EFFECTS of TiB and Ce ADDITIONS on THE MICROSTRUCTURE and MECHANICAL PROPERTIES of 2024 Al-Cu ALLOY

By

Eng/ Rania Mohamed Sayed El-Shorbagy

A thesis submitted to the
Faculty of Engineering at Cairo University
in partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
METALLURGICAL ENGINEERING

FACULTY OF ENGINEERING, CAIRO UNIVERSITY,
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Title of Thesis:

Effects of TiB and Ce additions on the microstructure and mechanical properties of 2024 Al-Cu alloy

Key Words:

2024 aluminum alloy, TiB and Ce mishmetall, Grain refining, Microstructure, Mechanical properties

Summary:

2024 Al-Cu-Mg alloy offer high specific strength, good corrosion resistance and excellent fatigue resistance. These excellent properties make the 2024 alloy a very important alloy in the aerospace and automotive industry. However, the alloy suffer some problems during casting such as hot tearing, undesirable coarse dendrites structure and the presence of free impurity elements such as Fe and Si. These problems lead to deterioration in the mechanical properties of the alloy.

In the present study, the effect of Al-5%Ti-1%B master alloy additions and the rare earth cerium (Ce) with different additions (0.2 and 1% Ce) on microstructure and mechanical properties of 2024 alloy in different conditions (cast, homogenized and aged) was investigated. The microstructures of specimens were examined by optical microscope and scanning electron microscope (SEM) attached with EDS analyzer. It was found that Al-5%Ti-1%B and 0.2% Ce refines the microstructure; meanwhile, the 1% Ce addition increased the grain size again. The maximum refining obtained in this investigation is obtained by adding Al-5%Ti-1%B master alloy. A decrease in grain size from 81.5 µm to 30 µm was successfully achieved by these additions. The mechanical properties were determined by hardness and tensile tests. The mechanical properties were improved by the additions of Al-5%Ti-1%B and 0.2% Ce. A good combination of hardness, yield strength, ultimate tensile strength and elongation was obtained by means of Al-5%Ti-1%B additions. The percent increase is 20% for hardness, 104% for UTS, 71% for Y.S, meanwhile the elongation increased by 45.5%. On the other hand, with increasing the cerium content to 1% Ce, a drop in mechanical properties of the alloy was observed due to the appearance of eutectic lamellar structure (Al_3Ce Cu). Meanwhile, the peak aged condition does not recognized in this case.

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Dedication

I dedicate this thesis to my parents, my brother and sisters, my husband and my daughter, their love give me forces to perform this work

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Abstract

2024 Al-Cu-Mg alloy offer high specific strength, good corrosion resistance and excellent fatigue resistance. These excellent properties make the 2024 alloy a very important alloy in the aerospace and automotive industry. However, the alloy suffer some problems during casting such as hot tearing, undesirable coarse dendrites structure and the presence of free impurity elements such as Fe and Si. These problems lead to deterioration in the mechanical properties of the alloy.

In the present study, the effect of Al-5%Ti-1%B master alloy additions and the rare earth cerium (Ce) with different additions (0.2 and 1% Ce) on microstructure and mechanical properties of 2024 alloy in different conditions (cast, homogenized and aged) was investigated. The microstructures of specimens were examined by optical microscope and scanning electron microscope (SEM) attached with EDS analyzer. It was found that Al-5%Ti-1%B and 0.2% Ce refine the microstructure; meanwhile, the 1% Ce addition increased the grain size again. The maximum refining obtained in this investigation is obtained by adding Al-5%Ti-1%B master alloy. A decrease in grain size from 81.5 µm to 30 µm was successfully achieved by these additions. The mechanical properties were determined by hardness and tensile tests. The mechanical properties were improved by the additions of Al-5%Ti-1%B master alloy and 0.2% Ce. A good combination of hardness, yield strength, ultimate tensile strength and elongation was obtained by means of Al-5%Ti-1%B additions. The percent increase is 20% for hardness, 104% for UTS, 71% for Y.S, meanwhile the elongation increased by 45.5%. On the other hand, with increasing the cerium content to 1% Ce, a drop in mechanical properties of the alloy was observed due to the appearance of eutectic lamellar structure (Al_3CeCu). Meanwhile, the peak aged condition does not recognized in this case.

