy (86.3 HV) is decreased due to the dissolution of precipitates. The hardness of the artificially aged alloy at temperatures 90° C, 120° C,150° C, 180°C and 210°C are 80.25 HV, 86.3 HV, 103 HV, 105 HV, 120 HV, and 114 HV respectively.

The hardness seems to increase to a certain temperature and then decrease due to over-aging. The decrease in hardness could be due to particle coarsening. The peak hardness is 120 HV which is observed at 180°C aging temperature. So we can conclude that for this composition, enhanced properties are achieved at 180°C aging temperature.

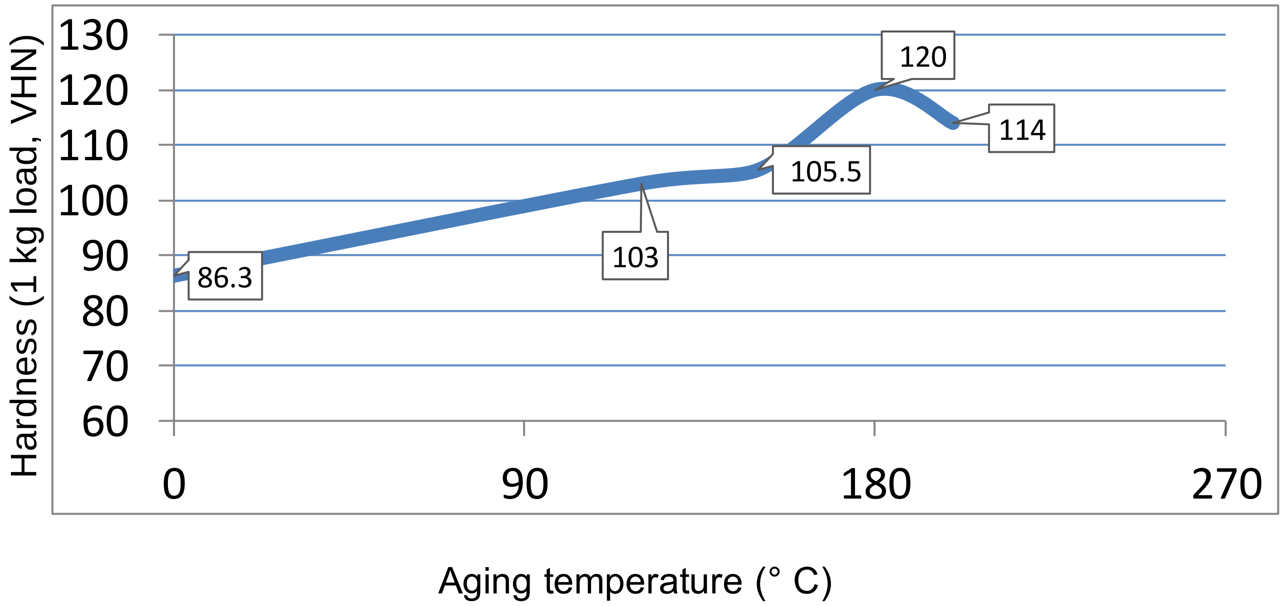

Fig 5.14: Hardness vs Aging temperature Graph

The peak hardness is **120 HV** which is achieved at 180°C.

CHAPTER 6

CONCLUSION

- Based on the experiments conducted, it is clear that the A357 alloy with 0.05% Be content demonstrates a higher peak hardness of 120 HV, compared to the A357 alloy without Be content which has a peak hardness of 101.83 HV.
- Hardness is a measure of a material's resistance to indentation or scratching, and higher hardness typically indicates improved mechanical properties, such as increased strength and wear resistance. In this case, the higher peak hardness of the A357 alloy with 0.05% Be content suggests that it possesses superior mechanical properties compared to the A357 alloy without Be content
- The addition of 0.05% Be content in the A357 alloy could be contributed to the formation of a harder and more durable microstructure, resulting in improved mechanical performance. Beryllium (Be) is known for its ability to form solid solution strengthening, which can enhance the mechanical properties of alloys by reducing dislocation movement and increasing the strength of grain boundaries.
- It can be concluded that the A357 alloy with 0.05% Be content exhibits better mechanical properties, as evidenced by its higher peak hardness, compared to the A357 alloy without Be content.

CHAPTER 7

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