FINAL REPORT

ANALYSIS OF BINARY ALUMINIUM-MAGNESIUM PRODUCTS WITH VARYING COMPOSITIONS AND OPTIMUM FLOWABILITY,TENSILE STRENGTH AND HARDNESS

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ABSTRACT

This research is to investigate how far the influence on mechanical properties and microstructure of varying aluminium-magnesium alloy using CO_2 moulding process.Casting is a process that can produce a complex and complicated component.In this research,three composition samples will be prepared into casting method and determine its properties.Main parameter used in this process is varying composition between aluminium and magnesium.Purpose of this research is to see the changes of the mechanical characrteristic and microstructure base on different composition according to aluminium-magnesiumalloys.Mechanical characteristic quality that will be consider, which are of major concern,included tensile strength,hardness and flowability,while microstructure research is to see the microstructure changes.Tensile strength,and hardness test will help to obtain grain sizes of aluminium-magnesium alloys.The flowability at its given composition level will be determinate to be used in various production criteria.

Keywords:Metallurgy,foundry metallurgy,nonferrous metals

INTRODUCTION

Aluminium Casting

Aluminium castings have played an integral role in the growth of the aluminium industry since its inception in the late 19th century. The first commercial aluminium products were castings, such as cooking utensils and decorative parts, which exploited the novelty and utility of the new metal. Those early applications rapidly expanded to address the requirements of a wide range of engineering specifications. Alloy development and characterization of physical and mechanical characteristics provided the basis for new product development through the decades that followed. Casting processes were developed to extend the capabilities of foundries in new commercial and technical applications. The technology of molten metal processing, solidification, and property development has been advanced to assist the foundry man with the means of economical and reliable production of parts that consistently meet specified requirements.

Project Objectives

The objective of this research is to investigate:

- To get better understanding about mould making process
- To study casting process
- To study flow ability of molten metal through the different of moulding casting
- To study presence of microstructure appear with different mould casting
- To understand about gating and riser techniques
- To study the influence on mechanical properties and microstructure of aluminium alloys after casting using necessary equipments.
- To choose the best way for foundry process according production's need (To produce products with high quality,reliability and durability.

EXPERIMENT

Aluminium Alloys

Pure aluminium is soft, ductile, corrosion resistant and has a high electrical conductivity. In consequence it is widely used for foil and conductor cables, but alloying with other elements is necessary to provide the higher strengths needed for other applications. The main alloying elements are copper, zinc, magnesium, silicon, manganese and lithium. Small additions of chromium, titanium, zirconium, lead, bismuth and nickel are also made and iron is invariably present in small quantities. There are over 300 wrought alloys with 50 in common use. They are normally identified by a four figure system which originated in the USA and is now universally accepted. Table 1 describes the system for wrought alloys. Cast alloys have similar designations and use a five digit system .

Major Alloying Element	**Wrought**	**Cast**
None (99%+ Aluminium)	1XXX	1XXX0
Copper	2XXX	2XXX0
Manganese	3XXX	
Silicon	4XXX	4XXX0
Magnesium	5XXX	5XXX0
Magnesium + Silicon	6XXX	6XXX0
Zinc	7XXX	7XXX0
Lithium	8XXX	
Unused		9XXX0

Table 1 The system for wrought alloys

Finally, aluminum alloys are very well-known alloys due to their high use in several industries, from automotive and aeronautics to leisure .Their excellent behavior, from different points of view (strength, ductility, corrosion), is very well known and can be modified in order to satisfy different applications.

During this experiment, alauminium alloys have been used to show the different of mold casting will produces the different of flowability, hardness, strength and microstructures of alloys. flowability is the ability of the molten metal to flow through the mold without prematurely solidifying. The samples of varying composition have beeb examined under XRF machine to see the chemical composition of samples. Their chemical composition will course the addition properties of aluminium alloys. Then, Sample hardness from different percentage in Aluminium-Magnesium alloys will be checking to see the different. In order to test the strength of casting samples, samples should be prepared to ASTM tensile test. The structure of sample casting will be examined under light microscopes

Chemical Composition of Aluminium alloys

For this research, three varying composition of aluminium alloys consists of below composition and they have determined under XRF examinant, as shown in Table 2 a,2b and 2c

Sample No.	Aluminium	Magnesium
1	91 w%	9 w%
2	80 w%	20 w%
3	72 w%	28 w%

Table 2a: Chemicals composition of Aluminium alloys

Report of Analysis

Spectrum: Spectrum1.evt, Spectrum1.evt

Date March 03, 2009 12:10:25

Acquisition time: 301 seconds

At. Numb	Element	Series	Intensity	Concentration
13	Al	K	232	91.[illegible] %
30	Zn	K	53	4.248 %
90	Th	-	135	4.562 %

Table 2 b: Chemicals composition of aluminum alloy for sample no.1

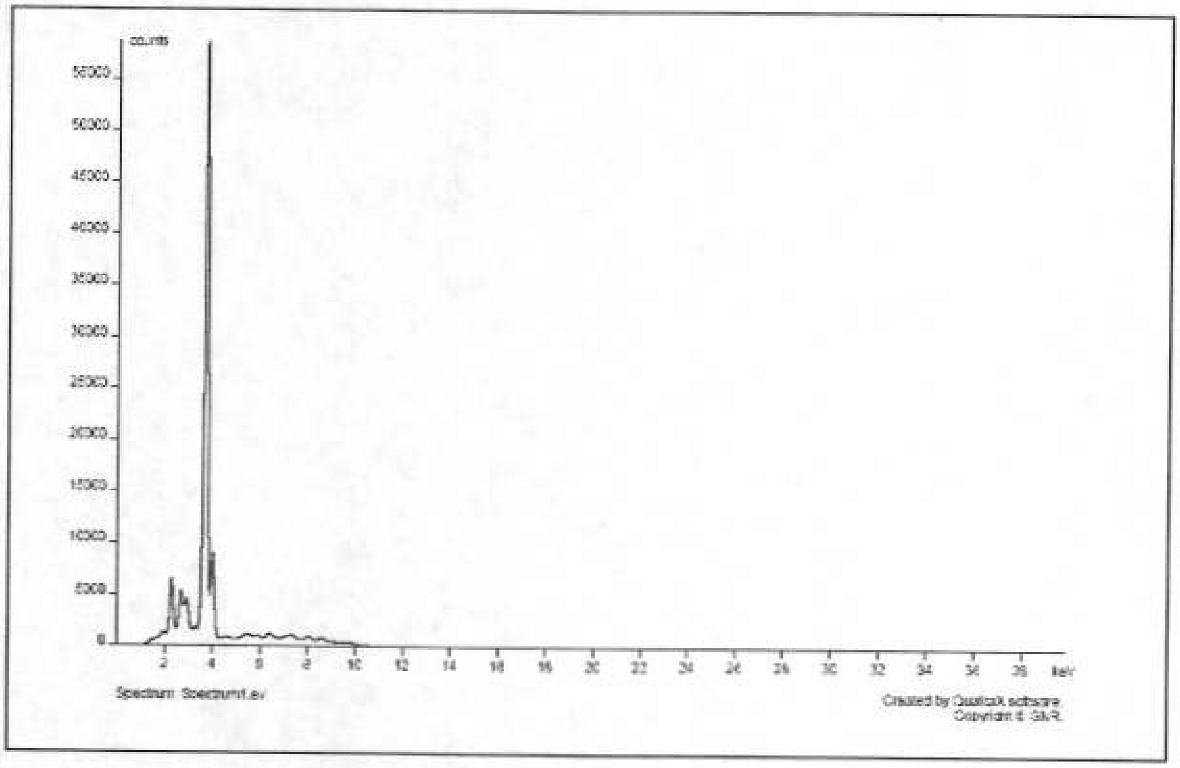


Figure 2c: Graph of XRF examinant for sample no.1

Sand Moulding

A Sand Casting is the most commonly used casting method in the whole Casting Industry. Foundries can produce Sand Castings, in most alloys or blends, of Aluminum, Al-Mg, Brass, Bronze, Gray Iron, Steels, and some Exotic Metals. All foundries use the traditional sand casting production methods, like floor moulding, cope / drag, squeezer molds, no bake, etc. In all Sand Castings there is a top, a bottom, and middle to a mold. The pattern, or impression device, sits in the middle of the mold, and later is surrounded with sand. These are the basic, universal casting components, which can be applied to all casting processes.

