UNIVERSITI TEKNIKAL MALAYSIA MELAKA

MECHANICAL AND MICROSTRUCTURE CHARACTERIZATION OF OIL TREATED ALUMINUM ALLOY7075

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

by

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DECLARATION

I hereby, declared this report Entitled "Mechanical and Microstructure Characterization of Oil Treated Aluminum Alloy 7075" is the results of my own research except as cited in references.

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Date : 06 JUNE 2012

ABSTRAK

Tujuan kajian ini dijalankan ialah untuk menyiasat kesan proses kemunduran dan penuaan semula terhadap struktur mikro, tekanan kakisan retak, kekonduksian dan ciri mekanikal untuk aloi aluminium 7075 bila dikenakan proses kemunduran di dalam minyak. Dalam kajian ini, aloi aluminium 7075 akan digunakan sebagai bahan mentah berdasarkan sifatnya yang mempunyai paras kekuatan tertinggi di kalangan aloi tempa dan mempunyai rintangan tekanan kakisan yang baik. Ketika penyediaan sampel, aloi aluminium 7075 dikenakan solusi rawatan haba dengan dipanaskan sampel di dalam relau pada suhu 470 °C selama 1 jam dan diikuti dengan penyejukan mendadak pada suhu bilik menggunakan air. Sampel penyejukan mendadak akan dipanaskan semula untuk pengerasan penuaan pada suhu 120 °C selama 24 jam. Keputusan menunjukkan sampel yang menjalankan dengan kemunduran minyak pada 165^{o}C selama 10 minit mempunyai sifat-sifat mekanikal tertinggi dicapai menghampiri kekuatan T6 berbanding dengan parameter sampel lain. Dengan parameter yang semakin meningkat pada masa dan suhu, kekuatan mekanikal secara beransur-ansur berkurangan kepada nilai kekuatan T73. Mikrostruktur aluminium aloi 7075 dirawat banyak mempengaruhi sifat mekanik spesimen. Pembentukan fasa η yang hadir sebagai pengukuhan mendakan menyumbang kepada kekuatan sampel. Perbandingan untuk kerentanan kakisan aloi aluminium dirawat 7075, keputusan menunjukkan kerentanan SCC boleh dipertingkatkan dengan rawatan RRA. Kemunduran dan penuaan semula (RRA) menunjukkan rawatan mampu menghasilkan kombinasi sifat T6 dan T73 dengan pengurangan kekuatan T6 untuk meningkatkan kerentanan SCC mendekati T73 tempers.

ABSTRACT

The objectives of this research are to investigate the effect of retrogression and re-aging (RRA) process on microstructure, corrosion susceptibility (both in applied force (SCC) and without applied force condition) and mechanical properties of aluminum alloy 7075 when performed by oil retrogression. In this research, aluminum alloy 7075 have used as raw material of sample according to the highest attainable strength levels of all forged alloys and is capable of good stress corrosion resistance. In this sample preparation, aluminum alloy 7075 was have solution heat treatment by heated samples in the furnace to the temperature of 470 °C for one hour and followed by water quenching at room temperature. The quenched samples have preheated for age hardening at 120 °C for 24 hours. Then, the RRA process has applied to the sample in the T6 condition to improve its stress corrosion cracking (SCC) by immerse it into oil. Temperature and time is the variable for the RRA process. Samples that have done with oil retrogression then have re-aging at 120 °C for 24 hours. Result shows the samples that perform with oil retrogression at 165^{o}C for 10 minutes have highest attainable mechanical properties approximate the T6 strength compared to others parameters of sample. With increasing parameters of time and temperature, the mechanical strength gradually decreases to the values close to the T73 tempers. Microstructures of the treated aluminium alloy 7075 majorly influence the mechanical properties of the specimens. Formation of the η phase that presents as strengthening precipitates contributes most to strength of the samples. Comparison to the corrosion susceptibility of the treated aluminium alloy 7075, the results showed SCC susceptibility can be enhanced by RRA treatment. Retrogression and re-aging (RRA) treatment shows able to produce combination of T6 and T73 properties by make reduction of T6 strength to improve SCC susceptibility approached T73 tempers.

