UNIVERSITI TEKNIKAL MALAYSIA MELAKA

MICROSTRUCTURAL MORPHOLOGY AND MECHANICAL PROPERTIES OF RHEOCAST A319 ALUMINIUM ALLOY

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering Hons. Of Manufacturing Process

By

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DECLARATION

I hereby, declared this report entitled "Microstructural Morphology and Mechanical Properties of Rheocast A319 Aluminium Alloy" is the results of my own research except as cited in references.

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Manufacturing Process) (Hons.). The member of the supervisory is as follow:

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ABSTRACT

A319 aluminium alloys are widely used in automotive industry as it has a good fluidity and also good mechanical strength. In this study, conventional casting and cooling slope casting has been studied to evaluate the microstructure and mechanical properties. Raw material of A319 aluminium alloy was melt using silicon carbide crucible furnace. For conventional casting, the temperature used was 700°C and directly poured into the mould. For cooling slope process, the temperature used were 650°C, 670°C, and 690°C while the cooling slope length were 200 mm, 300 mm and 400 mm. From the conventional casting, one of the specimens was undergone heat treatment and for cooling slope casting three specimens was used. Then CNC turning was used to cut the specimen. The specimens were examined using optical microscope. Microstructure analysis for non-heated specimens in conventional casting has shown a dendritic primary phase whereas cooling slope casting produce a globular microstructure. The heat treated specimens for both processes produce a precipitation among the phase. The specimen is then undergo hardness test using Vickers hardness tester by applying 100kg load and 1/16 inch diamond ball. The result for non-heated specimen of conventional casting is 81.1 HV and it increased up to 95.75HV in cooling slope casting process. It has proved that heat treatment specimen in cooling slope casting has a better result and the value for the hardness was 131.53HV. For tensile test, the dog bone shape was examined using Universal Tensile Machine. For conventional casting the yield strength, ultimate tensile strength and percent elongation were 140.1 MPa, 233.5 MPa and 2.0% respectively. The yield strength, ultimate tensile strength and percent elongation for non-heated specimen in cooling slope were 165.6 MPa, 237.5 MPa and 2.8% respectively. For heat treated specimen, conventional casting achieved yield strength, ultimate tensile strength and percent elongation 187.2 MPa, 234.9 MPa and 3.3% respectively. For cooling slope, shown yield strength, ultimate tensile strength and percent elongation it achived 204.1 MPa, 241.8 MPa and 3.6% respectively. In conclusion, it is found that cooling slope process is better than conventional casting. Moreover, the heat treated specimen has developed greater performance in mechanical properties of the studied alloy.

ABSTRAK

Aloi aluminium A319 digunakan secara meluas dalam industri automotif kerana ia mempunyai sifat mudah dibentuk dan juga mempunyai sifat mekanikal yang baik. Dalam kajian ini, tuangan dan tuangan cerun penyejuk akan di kaji mengenai mikrostruktur dan sifat mekanik. Bahan mentah aloi aluminium A319 akan dileburkan dengan menggunakan silikon karbida relau pijar. Untuk tuangan, suhu yang digunakan adalah 700 ° C dan akan dituang terus ke dalam acuan. Manakala, untuk tuangan cerun penyejuk pula suhu yang digunakan adalah 650°C, 670°C, dan 690°C bersama-sama dengan jarak tuangan pada 200 mm, 300 mm dan 400 mm. Dari tuangan, salah satu daripada bahan kajian akan menjalani rawatan haba dan untuk tuangan cerun penyejuk tiga contoh yang akan menjalani rawatan haba. Kemudian mesin larit kawalan berangka komputer akan digunakan untuk memotong bahan kajian. Bahan kajian telah siap dipotong akan diujian mikrostruktur menggunakan mikroskop optikal. Analisis mikrostruktur bagi bahan kajian tidak menjalani rawatan haba dalam tuangan telah menunjukkan fasa utama dendrit dan cerun penyejuk menunjukan globular mikrostruktur. Bahan kajian yang telah dirawat haba untuk kedua-dua proses telah mewujudkan pengerasan mendakan antara fasa. Bahan kajian kemudiannya akan menjalani ujian kekerasan menggunakan Mesin ujian kekerasan dengan menggunakan beban 100kg dan 1/16 inci berlian bola. Hasil untuk bahan kajian tuangan yang tidak menjalani rawatan haba adalah 81.1 HV dan nilai meningkat pada 91.75HV untuk cerun penyejuk. Manakala, bahan kajian yang telah menjalani rawatan haba menghasilkan keputusan yang lebih baik dengan 131.53HV nilai kekerasan. Untuk ujian tegangan, bahan kajian telah di uji menggunakan mesin mesin tegangan universal untuk menguji kekuatan alah, kekuatan tegangan muktamad dan peratus pemanjangan. Nilai untuk tuangan ialah 140.1 MPa, 233.5 MPa dan 2.0%. Manakala, nilai untuk bahan kajian cerun penyejuk yang tidak menjalani rawatan haba ialah 165.6 MPa, 237.5 MPa dan 2.8%. Manakala bagi bahan kajian yang telah dirawat haba untuk tuangan ialah 187.2 MPa. 234.9 MPa dan 3.3% dan untuk cerun penyejuk, adalah 204.1 MPa, 241.8 MPa, 3.6%. Kesimpulannya, mendapati bahawa tuangan cerun penyejuk adalah lebih baik daripada tuangan. Walaubagaimanapun, bahan kajian yang telah dirawat haba menunjukan prestasi yang lebih baik dalam sifat-sifat mekanikal dalam kajian aloi.