CO_2 Molding Process

Generally CO_2 moulding process has many advantages over other forms of sand moulding. But it is not more economical to do than green sand moulding, but moulds can be made to much closer tolerances, which can reduce machining time of castings, this will only appeal to commercial operators, and not be of much concern to the hobby caster, where time taken to do a certain process is not important.

In making CO_2 sand moulding, every step is followed correctly to get the best result. 14kg silica sand is mixed with 700g sodium silicate (5%) in a mixer for 10 minutes. Pattern and moulding box is prepared before placing silica sand into moulding box (cope side). Parting powder (carbon) is shaked on the pattern to saperate pattern and mold easily soon. Slowly, the sand is full in moulding box. Small holes are made through the sand to flow CO_2 into the sand. The reaction as follows:

$$Na_2SiO_3.x\ H_2O + CO_2 \longrightarrow Na_2CO_3\ x\ H_2O + SiO_2$$

The sand is now hard and not easy to destroy. The sand is made 3 semi-circle hole to match another side (drag). The drag is combined to cope. Gate and riser is hold in moulding box and the sand is full to moulding box as procedure doing before for cope. The gate, riser and pattern is took out from the sand in both side. A canal is made from gate to mould and mould to riser to flow the molten metal. The mold is heated in furnace and the mould is now ready to pour the molten metal.

Pouring

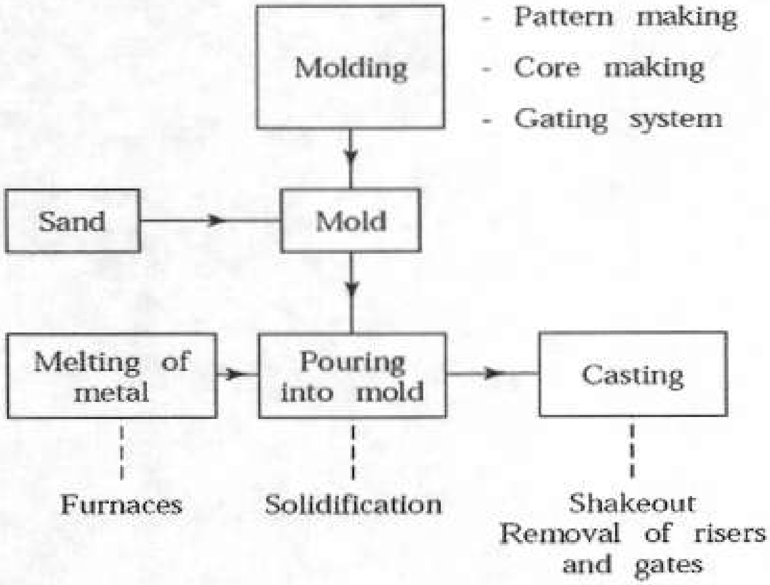


Figure 3a: Flow of casting process

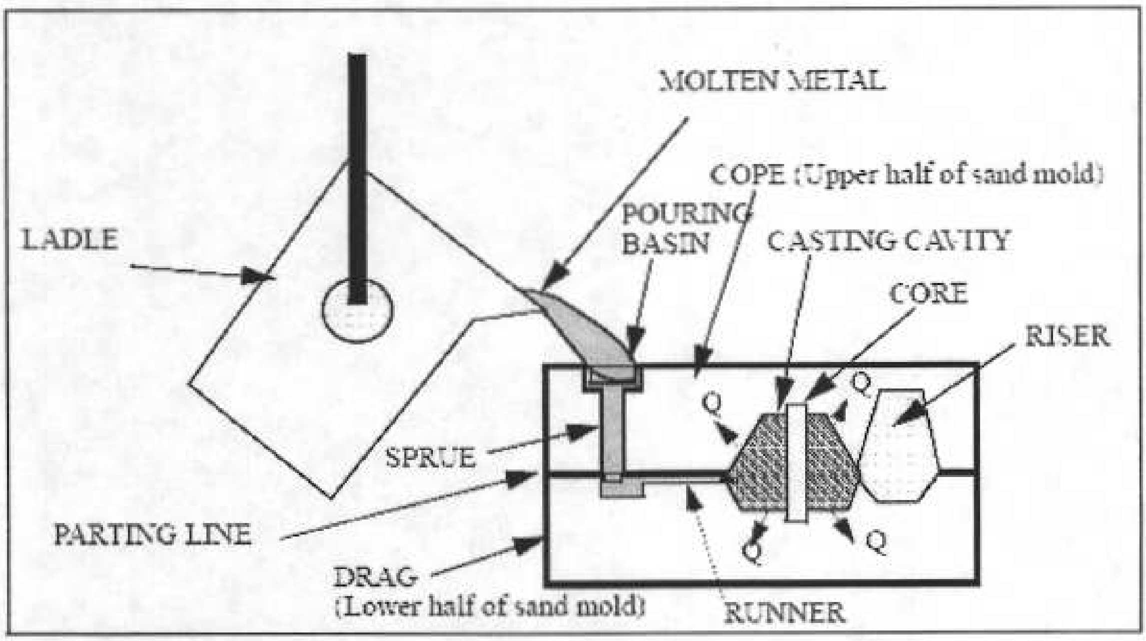


Figure 3b: Pouring process

The process of transferring molten metal to a mold is termed casting or pouring. The liquid metal is conveyed from the furnace to the mold for this process. Refered to the Figure 3.a and 3 b shows the step and process of pouring. The containers in which the metal is carried are called ladles. Pouring is the process where aluminum alloys are heated in a controlled- furnace to 750°C to make sure alloy is exactly melt. This temperature is consider melting temperature of aluminium (660°C) and magnesium (650°C)

Temperature controller

The furnace used for pouring process model MTF 12/25/400. Begin with the sample Aluminum Alloy is put in electric furnace model at 750°C for 73 minutes, with heating rate 10°C/min. Before achieve 750°C there is one stage for smelt and demoisture at 400°C (alpha phase) and soak in 60 minutes. Then, the temperature continues with heating rate 10°C/min to achieve 750°C and soaking for 60 minutes. Finally, cooling down the sample in furnace atmosphere with cooling rate of 10°C/min, as shown in Figure 4

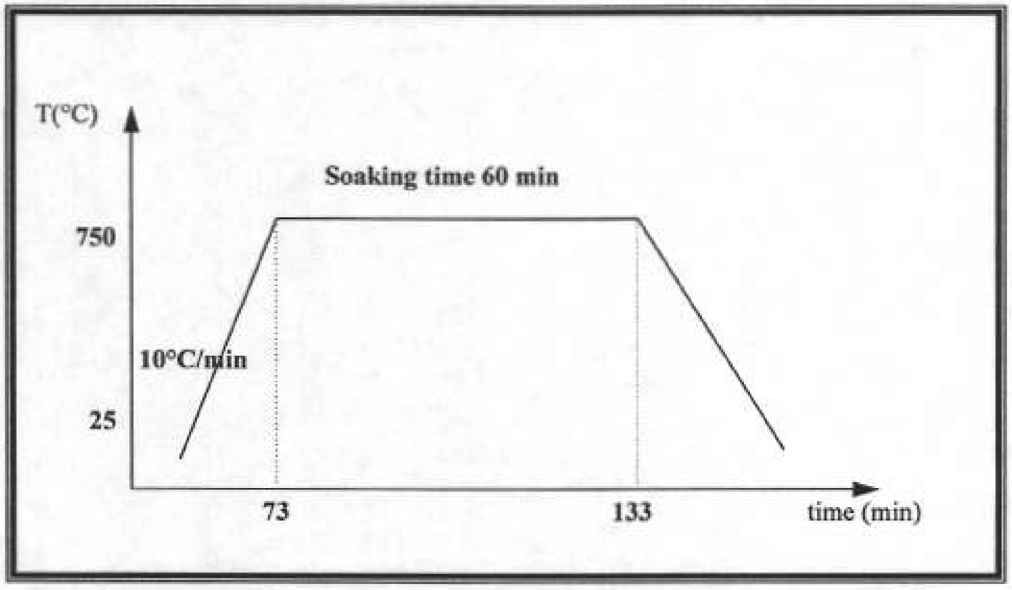


Figure 4: Temperature Vs Time of melting process

Metallographic Specimen Preparation

Finishing

Finishing includes all of the steps required to convert the semi finished shapes to the final products offered to use. These steps include some or all of the following steps:

reheating, machining, surface conditioning, rolling, heat treating, surface coating, cooling, cutting, coiling and sizing.