Chapter one: Introduction

Pure aluminum obtained from the electronic reduction of Alumina (AI_2O_3) is a relatively weak material. Therefore, for applications required greater mechanical properties, aluminum is alloyed with other alloying elements such as copper, zinc, magnesium and manganese, usually in combinations of two or more of these elements together with iron and silicon. Aluminum alloys have traditionally been associated with applications in the automobile and aerospace industries, because their specific strengths (strength-to-weight ratios) are outstanding compared to both engineering alloys of other metals, and other engineering materials in general. The advantages of decreased density become even more important in engineering design for parameters such as stiffness and resistance to buckling. Concern with aspects of weight saving should not obscure the fact that the aluminum alloys possess other properties of considerable technological importance, e.g. the high corrosion resistance and good electrical and thermal conductivities[1-2].

Precipitation hardening 2xxx series aluminum alloys are used in many applications for their particular combinations of strength and corrosion resistance, high specific strength, good fracture toughness, excellent fatigue properties and damage tolerance. In aerospace and automobile industries, the high strength-to-weight ratio, which is particularly important in the design of structural components, makes these alloys a very attractive class of materials[3].

Among the present 2xxx series aluminum alloys, alloy 2024, whose principal alloying elements are copper (Cu) and magnesium (Mg) with small amount of manganese (Mn) and other minor elements such as Zn, Ti, Si and Fe, is widely used in aircraft structures, rivet hardware, truck wheels, screw Machine products and other miscellaneous structural applications because of their good Performance below 100°C[4].

Despite the attractive applications of 2024 aluminum alloy, the alloy are generally considered difficult to cast due to their tendency to hot tear during solidification. Also, the alloy has other problems which lead to the decrease in mechanical properties such as the coarse dendrites formed during the solidification of the alloy and The formation of intermetallic particles results from the presence of impurities, e.g. Fe and Si, and excessive content of alloying elements such as Cu, Mg, Mn in this type of aluminum alloys, this coarse intermetallic phase particles are responsible for the low fracture resistance and reduced ductility, because these particles act like the cracks initiators or the preferential cracks paths[5].

The present investigation attempts to refine the microstructure of 2024 aluminum alloy through the additions of 0.2% TiB to the alloy and also, through the additions of the rare earth Ce to the alloy with different amounts (0.2 and 1% Ce) and show the improvement in microstructure and mechanical properties of the alloy.

Chapter two: Literature survey

2.1 Overview:

Aluminum is the third most abundant element in the Earth's crust, after oxygen and silicon, and hence, the most abundant metal. It is a relatively light metal with a density of 2.7 g/cm^3 compared with others metals such as iron, nickel, brass, and copper. Aluminum and its alloys are used in a wide range of industrial applications for different aqueous solutions due to their high strength-to weight ratio, besides other desirable properties like desirable appearance, non-toxic, non-sparking, nonmagnetic, high corrosion resistance, high electrical and thermal conductivities and ease of fabrication[5]. These properties led, also, to the association of these alloys with transportation particularly with aircraft and space vehicles, construction and building, containers and packaging and electrical transmission lines[6-7]. In addition to high strength, they have a strong resistance to corrosion, which is a result of a tenacious oxide surface that forms quickly in air. This hard, microscopic oxide coating protects aluminum from many chemicals and weathering conditions. At the same time, they are characterized by good workability that enables them to be economically rolled, extruded, or forged into useful shapes[2].

The commercial Al alloys normally contain copper, manganese, magnesium, zinc, silicon, iron and nickel as major alloying elements or impurities to meet the various demands during service [3,8]. These alloying elements induce formation of second phase particles. Thus, due to its extremely low solid solubility in aluminum, nearly all iron segregates to dendrite arm boundaries during solidification where it reacts with aluminum, silicon, copper and manganese to form a large number of intermetallic phases[9]. The morphology of phases formed by the combination of these impurities with major solute additions cannot be affected by heat treatment. In all aluminum alloys, the percentages of alloying elements and impurities must be controlled carefully. If they are not, properties such as strength, toughness, formability, and corrosion resistance, for example, may be affected adversely[2].

Aluminum-copper alloys offer both high strength and excellent ductility, where those values are approaching some grades of ductile iron and they are significantly higher than these of Al-Si-Mg family. They have a number of potential applications in automotive industry to reduce vehicle weight, including automotive suspension knuckles, vehicle control arms, and differential carrier parts, aerospace and military castings[10]. However, the alloy is very difficult to cast because of its tendency for hot tearing. Hot tearing is a severe casting defect that generally occurs when casting solidifies and contracts under conditions that hinder the free contraction of casting parts[11].

Many efforts have been done to overcome this problem through the refine of the microstructure including: addition of refiner elements, rapid solidification, and severe plastic deformation,..etc. So that, it has a very good prospection industrial applications.