UNIVERSITI TEKNIKAL MALAYSIA MELAKA

INVESTIGATION OF DAMAGE PROCESS DUE TO FATIGUE ON HEAT TREATED ALUMINUM 7075

Thesis submitted in accordance with the partial requirements of the Universiti Teknikal Malaysia Melaka for the Bachelor of Manufacturing Engineering (Engineering Material) with Honours

By

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This report is submitted to the faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirement for the degree of Bachelor of Manufacturing Engineering (Material Engineering).

MOHD HAIDIR B. MASLAN

(PSM Supervisor)

DECLARATION

I hereby declare that this report entitled "Investigation of damage process due to fatigue in heat treated Aluminum 7075" is the result of my own research except as cited in the references.

Signature : ……..

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Date : 19th April 2009

ABSTRACT

The objectives of this research are to investigate the damage process due to the fatigue failure on heat treated Aluminum Alloy 7075 on the mechanical properties and microstructures structure. In this research, the aluminum alloy 7075 being used widely in automotive and aircraft industry because of it highest in strength level of all alloy. Besides that, many researches on this material behavior being discuss nowadays because of it important in safety and reliable. In the sample preparation, the aluminum alloy 7075 will be heated to T6 heat treatment process. Then, the RRA process is applied to the material in the T6 condition. The sample will be testing mechanically to investigate the tensile strength, hardness properties and the fatigue damage process to the Aluminum alloy 7075. Here, the result of the damage process will be discussed and at the same time, the surface structure of the fracture process for the fatigue failure also will be observed under optical microscope. From the result, the discussion about microstructure and damage phenomenon that lead to the degradation process of the aluminum alloy 7075-T6 will be covered. Lastly, the conclusion for the whole of the research will be covered based on the observation from the experimental and discussion.

ABSTRAK

Objektif penyelidikan ini adalah untuk mengkaji proses kegagalan disebabkan oleh kelesuan pada proses pemanasan aluminium aloi 7075 dari segi sifat mekanikal dan bentuk mikrostrukturnya. Dalam kajian ini, aluminium aloi 7075 telah digunakan secara meluasnya dalam industri automotif dan kapal terbang disebabkan oleh tahap kekuatan aloi itu. Selain itu, banyak kajian telah dibincangkan terhadap sifat bahan ini sendiri kerana kepentingan di dalam keselamatan dan kebolehpercayaan. Di dalam penyediaan sampel, aluminium aloi 7075 akan dipanaskan kepada proses pemanasan T6. Kemudian proses RRA dikenakan pada bahan dalam keadaan T6 itu. Sampel akan diuji untuk menyiasat tentang kekuatan terikan, sifat kekerasan dan proses kegagalan terhadap aluminium aloi 7075. Selepas itu, keputusan tentang proses kegagalan akan dibincangkan dan pada masa yang sama struktur permukaan untuk kegagalan disebabkan oleh kelesuan akan dikaji dibawah mikroskop. Daripada keputusan itu, perbincangan tentang mikrostruktur dan fenomena kerosakan yang mana mempengaruhi proses kegagalan aluminium aloi 7075 akan di liputi. Akhir sekali, kesimpulan bagi keseluruhan ujikaji ini akan dibuat berdasarkan kepada pemerhatian daripada eksperiment dan perbincangan yang telah dijalankan.

DEDICATION

To my beloved parent, family and friends who have give their attention and help me to finish this thesis.

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LIST OF ABBREVIATIONS, SYMBOLS, SPECIALIZED NOMENCLATURE

A	-Cross sectional area
AA	-Aluminum Alloy
Al	-Aluminum
ASTM	-American Standard Test Method
C^o	-Degree Celsius
Cr	-Chromium
Cu	-Copper
E	-Young Modulus
Fe	-Ferrous
GP	-Guiner Preston Zones
Hr	-Hour
L	-Length
Mg	-Magnesium
Mn	-Manganese
Mpa	-Mega Pascal
N	-Newton
RRA	-Retrogression and Re-ageing
SSSS	-Super Saturated Solid Solution
SHT	-Solution Heat Treatment
T	-Temper
Wt. %	-Weight of percentages
Zn	-Zinc
σ	-Stress
ε	-Strain
η	-Stable $MgZn_2$
η'	- Metastable precipitation