DEDICATION

To my beloved parents and siblings

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Al	-	Aluminium
ASTM	-	American Society of Testing and Material
B	-	Boron
CNC	-	Computer numerical control
CS	-	Cooling slope
Cr	-	Chromium
Cu	-	Copper
DC	-	Direct Chill
Fe	-	Iron
GISS	-	Gasinduced semi-solid
GS	-	Grain size
HPDC	-	High pressure die casting
HV	-	Hardness Vickers
Kg	-	Kilogram
KN	-	Kilo newton
Ksi	-	kilopound per square inch
Min	-	Minute
Mg	-	Magnesium
MHD	-	magneto hydro dynamic
Mm	-	Millimeter
Mn	-	Manganese
Mpa	-	Mega Pascal
Na	-	Sodium
Ni	-	Nickel
PSM	-	Projek sarjana muda
RCP	-	rheo-container process

SF	-	Shape Factor
Si	-	Sillicon
SOP	-	Standard operation procedure
Sr	-	Strontium
SSM	-	Semi-solid metal
SSR	-	Semi-solid rheocasting
Ti	-	Titanium
UTM	-	Universal Testing Machine
UTS	-	Ultimate Tensile Strength
YS	-	Yield strength
Zn	-	Zinc
α	-	Alpha
°C	-	Degree Celsius
µm	-	Micron meter
%	-	Percentage

CHAPTER 1
INTRODUCTION

1.1 Background

In the automotive industries, demands for equipment with high-performance equipment force scientist to improve the capacities of countless applications by create a new creative solution. They were forces to investigating and also distinguish the possibilities for minimize weight and higher consistency of the components in facility. Thus, choosing the best possible manufacturing process and suitable alloy is an acute step in scientific applied and perspective.

Regarding on limitation in the industry from the need and advance technical material solution, such as erosion resistance, low-density, high durability, and high thermal conductivity as well as recyclability has make the aluminium alloy as perfect applicant. The advanced mechanical process method of aluminium alloys such as extrusion, forging, casting and machining is very common manufacturing process. Most of the cases, negotiations in certain criteria such as price, design characteristics, dimensions, and material characteristics the limit range of processes and contribute to the utilization is the most competent process. Conversely, when shape of component that is more intricate, casting process specifically high pressure die casting (HPDC) is alleged highly in cost effective and productive alternative in aluminium die casting (Kaufmann and Uggowitzer, 2007).