In this project, finishing is made by using cutting and machining to the product before use them to be tested. The products made have to cut from the gating system and then the surface of products have to machine from wrought surface. After that, the products are ready to test for tensile strength.

Grinding and Polishing

In this testing, 3 samples were grinded and polished to remove the entire oxide layer and to make the surface clean and clear without any scratch and like mirror surface. First of all, each sample was label. Then, rough grinding was done on Buehler Phoenix Beta Grinder as shown in figure 5a to eliminate the rough surface or oxide by using 240 grid of SiC paper. By using this grid, we have to grind sample for about 15 minutes to 30 minutes to avoid particle pull out. The good SiC paper grid for aluminum alloys is starting from 600 grid and above and take much time to clear the surface because the grid is so smooth. Grinding process was done starting from 240, 600, 800,1000 and 1200 grid.

Figure 5a: Buehler Phoenix Beta Grinder – Polisher

Then, after each step of grinding, before change to another grid paper, all samples were cleaned with Buehler Ultramet 2003 sonic cleaner using distilled water for about 5 to 10 minutes. Figure 5b below shows the picture of ultrasonic cleaner. Next step was checking sample under Olympus optical microscope to check surface of sample and make sure there were no scratch before proceed to another step which is polishing. If the scratch occurred on the surface, the sample will grind more until scratches disappeared.

Figure 5b : Buehler Ultramet 2003 sonic cleaner

When all the scratches disappeared, samples were polished using Buehler Phoenix Beta Polisher as shown in Figure 5c with diamond grid of 1μm and liquid alumina. The polished samples were cleaned by Buehler Ultramet 2003 sonic cleaner with distilled water for about 5 to 10 minutes. The samples were dried with Pensonic hair dryer to remove water that stuck on the sample surface before checking under microscope. When we can see the microstructure clearly without any scratch, we've to proceed all the samples to light microscope. If we were not able to see microstructure, we've to polish again sample until good microstructure appeared.

Figure 5c: Buehler Phoenix Beta Polisher

Etching

Keller's was used as etchant reagents for aluminum. 5ml of nitric acid prepared with 3ml hydrochloric acid alcohol and 2ml hydrofluoric acid solution in conical flask.

190ml distilled water is added until reach at the sign. Solutions will be mixed the in 10-15 second immersion. Soaked specimen about 10 seconds, then washed with distilled water. Finally dry it by using hot hair dryer and prepared for metallographic analysis.

Metallographic Analysis

Image Analyzer Procedure

Microstructure aspects of the investigation essentially involved observing the sample under Image Analyzer (Fig 6)to investigate the presence of microstructure appear after etching procedure. Different solidification of molten metal will produce different dendrite spacing sample

Figure 6: Image Analyzer.

First of all, the lamp is turned on for transmitted light. The power is supply to the Nikon box on the left of the microscope (the top power supply is for transmitted light, the bottom supply for reflected light). Place the aluminum sample on the stage. The magnification has set to 10x larger at the top of microscope. Magnification of 10x, 20x, 40x, 60x set at the below. Then the width is adjusted of the eyepieces, and focus on specimen. observations are made on the microstructure of the coil sample. Finally, with various magnifications find an accurate location, identify and recorded the image to analyze.

Mechanical Test

Vickers Hardness Test

For this testing Mitutoyo Vickers Microhardness, Model HM-114 was used (Figure 7). The same samples that were used for microstructure analysis were also used for this macrohardness testing. This testing requires flat surface samples as the operator has to determine first, which area of the surface that is going to be tested on. Under the microscope observation, the aluminum alloy surface does not show any grain structures before they were etched and therefore it is quite difficult to spot and obtain hardness of specific area of the alloy zone.

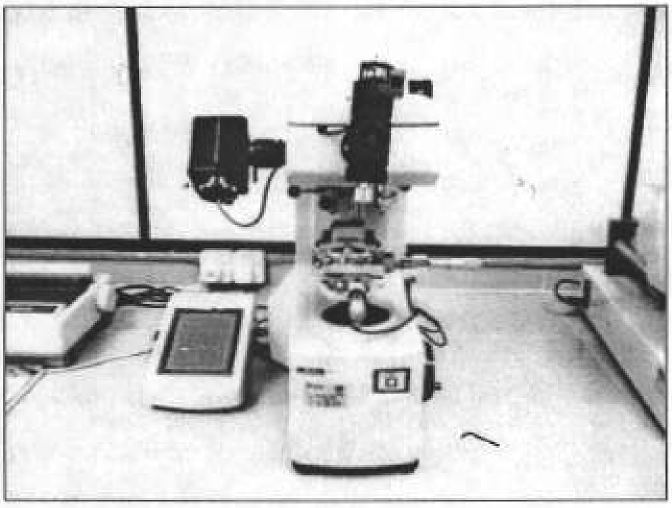


Figure 7: Micro Vickers Machine.

Before starting testing, the machine has to be set first. HV mode was chosen for this testing. The force was set to 0.005 and time is 10 μm/s. Then the sample was mounted on the clamper and the sample surface was observer under the microscope. The magnifying glasses were shifted to the indenter. The area to be tested was spotted and the test started by pushing the loading button. The indenter penetrates the sample surface leaving a diamond shape.

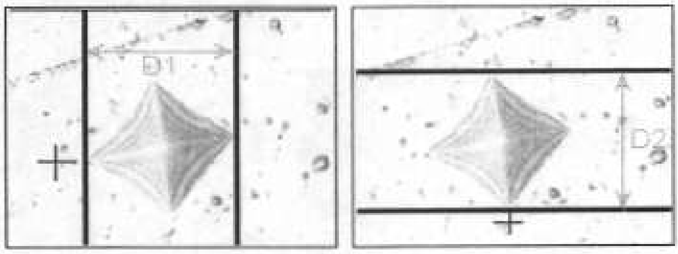


Figure 8: Y exists measurement

After the indenter finished unloading, it was shifted back to the magnifying glass and the sample surface was observed. After the image with the indents is loaded on the sample the user shall outline the indents on the image. The line that can be seen under the glasses was adjusted so that it becomes two lines. These lines were then adjusted to be parallel to the edges of the diamond dent on the surface and finally the hardness reading of that spot will be displayed (Figure 8). The procedure was repeated at least three times on different spot of the same area to obtain the average hardness reading of that area.

Tensile Test

Gotech Universal Tensile Machine was used for this test (Figure 9). This machine uses a hydraulic pump in its operations and "U-67" software to setup the variable. For tensile test, there were two types of clamps that were used which are one for the round or bar sample and another one are for plate sample. For this test, bar clamps were used. In this study tensile test was subjected to 3 samples from each molding process.