CHAPTER 1
INTRODUCTION

1.1 Background of project

The 7xxx series aluminum alloys have been widely used as structural materials due to their attractive comprehensive properties, such as low density, high strength, ductility, toughness and resistance to fatigue (Feng, 2008). The 7075 aluminum alloy is one of the most important engineering alloys and has been utilized extensively in aircraft structures because of its high strength-to-density ratio. This study have been conducted to understand the fatigue behavior of aluminum alloys and the fatigue process consists of crack initiation and crack propagation to failure. Smooth specimens are usually used to study the crack initiation behavior because fatigue lives are related to the stress and strain quantities.

The choosing of alloy 7075 for this research due to the characteristic itself that has application throughout aircraft and aerospace structures where a combination of high strength will moderate toughness are required. Besides that, many heat treatment and heat practices are available to develop optimum strength, toughness and others desirable characteristics for proper application of aluminum alloy 7075 (Hatch, 1983).

1.2 Background of problem

Currently, aluminum alloy are commonly used in many types of application and most of them are for industry purpose. With the increasing popularity of the application, there are many challenges for the material to stand with other types of new material which have more advantages and opportunities. As we know, the airplane crack was happened long time ago and that is happens because the material properties exchange due to the time and environment factors. The purpose of this project is to investigate damage due fatigue or the degradation of fatigue life in the aluminum alloy 7075 series that used in aircraft application.

1.3 Statement of Problem

Base on this study, several question need to be answer at the end of the topic likes;

- How to investigate the fatigue failure.
- How to determine the growth of crack before it achieved failure.
- How to explain about the steps of crack.
- How to investigate the fatigue microscopic failure.

1.4 Objective

The objectives of this project are to:

- Investigate the effect of heat treatment on the aluminum alloy.
- Know about the degradation of fatigue life.
- Conduct an experiment to determine the fatigue characteristic.

1.5 Scope

The study of this paper covered damage due fatigue of aluminum alloy 70705 that use in the aircraft body. On that damage degradation, an investigation of the fatigue failure, the behavior of fatigue had been studied. The fatigue failure was investigated by compare the drop of young modulus value for each cycle that occurs the elongation of the material. There is limitation for the material because the material that uses to investigate the fatigue failure only aluminum alloys 7075 which prepared by some kind of heat treatment. For tensile test, the yield strength and young‟s modulus had been covered to see about the properties and the condition of the material. Besides that, the studied about the hardness of the aluminum alloy 7075 also covered as a tensile test and fatigue investigation.

1.6 Important of study

This project is an idea to investigate the damage due fatigue and its factor. On the fatigue failure scope, the steps factor that affects the fatigue failure had been studied in detail and what pressure the crack to continue. By doing this research, the factors that affect the fatigue failure will be known and as a result from that, the way to avoid it can be study and research in the future. By doing this project also, the opportunities for the aluminum alloy 7075 to used as a widely application will be maintain as before because this chapter will inform the others user about it weakness and a way to reduce that weakness.

1.7 Thesis Overview

In chapter 1, there are explanation generally about the project that had been research including it background of problems, objective of the project, scope, and the important of study. Next, in chapter 2, the discussion about the data collection for the project was applied. In the data collection there are include about the wrought alloy that used for the project, it alloys composition, the alloy application and properties. Besides that, this chapter also explains about the heat treatment that can apply to the alloy based on their application. For adding issues, this chapter was explaining more specific about the fatigue and it characteristic and also the process of fatigue failure. At the end of this chapter, the discussion about the way how to prevent the failure in the future was done. Moreover, in chapter 3, the research work that done in this field involved many types of experimental like fatigue test, tensile test, hardness test and optical microscope. In this chapter also discuss about the material preparation and used for the test. The material that used in the current experimental investigation was 7075-T6 aluminum alloy. The specimen dimension for each test also discuss in this chapter which consist of it size and dimension parameter. Lastly for this chapter, the discussion about the fatigue exposure that done as the primary result that expected from the experiment was conduct. Then in chapter 4, the result and the discussion about the testing like microstructure observation tensile test, hardness test, and fatigue test were covered. Lastly, the conclusion and recommendation for this thesis were covered.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