Semi-solid metal (SSM) is an advanced technology which is having multiplicity of use compared to liquid processing and solid processing. One of the benefit of Semi-solid metal (SSM) over casting process is it have an exclusive thixotropic behaviour that available in the semisolid state. There are two common methods in semisolid metal processing. First one is thixocasting process that states to a method of fine net shaping of molten non-dendritic alloy slug within die casting and the other is rheocasting which concern more on the application of shear during solid fixation to produce near net shape non-dendritic semi-solid slurry. In rheocasting process, the net shape of dendritic semi-solid can be conveyed instantly into a mould to form a part. It capable to smears semisolid behaviour as well as it reducing the macrosegregation, forming forces, and porosity through shaping process. Record of former research works had been taken out by a several spotters in order to exploit this procedure potential. It is to construct different product for automotive industry.

The fresh development for the industry is to produce fuel efficient vehicle which resulted aluminium alloy increase of consumption. A319 aluminium alloy were being gradually used in production of engine gears due to great volatility property combination and mechanical strength. Between the semisolid processing methods, cooling slope (CS) is unitary of the appropriate method to gain well globular structure with a high degree of sphericity. This method also involved in sheeting down the molten metal on inclined plate then proceed it into a cylindrical mould before it undergo solidified process. Crucial advantage using cooling slope is it may put up handle at ease. Besides it also cost effectiveness (Salleh, 2014).

1.2 Problem Statement

As most industry facing the same problem on using the conventional castings as it often produce low quality of parts contain weakness such as shrinkage, gas porosity and oxide that lead to poor mechanical properties. Usually it found that the microstructure morphology of solid-liquid interface in conventional casting is dendritic. The tip of the dendrite acts as a stress raiser, which may causes dendritic arm spacing. This situation may lead to failure by crack at porosity and deterioration of mechanical properties of the castings. One of the techniques to enhance mechanical properties is by modify or change the microstructure. The microstructure of the castings can be easily suited by semi-solid metal (SSM) processing techniques. SSM processing is combination of the plastic deformation and characteristics of casting which takes place between solidus and liquids temperatures.

Rheocasting process is an emerging technology that is applied to obtain components from the conformation of metals and alloys in the semi-solid state. There is many benefit appear by this process: a lower consumption of energy, a wide variety of alloys and geometric forms, excellent mechanical properties, an increase in the lifetime of the processing equipment, an excellent surface finish and high dimensional quality, among others qualities

1.3 Objectives

The main objectives of the study are:

1. To determine microstructural morphology of A319 aluminium alloy throughout rheocasting process.
2. To determine the mechanical properties of A319 aluminium alloy throughout rheocasting process.

1.4 Scope of Study

In this case study, the main focused is on the rheocasting processing on A319 aluminium alloy. There are two type test use on specimen after the rheocasting process which is tensile test and hardness test. Both of hardness and tensile test is use to determine the microstructural morphology and mechanical properties A319 aluminium alloy during rheocasting. In this study Cooling slope is use to analyse the effect of mechanical properties material at difference distance on cooling slope.

CHAPTER 2
LITERATURE REVIEW

Basically chapter 2 stated out the review of pass journal correlated with the study. The literature review is essentially examined according to the sources and described to justify the statement with proof of research or study in related subject.

2.1 Aluminium Alloys

Aluminium alloy has a very good mechanical and electrical properties as it have a high resistance to erosion, a high electrical and heat conductivity (Cook, 1976). Other than that, based on Zolotorevsky (2010) it found can be cast by basically all current procedures. Most speciality of aluminium alloy as their properties can be upgraded or change as demand by changing the solidification, composition of alloy, casting process, and solidification process. These variables most impact microstructural characteristics, additionally the most noteworthy elements in characterizing the last properties of a cast part in physical properties and mechanical properties (Kaufman, 2004). For that reason it has to undergo an improvement on execution qualities and convey the required level of quality, understanding the effect of these variables on microstructural characteristic.