DEDICATION

To my father; Abdul Hamid Bin Abd Razak, my mother; Noriah Binti Chik, siblings and friends. Your love is my driving force.

To my supervisor, Dr. Mohd Warikh Bin Abd Rashid

To my Love

To Alans Ng that mostly guide me in this project

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURES

RRA	-	Retrogression and Re-Aging
SCC	-	Stress Corrosion Cracking
OM	-	Optical Microscope
AA7075	-	Aluminum Alloy 7075
PCT	-	Process-critical temperature
FAA	-	Federal Aviation Administration
ASTM	-	American Testing for Testing and Materials
IACS	-	International Annealed Copper Standard
Cu	-	Copper
Si	-	Silicon
Fe	-	Iron
Mn	-	Manganese
Cr	-	Chromium
Mg	-	Magnesium
Zn	-	Zinc
Al	-	Aluminum
H	-	Hydrogen
GP	-	Guiner-Preston
SiC	-	Silicon Carbide
NaCl	-	Sodium Chloride

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Aluminum is one of the most elements in earth with appearance in range from silvery to dull gray that have properties like low density, ease of fabrication, good corrosion resistance, high strength-to-weight ratio and high fracture toughness. Because of these properties, aluminum used widely according to it most economical and structurally effective material for commercial applications. But, usually pure aluminum alloyed with several elements to improve properties required. Aluminum is a big family of material due to different alloying element that produces different series of aluminum alloy.

Nowadays, application of the aluminum alloy in automotive, aircraft, military and industry cannot be deny. Among the others series of aluminum, alloy 7075 commonly used in aircraft industry. Alloy 7075 listed with others in family of 7xxx series alloys. Mitchell (2004) state that alloy 7075, has one of the highest attainable strength levels of all forged alloys and is capable of good stress corrosion resistance. For that reason, AA7075 widely used in aircraft industry function well in aircraft body structure and component parts.

Alloy 7075 have characteristic that fulfill the requirement of aircraft body structure where a combination of high strength, moderate toughness and good corrosion resistance as required. Besides that, the optimum strength, toughness and others desired characteristic can be occupied by heat treatment and others heat treating process like retrogression and re-aging (RRA) process. Alloy 7075-T6 heat treatment condition has been widely used for aircraft structural applications. Corrosion damage is often the reason why 7075-T6 components are replaced.

According to Wallace *et al.,* (2006), the concept of retrogression and re-aging (RRA) was first developed by Cina and his colleagues at the Israel Aircraft Industries in 1974. Cina *et al.,* (1974) state that T6-treated alloy of AA7075 has high strength, but have poor stress corrosion resistance. Improvement of corrosion resistance for T6 required and the methods to improve this corrosion resistance is over-aging AA7075 to get T73 tempers. But by over-aging, the stress corrosion resistance can be improved, but the strength may be decreased by 10%−15% (Zhang *et al.*, 2010). This precludes the use of the T73 temper when high strength required. RRA that applied to 7075 alloy in T6 temper shown the result of stress corrosion cracking (SCC) resistance can be enhanced with minimal tradeoff in strength approaching T73 condition.

According to Quench Factor analysis, developed by Staley, there have relationship between the cooling rate and the mechanical properties of age-hardable aluminum alloy (Ma, 2006). During heat treatment, heating and cooling operation are performed that functions to alter the mechanical properties, microstructure, or residual stress state of the alloy. Alloys that have age-hardenable involve solutionizing, quenching, and then aging at room temperature (natural aging) or at the elevated temperature (artificial aging). Mechanical properties depend on high quench rates after the solutionizing treatment to maximize the artificial aging (precipitation hardening) response.

The precipitation treatment used to develop these tempers requires two-stage artificial aging, the second stage of which is done at a higher temperature than that used to produce T6 tempers. During the preliminary stage, fine high-density precipitation dispersion is nucleated, producing high strength. The second stage is then used to develop resistance to SCC and exfoliation. During age-hardening, or also known as precipitation hardening, precipitates form in a super saturated solid solution and strength increases as the number and size of precipitates increase until a maximum critical value is reached and the material becomes overaged and coarsening begins, reducing mechanical properties, Nowill (2007). The final microstructure was found to be highly dependent on the retrogression treatment, and the final microstructure of T6 and T73 tempers was both unique and significantly different from each others.