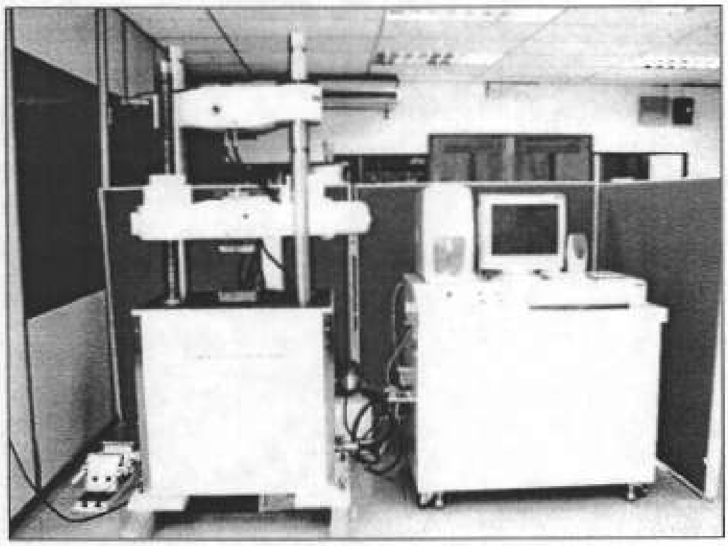


Figure 9: Gotech Universal Tensile Machines

Before starting the test, the important variables or information stated in the software must be set first. Bar or round sample was chosen for the 'sample shape' column and the 'material' column was filled as aluminum alloys. The dimension of the sample was set as diameter 10mm while the length and grip was each set as 80mm and 20mm. Tensile was chosen for the 'type of test' column and the speed for the test is 10mm per minutes.

After the variables in the software had filled, the sample is mounted on the clamps. To operate the clamps, hydraulic pump must be turned on. During the mounting work, the sample has to be sure that it was placed straight. When the sample is conformed clamped in the right position, the hydraulic pump was turned off.

Variables in the software and the sample position were check again. Then the test is started automatically by clicking at the 'test' icon. During the test, a graph is displayed on the screen. The curves on the graph elongates as the testing continues. The test stops automatically as the sample fracture. The result obtained which contains a graph is saved in 'JPEG' format. This graph contains the important information required such as tensile strength, yield strength and modulus young.

Flowability

Flowability of the aluminum alloy was measured by poring molten aluminum alloy to flowability mold made by CO_2 molding process. It's measured how far molten aluminum can flow before solid. Mold from CO_2 process is prepared with spiral pattern (Figure 10). Melted aluminum alloys in 750°C in the electric furnace. Then molten aluminum alloys is poured to the mold. After solidification of molten aluminum, the aluminium alloy is measured to how far the aluminum was flow.

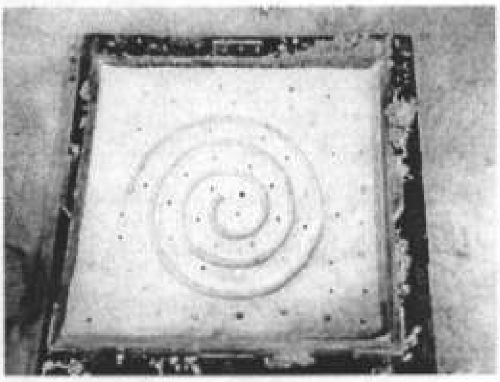


Figure 10: spiral pattern for flowability test

RESULT AND DISCUSSION

This Final Year Project is to analyze the mechanical properties and microstructure of aluminium alloys of varying composition using casting process. The experiment was doing to show different characteristic effect of the composition. The differences exanimate by flowability test, tensile test, hardness and microstructure analysis. This study used same alloy to show the effect of different composition between two base metal, aluminium and magnesium in aluminium alloys.

Mechanical Properties Analysis

Flowability

For flowability test, a mold of flowability pattern is made and molten metal is pour to the mold in same composition used in making casting product.

Flowability Result

The result of flowability test is noted in table 11a and figure 11 b below:

Sample No.	Sample	Flowability
1	91%Al 9%Mg	32 cm
2	80%Al 20%Mg	26 cm
3	72%Al 28%Mg	19 cm

Table 11 a: Result for flowability measurement

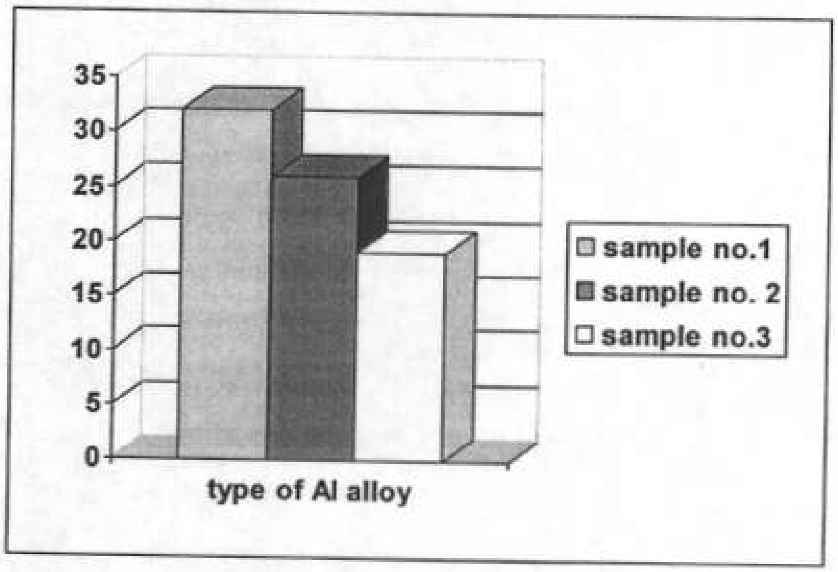


Figure 11b: The flowability measurements for varying composition of Al alloys

Figure 11c: The cast spiral open mould and a result of flowability test

Discussion of Flowability

Flowability of a metal is important to know in casting process because it may affect in production. Flowability is influenced by the alloy composition, which may vary the alloy's viscosity, surface tension, freezing range and solidification mode. Change in flowability arise from composition induced changes in viscosity and surface tension may be less significant than variations in the other two parameters.

Figure 11a shows the results from the flowability measurements of varing composition aluminium alloys. Flowability is measured by using the spiral test as shown in figure 11c. Referring to the graph in Figure 11b clearly, sample no.1 has much higher flowability length, that is 32cm than sample no.2 shows 26cm length and sample no.3, 19cm length. The result showed that higher aluminium percentage more able to flow in flowability spiral pattern mold than lower aluminium percentage alloys. In flowability research, some parameters should be considered in doing casting process. It's such as mold heat transfer coefficient, wall friction factor, pouring temperature and pouring basin head pressure through thin walled castings. This all parameters will affect the flowability of molten metal to fulfill the mold. In the present work, considerable attention has been paid to compile various factors influencing the fluidity of Al alloys and their composites. Certain in aluminum alloys, they have only little effect factors have significant impact on flowability.

Factor affecting flowability depends on 2 major:-

1. The intrinsic fluid properties of molten metal
2. Casting condition.

The properties usually thought to influence flowability are viscosity, surface tension, the character of the surface oxide film, inclusion content and manner in which the particular alloy solidifies.

Casting condition that influence flowability include part configuration; physical measures of the fluid dynamics of the system such as liquid static pressure drops; casting head and velocities; rate of pouring and degree of superheat.

Viscosity

The measured viscosities of molten aluminum alloys are quite low and fall within a relatively narrow range. Kinetic viscosity (viscosity/specific gravity) is less than that of water. It is evident on the basis that viscosity is not strongly in fluent in determining casting behavior and therefore is an unlikely source of variability in casting results. For example, increase in viscosity of composite slurries decreases their flowability drastically, where its influence is negligible in aluminum alloys.

Surface tension and oxide film:

A high surface tension has the effect of increasing the pressure required for liquid metal flow a number of elements influence effects in the surface tension of the oxide. In aluminum alloys, the true effect of surface tension is over powered by influence of surface oxide film characteristics. The oxide film on pure aluminum, for example, triples apparent surface tension.