This chapter explains about the aluminum alloy and it wrought which will choose to determine the material and heat treatment that used. In this chapter also, there were explanation about 7075 aluminum alloy based on its application and mechanical properties. Besides that, the explain about the term of heat treatment for the aluminum alloy and like basic Aluminum Heat Treatment Designations, Heat Treating T Temper Codes, and H Temper Strain Hardening Codes. Besides that, it was explain about the Quenching, artificial aging, and retrogression and re-ageing (RRA). Moreover, this chapter explains about the fatigue which includes the how the process fatigue happen and what type of force that will allow the process of fatigue. There also explanation about S-N curve and factor that affect the fatigue life. Lastly, this chapter explains about the fatigue failure process and how to design against that fatigue failure.

2.2 Aluminum Alloy

Aluminum alloys is a material that mixtures of aluminum with other metals (called an alloy), often with copper, zinc, manganese, silicon, or magnesium. They are much lighter and more corrosion resistant than plain carbon steel, but not as corrosion resistant as pure aluminum (Sanders, 2001).

Alloy systems are classified by a number system (ANSI) or by names indicating their main alloying constituents (DIN and ISO). Selecting the right alloy for a given application entails considerations of strength, ductility, formability, we ability and corrosion resistance to name a few.

2.2.1 Wrought alloys

The International Alloy Designation System is the most widely accepted naming scheme for wrought alloys. Each alloy is given a four-digit number, where the first digit indicates the major alloying elements.

- 1000 series are essentially pure aluminum with a minimum 99% aluminum content by weight and can be work hardened.
- 2000 series are alloyed with copper, can be precipitation hardened to strengths comparable to steel. Formerly referred to as duralumin, they were once the most common aerospace alloys, but were susceptible to stress corrosion cracking and are increasingly replaced by 7000 series in new designs.
- 3000 series are alloyed with manganese, and can be work-hardened.
- 4000 series are alloyed with silicon. They are also known as silumin.
- 5000 series are alloyed with magnesium; derive most of their strength from work hardening. It is suitable for cryogenic applications and low temperature work. However is susceptible to corrosion above 60°C.

- 6000 series are alloyed with magnesium and silicon, are easy to machine, and can be precipitation-hardened, but not to the high strengths that 2000, and 7000 can reach.
- 7000 series are alloyed with zinc, and can be precipitation hardened to the highest strengths of any aluminum alloy.
- 8000 series is a category mainly used for lithium all.

2.2.2 7075 Aluminum Alloy

It is be introduced in 1943 and has been the standard workhorse 7XXX 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 to develop good stress-corrosion cracking resistance in sheet products. Although other 7XXX alloys have since been developed with improved specific properties, alloy 7075 remains the baseline with a good balance of properties required for aerospace applications. This heat treatable alloy is considered high in strength. Corrosion resistance and machinability is fair. Rated low on workability and welded only by the resistance process. Alloy 7075 is available in bare and alclad sheet and plate product forms in the annealed state as well as several tempers of the T6, T73 and T76 types.

2.2.3 7075 Aluminum Alloy Applications

Alloy 7075 sheet and plate products have application throughout aircraft and aerospace structures where a combination of high strength with moderate toughness and corrosion resistance are required. Typical applications are alclad skin sheet, structural plate components up to 4 inches in thickness and general aluminum aerospace applications.

Besides, it is widely used for construction of aircraft structures, such as wings and fuselages. Because it properties are strength and light weight, alloy 7075 are also desirable in other fields likes rock climbing equipment, bicycle components, and hang glider airframes.

One interesting use for 7075 is in the manufacture of M16 rifle for the American military. It is also commonly used in shafts for lacrosse sticks and due to its strength, low density, thermal properties and its polish ability 7075 is widely used in mould tool manufacture (Sanders, 2001).