1.2 Problem Statement

Nowadays, aluminum alloys have been widely used in automotive and aircraft industries due to its good properties and high strength-to-weight ratio. Components and structure body of aircraft continuously expose to thermal shock, extreme weather, corrosion agent and others that tends it to corrosion damage. Because of that, the parts of aircraft required high corrosion resistance beside high strength. To fulfill the requirement of corrosion resistance, applications of over-aged temper T73 look suitable because performed high corrosion resistance, but in comparison to 7075-T6, there is a strength penalty of 10 to 15%, which precludes the use of the T73 temper, when high strength is required, (Peeler et al., 2002).

Stress corrosion cracking occurs commonly undetectable and not apparent at the first place. There initiates with microcracks, where the cracks normally occur at the grain level. The corrosion takes place on the surfaces of the material, forming surface discontinuities that eventually becomes the stress raiser or notch to crack propagation at microstructural level, but the mechanism of crack propagation in such phenomenon is not merely caused by the atomic dislocation due to the stress, but it is also caused by the chemical attack on the crack tip, causing inter-granular crack along the grain boundaries of the material. Hence, this cracks potentially causing the failure of the material according to chemical attacks and mechanical factors.

Extensive researches on RRA treatment were done before that mostly focuses on the effects of retrogression heating rate temperature and retrogression time on the microstructures, corrosion resistant and mechanical properties. Retrogression can be applied in air furnace and oil bath. Mostly research used the air furnace as retrogression medium. But, this research focused on the effects of retrogression process in oil bath with different parameter of retrogression temperature and time on the microstructures, corrosion resistant and mechanical properties of AA7075. Peeler et al., (2002) state RRA process can be applied to improve corrosion resistance of T6 to levels approaching those of the T73 condition while maintaining the strength. However, RRA heat treatment result reduction of 5 to 7 percent of tensile strength for T6 temper. Different retrogression medium absolutely gives different result and effects to 7075 alloys.

So, this investigation is to improve SCC resistance of aluminum alloy 7075-T6 approaching T73 while maintaining the strength at levels at or slightly below the T6 condition by retrogression it in oil medium. Affects of retrogression process in oil also will be analyzed experimentally in this research. Experiments have done to investigate the microstructure change of the RRA sample and interface behavior of mechanical behavior. Microstructure features has determine to compare with other alloy and found the formation of microstructure after RRA.

1.3 Objectives

The objectives of the study are listed below:

i. To investigate the effect of oil Retrogression and Re-aging (RRA) in different parameter of temperature and time to aluminum alloy 7075.

ii. To analyze the microstructure of sample after retrogression in oil bath.

iii. To determine the mechanical properties and corrosion resistant of AA7075-T6 after retrogression in oil bath.

1.4 Scope of Study

The scope of this analysis is to investigate the role of heat treatment to aluminum alloy 7075. Completely understand the heat treatment process especially retrogression and re-aging (RRA) effects that can improve the aluminum alloy to desire properties. Extensive researches on RRA treatment were done before that mostly focuses on the effects of retrogression heating rate, but this analysis focused on the effects of retrogression in oil in different parameter of temperature and retrogression time. Improvement mechanical properties and alteration of microstructure covered in this study. Optical microscope (OM) used to observe the microstructure change after RRA process. Hardness and tensile test used to determine the mechanical properties. Corrosion resistance of the aluminum alloy 7075 was measured in term of normal corrosion rate (no load applied) and corrosion rate with applied load (SCC) by using Tafel Extrapolation Method to find the SCC properties of the 7075 alloy.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction Heat treatment of Aluminum Alloy

Aluminum alloys fall into two general categories: heat-treatable and non-heat treatable. Heat treatment can be either of the heating or cooling operations that performed for the purpose of changing the mechanical properties, the metallurgical structure, and the residual stress state of alloy. Wrought and casting alloy is restricted to the specific operations employed to increase strength and hardness by precipitation hardening thus the term heat treatable serves to distinguish the heat treatable alloys from those alloys in which no significant strength improvement can be achieved by heating and cooling. According to Quench Factor analysis, developed by Staley, there have relationship between the cooling rate and the mechanical properties of age-hardable aluminum alloy (Ma, 2006).