Inclusions

In form of suspended insoluble particles that cannot seen clearly will dramatically reduce in fluidity of molten aluminum.

Solidification

It has been shown that fluidity in inversely proportional of freezing range (that is, fluidity is highest for pure metal and eutectics and lowest for solid solution alloys). The manner in which solidification occurs may also influence flowability.

Second laws of thermodynamics tell that heat flows spontaneously from a hot body to a cool one and this can be applied in casting. Flowability of molten metal will effected by cool body of the mold. So, the result shown that flowbility of molten metal is lower than actual result because the metal cool down faster when they poured to the mold. lower temperature decreasing the result of flowability.

Different composition of alloy elements having a different viscosity and this will cause a different solidification rate. During solidification rate more air gap in the molding will cause a faster of solidification because heat was transfer to environment easier.

Higher flowability is commonly associated with long freezing range alloys, such as pure metals and eutectic alloys, where solidification takes place by the advance of plane interface. Minimum flowability is observed in short freezing range alloys, where constitutional under cooling and other phenomena produce independent crystallization in the main liquid mass, leading to the presence of free crystals in the liquid which can arrest the flow and hence reduce the flowability.

Further, the maximum solid fraction at which the molten metal flow ceases is dictated by ram pressure, the thickness of the flow channel, and the grain size of the solidifying phases. Hence, it is expected that the critical solid fraction can be higher, which means that the temperature at which the flow ceases can be closer to the solids temperature of the alloy. Under this condition, most of the latent heat can be the driving force for mold filling. Flowability of binary aluminum alloys is well documented. However, the flowability of ternary and commercially important aluminum alloys is least understood and warrant further probing. Generally, flowability of aluminum alloy increases with decreasing melt temperature for a given alloy composition.

Despite the long history of grain refinement, its influence on flowability is still controversial. While some studies have concluded that grain refinement decreases flowability while others have reported increased flowability. Grain refiner addition in aluminum alloys influences the flowability in two different ways. Firstly, it refines aluminium dendrites during solidification. It is known that fine particles are more effective in stopping a flowing stream than an equivalent percentage of coarse particles. Hence, flowability is expected to decrease with grain refinement. Secondly, grain refinement postpones the dendrite coherency point, which can be related to flowability. The flow of liquid stream can be assumed to be impaired when the dendrites at the tip become coherent which means that a late coherency would be expected to increase the flowability with grain refinement. Depending on the dominance of one of the above mechanism grain refiner addition can either increase or decrease flowability. Hence, the effect of grain refinement on the flowability of Al-based alloys is a complex phenomenon and depends on many factors: type and amount of grain refiner, alloy composition, holding time and temperature in the furnace.

Tensile Test

Tensile Result

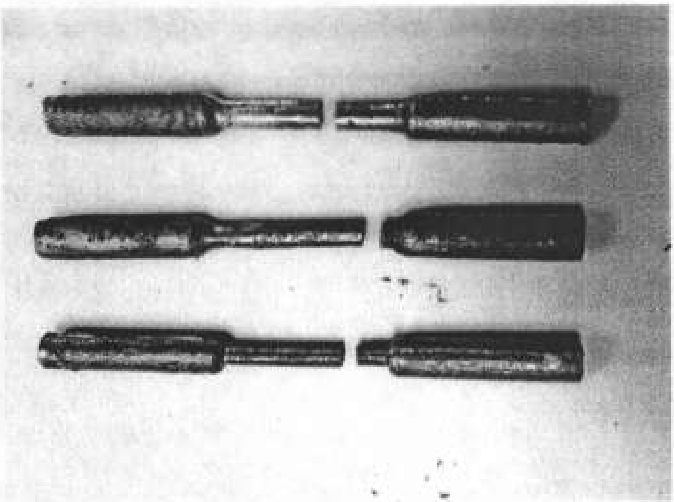


Figure 12a: Tensile test for aluminium alloys in varying composition

Sample No.	Test Sample	Tensile Strength (Mpa)	Yield Strength (Mpa)	Modulus Young (Mpa)
1	Al 91w% Mg9w%	10.270	36.610	676.518
2	Al 80w% Mg20w%	6.149	42.301	611.337
3	Al 72w% Mg28w%	2.668	12.284	193.671

Table 12b: Result for tensile test for aluminium alloys in varying composition

Discussion of Tensile Test

From the graph shown the aluminium alloy for all composition tested are elastically before reach a maximum load, they change to plastically after above this load stress. This is showed that aluminium alloys are ductile products (see Appendix A). after the experiment session, the specimens break at their neck as shown in figure 12a.

From the result of the tensile test, refer to the Table 12 b, which shows the variation of tensile strength, yield strength and Modulus Young's with different sample. As shown here, the tensile strength of the aluminum magnesium alloy increased with an increasing amount of load till break. There are three samples in this test that are in different composition. Each sample is divided into three tests which indicate by sample T1, T2 and T3 with same technique to have the best result. In this experiment, sample of Al 90w%Mg10w% state the highest value of tensile strength that is 10.270 Mpa followed by sample no 2 (Al 80w%Mg20w%) with 6.149Mpa and the lowest value is sample no.3 (Al 70w%Mg30w%) that is 2.668Mpa.

This shows that sample no.3 product is more ductile than sample no.2 and no. 1 products that they can stand with higher load than sample no.3.

From the data, it seen that tensile strength for sample no.1 is more toughness than sample no.2 and sample no.3. It's because aluminium element s are more ductile referred to magnesium elements. So higher aluminium composition in the product make it more ductile and tougher to the load given.

Casting product from sample no.1 poses smooth shape and less carbon, compared to sample no.3 that is rougher and more carbon seen at the surface. This is because sample no.3 has more magnesium elements in it. Molten magnesium is easy to react with oxygen in air and become flameable. Therefore, more carbon exit in the product and become rough surface. More carbon content in the product make it more brittle. This have been proved in tensile test tat shows sample no.3 is brittle that others.

Hardness

Hardness Result

Sample No.	Test Sample	1	2	3	Average
1	Al 91w% Mg9w%	80.4	78.5	81.5	80.13
2	Al 80w% Mg20w%	88.1	89.4	91.8	89.77
3	Al 72w% Mg28w%	110.8	107.6	110.6	109.69

Table 13a: Result from Vickers hardness test

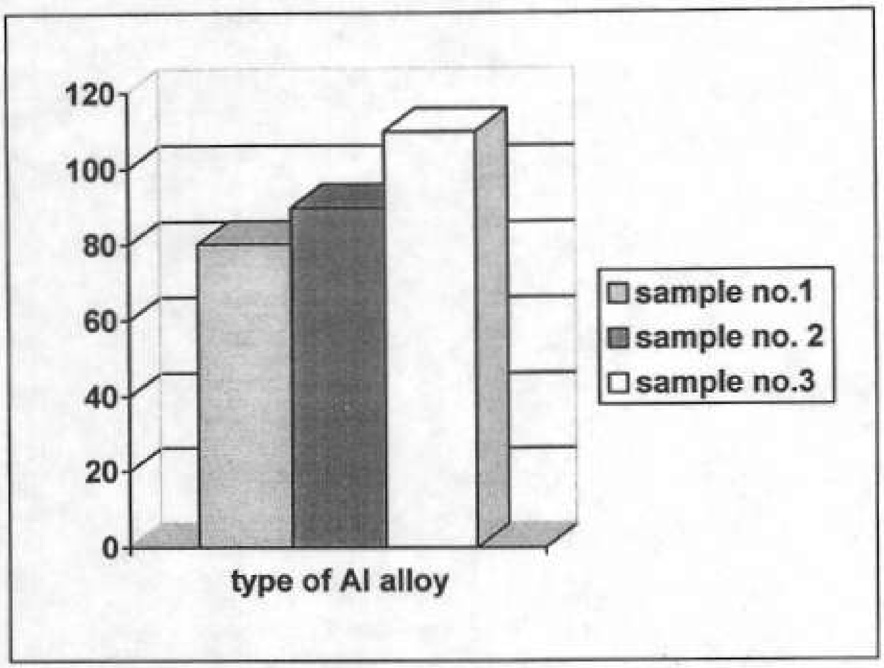


Figure 13b: The hardness measurements for varying composition of Al alloys

Discussion of Hardness

The Vickers hardness test was tested to compare the hardness of the casting product for the different composition of aluminium alloys. The Vickers hardness test method consists of indenting the test material with a diamond indenter, in the form of a right pyramid with a square base and an angle of 136° between opposite faces subjected to a load of 1 to 100 kgf. The full load is normally applied for 10 seconds. The two diagonals of the indentation left in the surface of the material after removal of the load are measured using a microscope and their average calculated. The area of the sloping surface of the indentation is calculated. The Vickers hardness is the quotient obtained by dividing the kgf load by the square mm area of indentation.

