MICROSTRUCTURE AND MECHANICAL PROPERTIES OF Al-ALLOY WITH RARE EARTH

NATEG MOHAMMAD DIAB

UNIVERSITI TEKNOLOGI MALAYSIA

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NATEG MOHAMMAD DIAB

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To

My beloved family

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ABSTRACT

The development of aluminum alloys is of great interest to many of the industries and biomedical applications, because they provide a high strength to weight ratio, high wear resistance, low density and low coefficient of thermal expansion compared with other materials. These improvements in the field of application make the study of their mechanical behavior of utmost importance. However, these alloys possess some limitations in terms of the interactive effects of additives. Therefore, the present study aims to investigate the influence of the rare-earth, e.g., Lanthanum and yttrium with the amounts of 0.5, 1.0, and 1.5 wt.% on the microstructure and mechanical properties of hypereutectic Al-Si and hypoeutectic Al-Mg alloys. The microscopic observations contain of optical, field emission scanning electron, energy dispersive spectroscopy and X-ray diffraction, and mechanical properties testing, such as tensile, impact, and hardness test were carried out. A good agreement was observed between the results of microstructure and mechanical properties. XRD and EDS results indicate the formation of intermetallic compounds that associated with the modifications, which may play a major cause in improving the mechanical properties. It was also found that the secondary dendrite arm spacing value became smaller with increasing La addition, and decreased slightly from the unmodified 5 μm to 4.1 μm. On the other hand, when the content of La is 1.0%, the iron-rich phases tend to be slender with a size of about 0.5 μm. While with the addition of 1.0 wt.% of Y, the volume fraction of the dendritic phase are tend to decrease along with increase the grain size to 40 μm. The modifications of Al-alloy eutectic structure were improved ductility from 0.7% and 8% to 1.8 and 10.5 with the addition of 1.0 wt.% of La and Y, respectively. However, the addition of 1.0 wt.% of La and Y led to increase the ultimate tensile strength from 100 MPa and 180 MPa to 150 MPa and 200 MPa, respectively. A further addition of La and Y results in a reduction in mechanical properties.

ABSTRAK

Pembangunan aloi aluminium telah menarik minat pelbagai industri dan aplikasi perubatan, di sebabkan aloi ini mempunyai kekuatan tinggi berbanding nisbah berat, rintangan lelasan yang tinggi, ketumpatan yang rendah dan pekali pengembangan haba yang rendah jika di bandingkan dengan bahan lain. Penambahbaikan dalam bidang aplikasi menyebabkan penyelidikan berkaitan sifat mekaniknya tersangat penting. Walaubagaimanapun aloi ini mempunyai limitasi dari segi kesan interaktif terhadap bahan tambah. Oleh itu kajian ini bertujuan mengkaji pengaruh nadir bumi, seperti Lantanium dan Yitrium dengan jumlah 0.5, 1.0 dan 1.5 % berat keatas mikrostruktur dan sifat mekanik aloi hipoeutektik Al-Si dan aloi hipoeutektik Al-Mg. Pemerhatian di lakukan melalui mikroskop optik, mikroskop imbasan, spektroskopi tenaga serakan (XPS) dan difraktor sinaran-X (XRD), dan ujian sifat mekanik seperti ujian tegangan, impak dan kekerasan juga telah di jalankan. Satu keputusan sepadanan di antara keputusan mikrostruktur dan sifat mekanik telah di perolehi. Keputusan XRD dan XPS mendapati pembentukan sebatian antaralogam terbentuk selepas modifikasi, memainkan peranan utama dalam peningkatan sifat mekanik. Kajian juga mendapati jarak lelengan dendrit sekunder menjadi kecil dengan pertambahan La, dan berkurang sedikit jika di bandingkan dari aloi asal dari 5 mikron kepada 4.1 mikron. Di sebaliknya jika jumlah La sebanyak 1.0%, fasa tinggi-ferum akan mengecil kepada 0.5 mikron. Sementara penambahan Y sebanyak 1.0%, nisbah isipadu fasa dendrit akan berkurang sepadan dengan kenaikan saiz bijian kepada 40 mikron. Modifikasi struktur eutektik aloi-Al menambahbaik kemuluran dari 0.7% dan 8% kepada 1.8 dan 10.5 dengan kemasukan La dan Y sebanyak 1.0% berat masing masing. Walaubagaimanapun , penambahan 1.0% La dan Y meningkatkan kekuatan tegangan muktamad dari 100MPa dan 180 MPa kepada 150 MPa dan 200 MPa masing masing. Penambahan seterusnya La dan Y menghasilkan penurunan sifat mekanik bahan aloi tersebut

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LIST OF ABBREVIATIONS

DAS	-	Dendrite Arm Spacing
MR -	-	Modification Rate
EDS	-	Energy dispersive spectroscopy
FE-SEM	-	Field emission scanning electron microscopy
OM	-	Optical microscope
XRD	-	X-ray diffraction
UTS	-	Ultimate Tensile Strength
YS	-	Yield Strength

LIST OF SYMBOLS

ϵ^f	-	Fracture strain
σ^f	-	Fracture stress
a.u	-	arbitrary unit
Hv	-	Vicker’s hardness
K/min	-	Kelvin per minute
^oC	-	Centigrade degree
T	-	Temperature
Wt.%	-	Weight percentage
α-Al	-	primary aluminum dendrite
s	-	Second

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CHAPTER 1

INTRODUCTION

1.1 Background

With the aims of giving light and rationally high quality mechanical characteristic materials, expenditure and energy efficiency and also reduction of harmful effects on the ecosystem, the aluminum industries are moving towards using secondary aluminum in the form of returns and scrap as a replacement of virgin ingots [1]. Nevertheless, they are challenged by buildup of contaminants from the crumbs and returns applied. The secondary matter is basically made up of molding and bent crumbs of aluminum alloys, and like the pollution matter of the secondary alloys, relies on the manner of production technique. The Si part of the mold is customized, since a development twin has been made at the border when the proportion of atomic radius of the metal in relation to silicon goes beyond limit 1.65 [2].