Series 7xxx alloys, considered the high strength aircraft alloy family, are heat treatable by solution and aging. Various aging cycles produce desired attributes such as maximum attainable strength (T6 temper) or stress corrosion resistance (T73 temper). Either way, the alloy must go through solution treatment, the goal of which is to completely dissolve into solid solution all alloy elements responsible for subsequent precipitation hardening and retained by rapid quenching. Subsequent heat treatment at tower temperatures i.e. ageing or natural ageing at room temperature allows for a controlled precipitation of the constituents thereby achieving increased hardness and strength. The degree of hardening obtained depends on the size, number and relative strength of the precipitates.

2.1.1 Aluminum Alloy Temper Designations

The physical properties exhibited by aluminum alloys are significantly influenced by the treatment of the sample. A standardized system has been developed to designate these treatments. First character in the temper designation are defined and described as follows:

2.1.1.1 Basic Temper Designation

Table 2.1: Basic Temper Designation

F	**As Fabricated –** This designation is used for cast products made by any casting process and refers to the condition of the casting as it comes from the mold without any further thermal or mechanical treatment. No special control has been performed to the heat treatment or strain hardening after the shaping process such as casting, hot working, or cold working.
O	**Annealed** – This designation is used for cast alloys that are annealed. For casting, the treatment (high-temperature stabilization and recrystallization treatment) may be used both to improve ductility and increase dimension stability. This is the lowest strength, highest ductility temper.
H	**Strain Hardened** - (applied to wrought products only) Used for products that have been strengthened by strain hardening, with or without subsequent heat treatment. The designation is followed by two or more numbers as discussed below.

W	**Solution Heat Treated** - This is seldom encountered because it is an unstable temper that applies only to alloys that spontaneously age at ambient temperature after heat treatment.
T	**Solution Heat Treated** - Used for products that have been strengthened by heat treatment, with or without subsequent strain hardening. The designation is followed by one or more numbers as discussed below.

2.1.1.2 Heat Treating T Temper Codes

Table 2.2: T Temper Codes

T1	Cooled from an elevated temperature shaping process and naturally aged to a substantially stable condition.
T2	Cooled from an elevated temperature shaping process, cold worked, and naturally aged to a substantially stable condition.
T3	Solution heat treated, cold worked, and naturally aged to a substantially stable condition.
T4	Solution heat treated, and naturally aged to a substantially stable condition.
T5	Cooled from an elevated temperature shaping process then artificially aged.
T6	Solution heat treated then artificially aged.
T7	Solution heat treated then and over-aged/stabilized
T8	Solution heat treated, cold worked, and then artificially aged.
T9	Solution heat treated, artificially aged, and then cold worked.
T10	Cooled from an elevated temperature shaping process, cold worked, then artificially aged.

2.2 Strengthening by Heat Treatment

Heat treating process for aluminum alloys are precision processes. They must be carried out in furnace properly and build to provide the thermal conditions required, and equipped with control instruments to insure the desired continuity and uniformity of temperature and time. Process details must be established and controlled carefully to ensure it occupied the final desired characteristics.

Based on Federal Aviation Adminstation (2008), the hardening of aluminum alloy by heat treatment consists of four-step:

- Solution heat treatment: heating to predetermine temperature and soaking for a period of time
- Quenching: rapidly quenching to relatively low temperature
- Age hardening: precipitation of solute atoms either at room temperature (natural aging) or elevated temperature (artificial aging or precipitation heat treatment).
- Retrogression and re-aging (RRA): is an intermediate heat treatment which when applied to Al 7075-T6 material results in improved corrosion resistance approaching the T73 temper, while maintaining the high strength of the T6 temper.

2.2.1 Solution Heat Treatment

To take advantage of the precipitation hardening reaction, it is necessary first to produce a solid solution. The process by which this is accomplished is called solution heat treating, and its objective is to take into solid solution the maximum practical amounts of the soluble hardening elements in the alloy. The principles and procedures for heat treating wrought and cast alloys are similar. The process consists of heating and holding the alloy at a temperature sufficiently high and for a long enough period of time to achieve a nearly homogenous solid solution.