Accordingly, loads of various magnitudes are applied to a flat surface, depending on the hardness of the material to be measured. The Vickers Pyramid Number (HV) is then determined by the ratio **F/A** where **F** is the force applied to the diamond and **A** is the projected surface area of the resulting indentation, as seen from above. **A** can be determined by the formula:-

$$HV = \frac{2F\sin\frac{136^{o}}{2}}{d^2} \qquad HV = 1.854\frac{F}{d^2}\ \text{approximately}$$

HV = Vickers hardness

F= Load in kgf

d = Arithmetic mean of the two diagonals, d1 and d2 in mm

Table 13a shows the reading of Hardness Vickers value. This result obtained by using 'Microhardness Vickers'. The pyramidal indenter has a square base, and the included angle between the faces is 136 degrees. The graph showed the average of hardness value of aluminum copper in different area at sample.

Figure 13b shows that hardness for sample no.1 is the lowest, 80.13HV compared to sample no.2 (89.77HV) and sample no.3 (109.69HV). This mentioned that properties and brittle compare with sample no.1 that is soft and ductile. Form the experiment different percentage of aluminium and magnesium may effect the hardness of the product.

This mentioned that properties of magnesium is harder and more brittle compared with aluminium that is soft and ductile. These different mechanical properties of alloy elements are suitable to design product for specific used. Figure 13b shows the experimental results of hardness test as a function of dendrite spacing for various composion of aluminium-magnesium alloys. In higher aluminium elements, the dendrite spacing are closed and this produce a soft product while higher magnesium elements, the dendrite spacing are increase and this produce harder product. It can be seen that hardness properties decrease with increase of dendrite spacing.

Microstructure Analysis

Microstructure Result

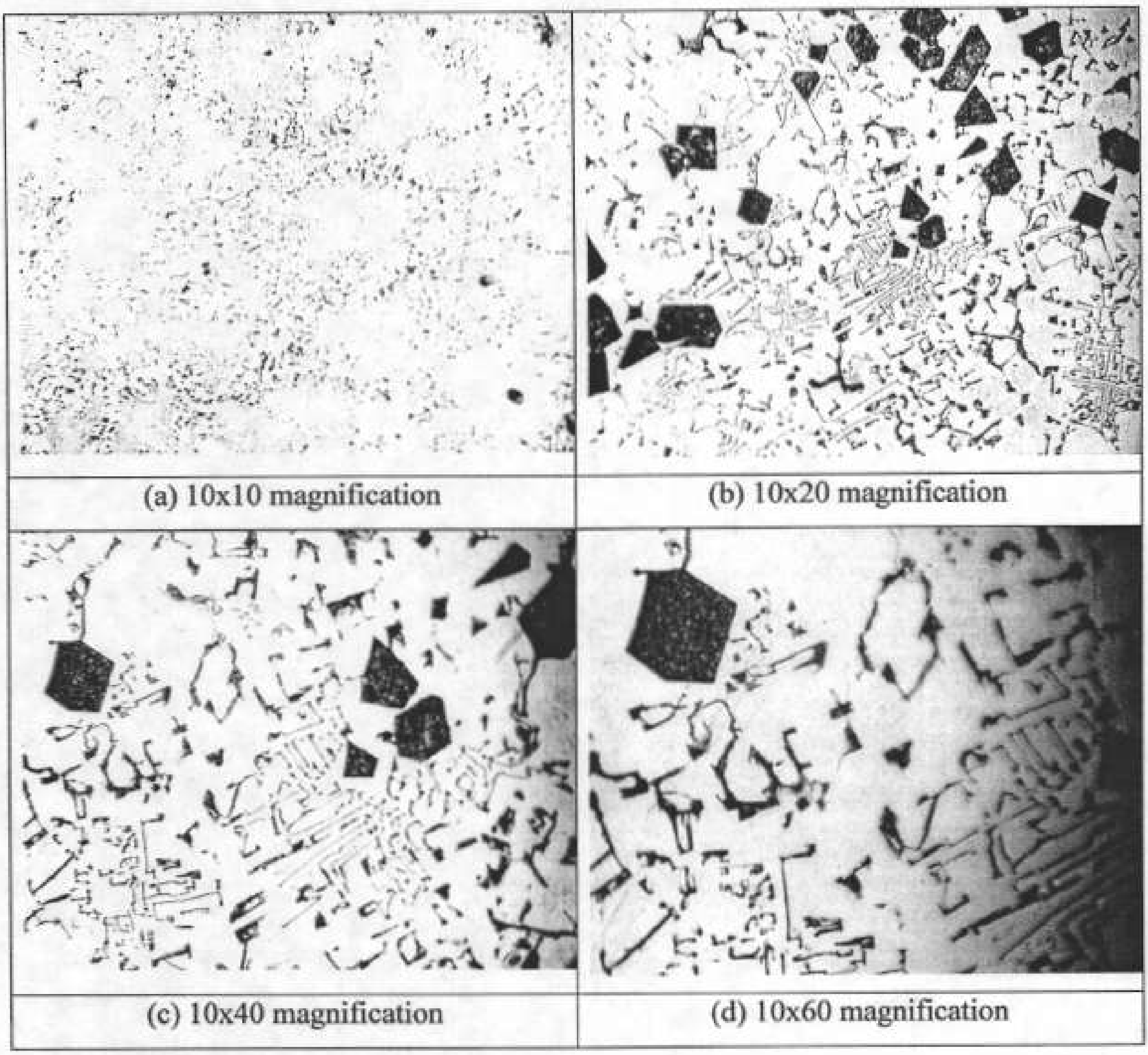
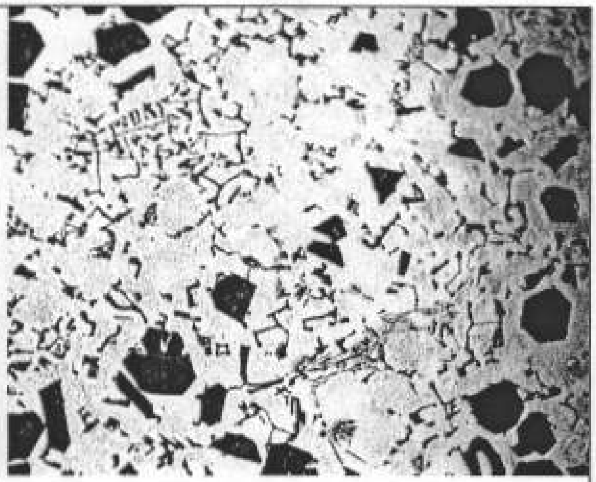
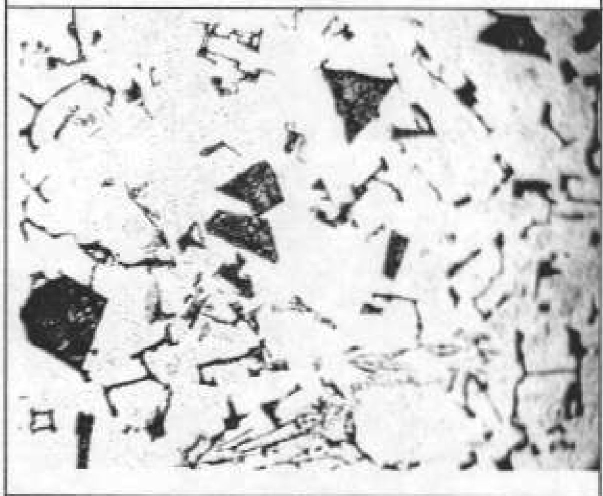


