UNIVERSITI TEKNIKAL MALAYSIA MELAKA

AN INVESTIGATION OF FRACTURE TOUGHNESS ON HEAT TREATED ALUMINUM ALLOY 7075 WITH EFFECT OF CORROSION

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

by

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Date	:	25 May 2010

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 (Engineering Materials) with Honours. The member of the supervisory committee is as follow:

……

(Principal Supervisor)

(Mr Mohamad Haidir Bin Maslan)

ABSTRACT

The aim of this project is to investigate the fracture toughness of heat treated Aluminum Alloy 7075 (AA7075) with effect of corrosion. As we know, characteristics of Aluminum are soft, light weight, and high corrosion resistant, but low strength. In this research, AA7075 is used as raw material. This AA7075 will be heated to T6, T73, and retrogression and re-aging (RRA) at proper temperature. After heat treatment, several specimens will be corroded by doing immersion in chemical solution corrosion process. But the important thing is we need to record the reading of hardness of each specimen before and after corrosion process. Finally, the specimen will be test by doing fracture toughness test, hardness test, and microstructure observation. The new properties of AA7075 are developing by heat treatment. We can compare the hardness, microstructure of phases and fracture surface and then decide which process is better to improve and build an excellent properties for future application.

ABSTRAK

Tujuan utama kajian ini adalah untuk mengkaji kekuatan kegagalan pada aloi aluminium 7075 (AA7075) yang telah diubahsuai sifat semulajadi melalui kaedah pemanasan haba dan dikenakan kesan pengaratan pada bahan. Seperti yang diketahui umum, sifat asli aluminium adalah lembut, ringan, dan mempunyai ketahanan kesan karat yang tinggi, tetapi memimiliki sifat daya tahan yang lemah. Di dalam kajian ini, AA7075 digunakan sebagai bahan utama kajian. AA7075 dipanaskan untuk mebghasilkan sampel ujikaji yang berlainan suhu, dan masa pemanasan. Selepas proses pemanasan, sampel yang telah siap akan didedahkan pada proses pengaratan melalui kaedah rendaman dalam larutan kimia. Perkara yang penting adalah bacaan kekerasan bahan perlu dicatat sebelum dan selepas proses pengaratan. Akhir sekali, sampel akan dianalisis melalui ujian kekuatan kegagalan, ujian kekerasan, dan pemerhatian struktur bahan. Sifat baru bahan akan dihasilkan melalui kaedah pemanasan haba. Di akhir kajian, kita dapat membuat perbandingan pada sifat kekerasan bahan, susun atur struktur bahan, permukaan kegagalan bahan, dan sifat bahan itu sendiri, yang telah diubahsuai dan akan digunakan untuk aplikasi pada masa akan datang

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LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES

LIST OF ABBREVIATIONS, SYMBOLS, SPECIALIZED NOMENCLATURE

UTeM	-	University Technical Malaysia Malacca
AA7075	-	Aluminum Alloy 7075
RRA	-	Retrogression and Re-Aging Treatments
SCC	-	Stress- Corrosion Cracking
Al	-	Aluminum
Zn	-	Zinc
Mg	-	Magnesium
Cu	-	Copper
FCC	-	Face Centered Cubic
SSSS	-	Supersaturated Solid Solution
GP	-	Guinier-Preston
CT	-	Compact Test
SENB	-	Single Edge Notch Bend
Cl	-	Chloride
SEM	-	Scanning Electron Microscope
UTM	-	Universal Tester Machine
ASTM	-	American Society for Testing and Materials
LEFM	-	Linear-Elastic Fracture Mechanics
EPFM	-	Elastic-Plastic Fracture Mechanics
K_{Ic}	-	Toughness
K	-	Stress Intensity
MPa	-	Mega Pascal
m	-	meter
nm	-	nanometer
^{o}C	-	degree Celsius

LIST OF ABBREVIATIONS, SYMBOLS, SPECIALIZED NOMENCLATURE

EXCO	-	exfoliation corrosion
NaCl	-	sodium chloride
KNO3	-	potassium nitrate
HNO3	-	nitric acid

TABLE OF CONTENTS

CHAPTER 1

INTRODUCTION

In this chapter, it will present briefly about heat treated Aluminum Alloy 7075, and problem that influence on AA7075 in aircraft application. We also briefly explain about the objectives and scope of this research.

1.1 Introduction

Aluminum is soft and lacks strength, but it can be alloyed with small amounts of copper, magnesium, silicon, manganese, and other elements to impart a variety of useful properties. It is much lighter and more corrosion resistant than plain carbon steel, but not as corrosion resistant as pure aluminum. The Aluminum Alloy 7075 (AA7075) in the peak aged heat treatment condition T6 has been widely used for structural applications in many aircraft. T6 temper was produced high strength of AA7075 but poor in corrosion resistant. Corrosion damage is often the reason why 7075-T6 components are replaced in older aircraft. The retrogression and re-aging treatments (RRA) was able to provide good corrosion protection and an excellent of strength (J. P. Auger, 1976). After heat treatment, the property of AA7075 was change in terms of structural, characteristics, and others.

1.2 Problem Statement

On 1988, incident on Boeing 737-200 is on an internal flight in Hawaii suffered sudden structural failure. The mechanism by which fatigue propagates in a structure is the well known crack. Cracks propagate because the geometry of a crack produces a very high concentration of stress at the end of the crack and eventually, if a growing crack goes undetected, fracture will occur. Nearly 6 meters of cabin skin and structure aft of the cabin entrance door and above the passenger floor line separated from the aircraft. The subsequent investigation found that the bonding and fatigue damage which had led to the failure. The aircraft involved had completed 89,680 flight cycles with an average flight time of only 25 minutes, almost all of them in the marine environment of the Hawaiian Islands, where a typical service life which was considered to have allowed corrosion to increase the failure rate. The factors that affect the corrosion behavior included the temperature, pressure, metallurgy, velocity and galvanic effects. In general, corrosion rates increase with increasing temperature or pressure. The retrogression and re-aging treatments can be improving the SCC of Aluminum Alloy 7075 at the same time it can be maintain the mechanical property of T6 temper Aluminum Alloy 7075.