2.1.1 Influence of alloy composition

Out the most important factor in the fluidity of the composition of alloying solidification as it determine the final properties of material. Also properties of materials are affected by metallurgical factors such as the formation of metal, morphology of particles, and the molecules in the solid solution (Mulazimoglu, 1989). Each alloy has a different chemical composition. By increasing alloy composition makes it difficult to control their properties due to shaping of complex phases structure in microstructure. The main weakness to the casting process is mostly casting alloys containing a high content of alloying elements. In this preparation, the chemical additive effect of alloying elements can be categorized into three main aspects:

1. Major elements: Si, Cu, and Mg, which to control fluidity of alloy and value of eutectic.
2. Minor elements: Sr, B, Ti, Na, and manganese, which hold in the solidification behaviour and the morphology of phases (Ware, 2002).
3. Impurities: Fe, which are unacceptable to eliminate but possible to modify in oder to enhance the properties (Zolotorevsky, 2010).

Applications of aluminium alloys are found to be mostly used in the automotive industries as it have a high elongation value, yield strength (YS), tensile strength, and ductile. According to Wang (2003) this property directly connected to microstructural qualities by depicting eutectic stages and Zahedi(2007) has stated thatgrain refinement and molecule morphology, and deformity arrangement. For instance, by expanding the Si content in a hypoeutectic Al-Si composite cause to increase the UTS but decreased elongation (Dwivedi, 2006). Morphology and distribution of Si-particles from needle shape to a globular shape as an after effect of change and refinement of Si by including the component, such as Na and Sr or increasing cooling rate as well as a heat treatment process can improve ductility and UTS (Ogris, 2002).

Also found that thermal conductivity is an essential material property for applications where heat is generated and should be taken out as a model in electronic gadgets and engine parts. Tritt (2005) has said that thermal conductivity is unequivocally dictated by the mean free way of electrons. An outcome of including alloying components is that the conductivity heat is decreased gradually. The alloy composition is added into cast aluminium alloy to get strong arrangement.

A high fixation of particles in a solid solution results in a low thermal conductivity because of the particles going about as little wellsprings of unsettling influence. Olafsson (1997) once stated that impact of these alloying components on electrical resistivity, synonymous with thermal conductivity. Additionally, the commitment of alloying components outside of solid solution for resistivity is normally one request of size littler than that of the components in the solid solution. However, the impact of Sr alteration on the electrical conductivity of Al-Si compound with Si grouping of between 0 and 12.6wt%, and reasoned that electrical conductivity increments in adjusted alloys as the Si particles get to be better (Mulazimoglu, 1989).

2.1.2 Influence of process

Based on Sjolander (2011), the casting process showed that solidification rate and also formation of defects has an important influence on the final properties of the cast part. In instance, the HPDC process as the rapid filling process with high solidification rate enable to manufacture components within a wide range of products making. The high solidification rate in this process proved that final microstructure formed as it improved the mechanical properties of product**.** In addition, components manufactured using HPDC produced product lower in shrinkage porosity and also reduce the size of entrapped gas pores. On the other hand, higher the velocity of melt during the filling process may results in higher amount of entrapped air in the final product compare to other processes. By applying a high pressure during the intensification stage can increase the inner pressure in the entrapped gas pores. Then, during the solution treatment process at high temperature, blistering may occur in the location that these porosities are placed near to surface of components (Vinarcik, 2003).

2.1.3 Influence of post solidification

Heat treatment process is involving all thermal practices in the solid state in a controllable way make it possible to achieve specific characteristics that fulfil engineering criteria. According to Lasa (2004) common thermal treatments used for Al alloys is containing Si, Cu or Mg as major alloying elements involve either artificial ageing, T5 or solution heat treatment, T6 process. In general, T6 treatment is not recommended for HPDC components as it can cause a formation of blistering when the solution treatment exceeds a certain temperature and time.

The heat treatment of cast components generally improved their mechanical properties by increasing the strength of the material. This can be related to phase and morphology changes associated with soluble elements and compounds, as well as minimising or eliminating microsegregation (Hatch, 1984). However by understanding the effect of alloying element as well as other melt treatment parameters such as modification and grain refinement on the heat treatment behaviour of the alloy is very complicated and need to study further.

2.2 SSM CASTING

2.2.1 General concepts

Presenting on exterior force throughout solidification to examine hot tearing on Sn-15Pb, the formation of non-dendritic solid particles has been witness by Spencer that it is found suspended in a liquid matrix. This spectacle may occurs due to the impact of mechanical exciting on the interaction between solidification fronts and melt flow,