Figure 14a: Microstructure of sample no. 1 (Al 91w%Mg9w%)

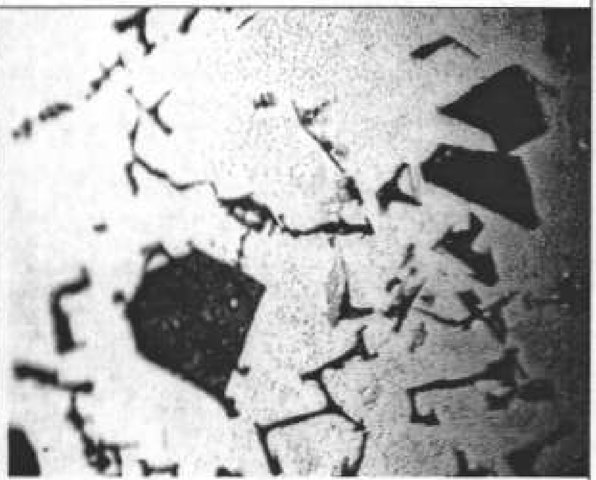
(a) 10x10 magnification



(b) 10x20 magnification

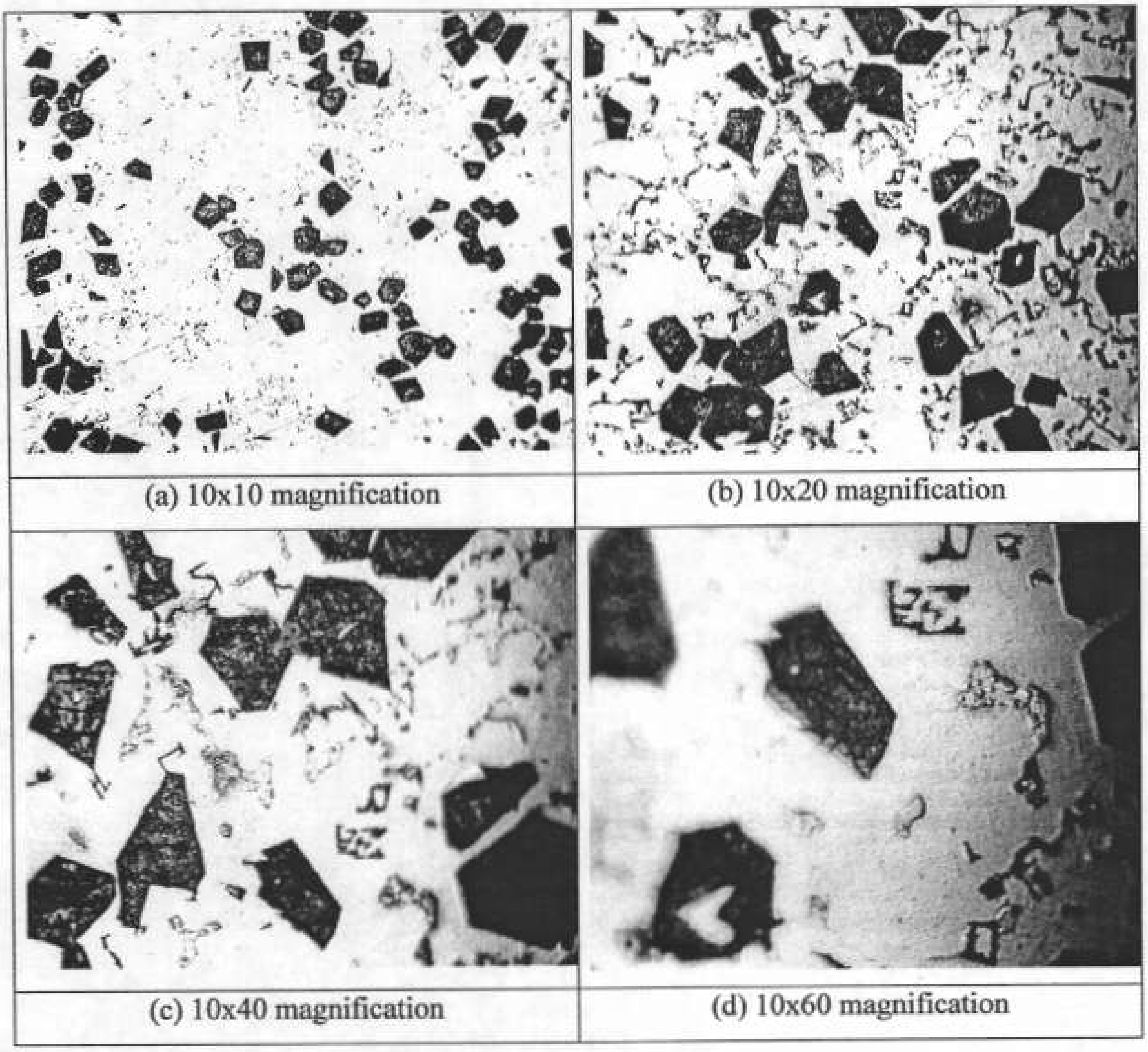


(c) 10x40 magnification



(d) 10x60 magnification

Figure 14b: Microstructure of sample no.2 (Al80w%Mg20w%)



(a) 10x10 magnification | (b) 10x20 magnification | (c) 10x40 magnification | (d) 10x60 magnification

Figure 14c: Microstructure of sample no.1 (Al72w%Mg28w%)

Discussion of Microstructure

After casting process the molten metal which they had fulfill the pattern need to lived to cool down till room temperature. The solidification is then progresses towards the interior of casting product. Dendrites have been shown growing with a tip undercooling which depends on growth velocity, temperature gradient and alloy composition. Because of this experiment pouring at the same temperature, the study wants to consider the velocity solidification rate of molten metal for different composition to compare the mechanical properties formed.

The dendritic segregation is the results of crystal growth and 'constitutional supercooling' phenomena. In this level, the crystals tend to develop from nuclei in well defined directions associated with the crystalline structure.

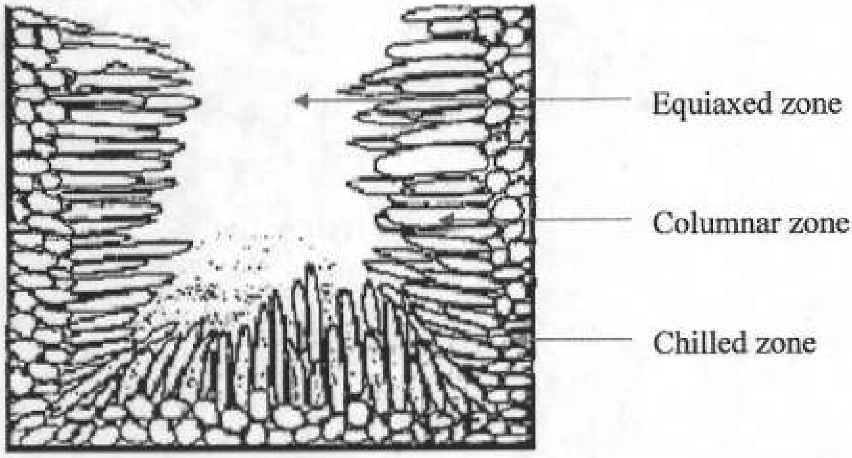


Figure 15a: Sketch of ingot grain structure showing chill, columnar and equiaxed zones

The atoms in the domain are moving in liquid conditions, but they form clusters as their temperature decreases below liquidus. When the cluster grows to a certain size it becomes a crystalline nucleus and this process is called nucleation. When a nucleation point has been established, one or more of the nearest neighbors may tend to join with it; this process is called grain growth. The solidification grain structures of a cross-section of casting sample are shown in Figure 15a. It was described by Flemings . Here three different zones can be identified, one of them is the outer zone also called chill zone, it comprises of fine grains with random orientation. The second, an intermediate zone is a columnar zone, with many elongated and oriented grains from the billet surfaces to the centre. Finally, there is a central equiaxed zone comprising of less randomly oriented grains.