1.3 Objectives

The objectives of this research are to

(a) Investigate the fracture toughness of heat treated AA7075 with effect of corrosion.

(b) Investigate the effect of heat treatment T6 and retrogression and re-aging treatments on fracture toughness.

(c) Correlate the morphological characteristics at Aluminum Alloy 7075 exposed to the different types of heat treatment and corrosion environment to the fracture toughness.

1.4 Scope

The scope and limitation of this project is we only used Aluminum Alloy 7075 as our raw material. We apply heat treatment process by using furnace as our main equipment to complete heating process. For corrosion process, we decide to use Chloride solution to develop corrosion behavior on our material. We use Universal Tester Machine (UTM) to perform fracture toughness test and Vickers Hardness Testing Machine for hardness testing. Finally, we will be used Optical Microscope to complete our investigation on morphology study.

CHAPTER 2

LITERATURE REVIEW

In this chapter, it will present about properties of Aluminum and Aluminum Alloy 7075. We also discuss the effects of different types of heat treatment process that will involve on this research. Besides that, we also discuss about the effect of heat treatment and corrosion into the properties of the material.

2.1 Introduction of Aluminum

Aluminum is a white mineral and an extremely useful metallic element. It is a shiny and silvery metal and ductile member of the boron group of chemical elements. Aluminum atoms are arranged in a FCC structure. Pure aluminum has excellent atmospheric corrosion resistance and is used extensively as cladding materials. It has own protected thin film when it exposed to the air and the surface of the metal reacts with oxygen to form an aluminum oxide coating, preventing further corrosion of the metal. (David R. Lide, CRC Handbook of Chemistry and Physics, 2007)

We can change their properties by doing heat treatment at proper temperature, in terms of strength, corrosion resistance, and their grain size. Aluminum is a relatively light metal compared to other metals such as steel, nickel, brass, and copper.

Table 2.1: Mechanical Properties of Aluminum

Melting Point:	660 °C
Elastic Modulus:	70-79 GPa
Poisson's Ratio:	0.33
Tensile Strength:	230-570 MPa
Yield Strength:	215-505 MPa
Percent Elongation:	10-25%

(Source: alumatter.uk.com)

2.1.1 Aluminum Alloys

Aluminum alloys are mixtures of aluminum with other metals that we called an alloy, which are often with copper, zinc, manganese, silicon, or magnesium. This combination is much lighter and more corrosion resistant than plain carbon steel, but not as corrosion resistant as pure aluminum. Aluminum alloys can be categorized into a number of groups based on the particular material's characteristics such as its ability to respond to thermal and mechanical treatment and the primary alloying element added to the aluminum alloy.

The wrought and cast aluminums have different systems of identification. The wrought system is a 4-digit system and the castings having a 3-digit and 1-decimal place system (Hatch, 1984).

Table 2.2: Alloy Series and Their Principle Alloying Element

Alloy Series	Principal Alloying Element
1xxx	99.000% Minimum Aluminum
2xxx	Copper
3xxx	Manganese
4xxx	Silicon
5xxx	Magnesium
6xxx	Magnesium and Silicon
7xxx	Zinc
8xxx	Other Elements

(Source: Wikipedia.org)

2.1.2 Aluminum Alloy 7075

Aluminum alloy 7075 (AA7075) is one of the highest strength aluminum alloys available. It may be formed in the annealed condition and subsequently heat treated. Aluminum Alloy 7075 defined as wrought aluminum. Introduced in 1943, alloy 7075 has been the standard workhorse series alloy within the aerospace industry ever since. It was the first successful Al-Zn-Mg-Cu high strength alloy using the beneficial effects of the alloying addition of chromium. Although other alloys have since been developed with improved specific properties, AA7075 remains the baseline with a good balance of properties required for aerospace applications.

General 7075 characteristics is very high strength material and used for highly stressed structural parts. This material is used as aircraft fittings, aircraft, aerospace and defense applications. 7075 is widely used for construction of aircraft structures, such as wings and fuselages. Its strength and light weight are also desirable in other fields. These alloys are often used in high performance applications such as aircraft, where a combination of high strength with moderate toughness, light weight, and corrosion resistance are required.

Table 2.3: Combination of Elements of Alloy in Aluminum Alloy 7075

Component	**W.t %**
Al	87.1-91.4
Cr	0.18-0.28
Cu	1.2-2.0
Fe	Max. 0.5
Mg	2.1-2.9
Mn	Max. 0.3
Si	Max. 0.4
Ti	Max. 0.2
Zn	5.1-6.1

(Source: Wikipedia.org)

Table 2.4: Properties of Aluminum Alloy 7075

Terms:	Metric:
Physical Properties	
Density	2.81 g/cm^3
Mechanical Properties	
Hardness, Brinell	60
Hardness, Knoop	80
Hardness, Vickers	68
Ultimate Tensile Strength	228 MPa
Yield Strength	500 MPa
Elongation at Break	17 %
Modulus of Elasticity	71.7 GPa
Shear Modulus	26.9 GPa
Shear Strength	152 MPa
Thermal Properties	
Heat Capacity	0.96 J/g-°C
Melting Point	477 - 635 °C

(Source: Wikipedia.org**)**