Modification of silicon is known as melt treatment, mostly used to form Al-Si-Mg and Al-Si-Cu-Mg alloys to sustain the material trait and technical needs. It is also acceptable that doping of modifier metals could have transformation in the metallurgical qualities of silicon in the eutectic stage, where the framework could influence the mechanical aspects of Al-Si moldings [2]. Hard and brittle silicon parts do enhance the outcome and overall tensile power of softer aluminum frames but cause poor ductility. To eliminate this weakness, the morphology of Si particles is changed from flake or acicular form into fibrous and globular form by introduction of adjusting elements [3, 4]. Additionally, it is achievable to lessen the elucidation time throughout heat dealing if modifier is used [5]. Nonetheless, the addition of modifier catalysts over a particular quantity will increase permeability, hydrogen contents [6], hot splitting, poor exterior finish [7] and excess of modification which leave destructive effect on quality [8]. Achievement and efficiency of the modification procedure should be aided by good and reliable investigation methods so that reliable and precise data can be obtained and accurately read. Metallographic and chemical examinations are some of the common and the conventional methods applied for sample examination. They take a lot of time, destructive [9], inclusive of post process management and their outcomes are reliant on area model assortment and research conditions.

The latest research included the fusion of uncommon earth elements, like La, Y, Ce, Yb and Er into aluminum alloy to study the influence on the microstructure and mechanical characteristics. As an example, a good quantity of La was used to alter the microstructure of the molten alloy, and enhance the mechanical characteristics, conductivity of electricity and thermal resistance [10]. Alongside, it was speculated that the use of 3 wt.% La should contribute to a small modification change in the silicon stages in A390 as prospected for the development of the $Al_7Si_7Cu_2La_{3.5}$ and $Al_5Mg_8Cu_6Si_6$, which means the plate-like silicon morphology has no refinement with the excess La in the alloy [11]. Besides, the rare earth La was found able to speed up the age-hardening development of 6061 alloys [12]. Nonetheless, the available reports did not study the mechanical aspects. The best amount of La and Y accumulations were found in A390 and A5083 alloys, correspondingly. Thus, the present research aims to investigate the optimum addition level of La and Y to modify the eutectic phase of A390 and A5083 alloys, and its effect on the microstructure and mechanical properties.

1.2 Problem Statement

Even though the application of secondary materials has risen, particularly in the manufacture of aluminum based items, their application nonetheless creates technical disadvantages mostly related with the impurities that may root from chemical corruption and counteract the influence of rare earth metals like lanthanum and yttrium on the framework and characteristics of Aluminum-alloys. Alterations may happen when an alloy crump, that has one type of refiner, is re-melted with the primary ingot and treated with a different percentage of modifiers. Thus, the effect and correct levels of other elements such as lanthanum and yttrium present in the melts need to be understood and are very essential in ensuring casting quality.

1.3 Purpose of the Study

This research addresses the problems described above, namely understanding on the probable interaction between the additive and the alloy element in secondary material alloys. The results obtained from this study will represent a technological step towards increased usage of secondary alloys in the aluminum industries. The individual effect of La and Y with different weight percentage additions of 0.5, 1, and 1.5 on the binary and ternary alloy A390 and A5083 alloys, respectively, were investigated. The results of this study were then compared with those of microstructural observations, as well as mechanical property tests, for hardness, impact and tensile strength.

1.4 Objectives of the Study

This study is geared towards achieving the following objectives:

1. To evaluate the modification and gain refinement treatments of the eutectic Al-Si structure in secondary materials through additions of La and Y using the microstructural observation.
2. To establish the correlation between results of structure, morphology and the concentration of additive element.
3. To evaluate the effects of different percentages of La and Y additions on the mechanical properties of the Al-alloys, e.g., A390 and A5083 alloy.

1.5 Scope of the Study

1. The binary system of A390 and A5083 alloys were used as the base alloys. Different concentrations of La and Y (0.5, 1, and 1.5 wt.%) additions were used to investigate the optimal concentration for refinement and modification. The melt pouring temperature was set at around 900 ± 10 °C.
2. Microstructural observations were carried out to investigate the effect of addition on the structure and morphology of Al- alloy via optical microscopy, X-ray diffraction, and Field emission scanning electron microscopy.
3. Energy dispersive scanning electron microscopy, along with elements mapping, was carried out to identify the chemical composition of the new intermetallic/precipitate that was formed due to the addition, associated with the elemental distribution of the alloy compound in the microstructure.

4. Mechanical properties investigation was conducted to identify the effects of La and Y additions on the tensile, impact and hardness properties of Al alloy.

1.6 Significance of the Study

The research work reported in this thesis is significant in providing new knowledge and understanding of the interaction between different percentages of additive with the properties of base alloy elements during melting of secondary aluminum alloys. Upon further implementation, the aluminum industries will benefit from this research work in terms of increased productivity, quality and cost and time savings due to increased use of aluminum-based secondary alloys. The research outcomes will also contribute towards sustainability of available material resources and better environmental protection through reduced materials waste.

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