After casting, all the specimens were cut longitudinally to observe the circular section in the middle height. Each specimen section was preliminarily subjected to metallographic preparation, etched with aqueous solution to reveal the microstructure and observed with an image analyzer.

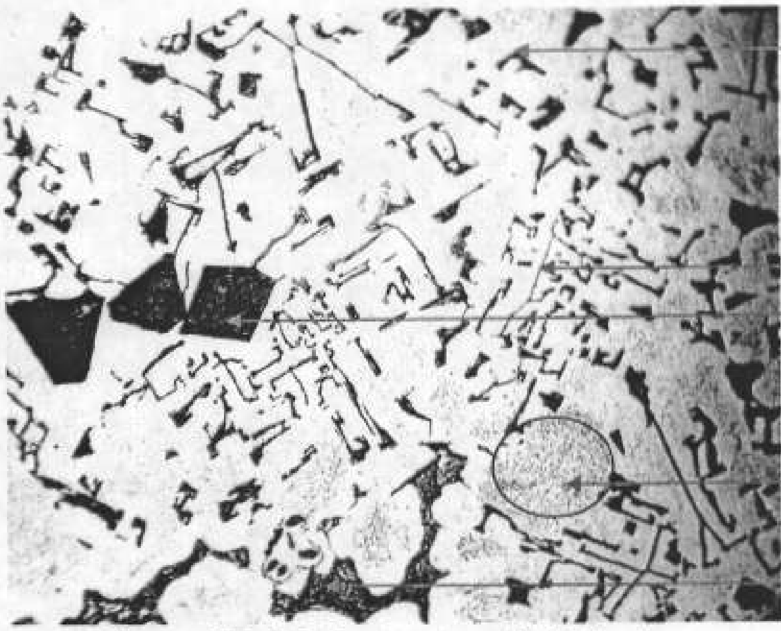


Figure 15b: Matrix structure of Al-Mg alloy

Optical micrographs of specimens in varing composition are shown in Figures 14a to 14c. It is observed that from Figure 15b, the matrix structure consist alpha aluminum-magnesium, primary and secondary dendritic arm, and as well as some porosity and carbon. The formation of dendrites is due to the solidification effect during casting. Molding process for sample no.1 produced closer, longer and much more dendrite spacing while observation for sample no.2 produced shorter dendrite arm. Sample no.3 shown less dendrite spacing than others.

Most metals and alloys will solidify by the formation and growth of dendrites of one phase in which alloy segregation occurs within the dendrite and second phase growth occurs external to the dendritic structure. This subject has been treated in great detail in many texts published on the solidification of liquid metals and will not be treated extensively in this work. As indicated above, most solidification events involve the production of dendrites followed by the precipitation of a second phase or phases in between dendrite arms. The reasons why dendrites form is defined by the kinetic and thermodynamic factors which allow atom rearrangement in a convenient way in an acceptable period of time.

The exact distribution of alloy elements segregated into and external to the dendrites and the magnitude of the SDAS (Secondary Dendrite Arm Spacing) is determined precisely by the alloy composition and the rate at which the heat is removed from the solidifying volume. Once the alloy composition and the size of the casting and mold material are selected, the solidifying material produce a dendritic base into which other phases or reaction products may be interspersed, such as porosity.

Clearly, observation of casting product from sample no.3 shown more carbon seen at the surface. This is because sample no.3 has more magnesium percentage then sample no.1 and 2. Molten magnesium is easy to react with oxygen in air and become flameable. Therefore, more carbon exit in the product and become rough surface. More carbon content in the product make it more brittle. This have been proved in tensile test that shown sample no.3 is brittle that others and related to the microstructure observed more carbon content.

CONCLUSION

Summary

Varying composition of aluminium-magnesium alloys casting resulting the different mechanical properties and microstructure of the products. This is because of mixing two elements will effect the mechanical properties and microstructure. Referring these properties, when designing any product the matter that should be considered is to choose of molding elements for specific product. This will reduce cost and more effectively when doing foundry process.

After complete this study the mold making in casting process better understands. Here the different of composition will affect the mechanical properties and microstructure of casting alloy. This study gives better understanding in casting process and casting production. The experiment shown which composition is better to choose regarding to the properties needed to produce better product when using casting process. Mechanical properties are important to determine to have the best production, save cost, energy needed and time requirement.

Based on the results and discussions, the following conclusions can be drawn from the study of this final year project:

Flow ability

- The flowability of aluminum-magnesium alloy will decrease with the addition of magnesium. This is because of magnesium's density is higher than aluminium although magnesium is lighter than aluminium according to their weight.
- The flowability of higher aluminium percentage was better than higher magnesium percentage. This cause of aluminium has lower density may reduce friction between mold and molten metal.
- The flowability of higher aluminium percentage is better than higher magnesium percentage.
- In casting production, flowability of an alloy must be determined before used in process to avoid any error because of unsuitable flowability.
- Small product must use high flowability to avoid fast cooling rate when pouring molten metal, while big product better use low flowability to fulfill the cavity before molten metal flows through riser.
- The flowbility of the metal must be in a good condition because during the pouring process, the ability of molten metal to flow is needed to complete fulfill to mold cavity. Bad flowability of molten metal will spoilt the product.

Tensile Test

- Aluminium is more ductile than magnesium. More magnesium element added in aluminium alloy make the product more brittle compared to lower percentage of magnesium.
- Using tensile test, higher percentage of aluminium can stand with higher load in testing and that shows it is more ductile.
- Production by using higher percentage of aluminium is more toughness than higher percentage of magnesium.
- The tensile strength and yield strength are correlate with dendrite spacing that experimental expression shown that both tensile properties increase with decreasing dendrite spacing.

- To design a product that have good tensile strength, better flowability is more suitable to use to get more ductile product. Ductile product may undergo the obstacle better than brittle product.

Hardness

- Properties of higher magnesium percentage in aluminium alloy are hard and brittle compare with higher aluminium percentage that are soft and ductile resulting from hardness test.
- Cooling rate and the tips of growth rate can be used as an alternative way to design mechanical properties
- To design a product that needs more toughness of alloy more aluminium percentage in alloy is suitable to use. While to design a product that needs more hardness of alloy, more aluminium percentage is suitable to use.

Microstructure Analysis

- From the experiment shows that higher aluminium percentage produced more precise and smooth surface product with less carbon content that make the product brittle.
- Higher percentage of aluminium produced longer and closer dendrite spacing while higher percentage of magnesium produced a quick far spacing dendrite when determination the microstructure of the products.
- Higher percentage of magnesium in casting may produce more carbon in the product. This is because the reaction magnesium and oxygen easy to aflame when molten magnesium exposed to the air.
- The control of as cast microstructures, by manipulating casting processing variables, such as the cooling rate and the tip growth rate can be used as an alternative way to design mechanical properties.

Finally, it can be concluded that each process have their advantages and disadvantages. For some product that is difficult to be shaped, the process that should be used is more aluminium elements because it has less friction and better flowability hat can fulfill the mold easier. While if the design just a simple form more magnesium elements may be used to reduce cost and good fulfillment of bigger cavity before flows through riser

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