UNIVERSITI TEKNIKAL MALAYSIA MELAKA

INVESTIGATION OF SHOT PEENING ON THE FATIGUE STRENGTH OF ALUMINUM ALLOY

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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ABSTRACT

Fatigue life is one of the most important mechanical properties of materials used in industrial application that need to be analyzed. This is because fatigue failures are sudden and occur without warning. Shot peening is a surface treatment process that can increase the fatigue life through incorporating the compressive residual stress on the surface of the component. This study investigates the effect of shot peening on the fatigue life of the 7075-T6 Aluminum alloy. The specimens are in the form of plates and bombarded with stainless steel shots. This study focuses on the effect of the stainless steel ball shot intensity on the resultant compressive residual stress and thus the fatigue life of the Aluminum alloy. Shot peening process increases the surface roughness of the component but this negative effect is compromised because of the significant benefit obtained through the increase in fatigue life. Thus the surface roughness of the specimens was analyzed after the shot peening process. The result shows that surface roughness increases as the shot intensity is increased. Axial Fatigue Test was done to determine the fatigue life. The obtained S-N curve showed that there is considerable increase in fatigue life as the shot intensity is increased. However, the shot intensity cannot be overdone because the bombardment can cause cracks in the surface that act as stress raisers. The obtained result also shows that shot peening accelerates fatigue crack growth if shot peening was executed on specimens with cracks on the surface.

ABSTRAK

Analisis terhadap hayat kelesuan adalah penting kerana ia merupakan sifat mekanikal yang utama bagi bahan kejuruteraan yang diaplikasikan dalam industri. Ini adalah kerana kegagalan kelesuan berlaku dengan tiba-tiba tanpa sebarang tanda awal. Pengepinan Tembakan merupakan proses rawatan permukaan yang dapat meningkatakan hayat kelesuan dengan mengenakan tekanan sisa terhadap sesuatu bahan. Kajian ini akan menjurus kepada kesan tembakan pengepinan terhadap aloi Aluminium 7075 T6. Spesimen ujian adalah berbentuk bongkah dengan ketebalan 5mm dan dihentam dengan bebola besi nirkarat sebagai medium tembakan pengepinan. Proses tembakan pengepinan meningkatkan kekasaran permukaan bahan uji. Maka, ujian kekasaran permukaan dijalankan untuk menguji tahap kemerosotan permukaan. Keputusan ujian kekasaran permukaan menunjukkan kekasaran permukaan meningkat sejajar dengan peningkatan tekanan penghentaman bebola nirkarat terhadap bahan uji. Ujian kelesuan paksi telah dijalankan terhadap bahan uji yang telah melalui proses tembakan pengepinan. Lengkung S-N yang diperolehi melalui ujian kelesuan sepaksi menunjukkan bahawa hayat kelesuan bertambah sekiranya tekanan penghentaman ditingkatkan. Walau bagaimanapun, bahan uji yang digunakan perlu dipastikan bebas daripada sebarang rekahan kerana berdasarkan keputusan ujian yang diperolehi, bahan uji yang mempunyai rekah sebelum proses pengepinan tembakan akan gagal dengan kadar yang lebih laju berbanding dengan yang tidak melalui proses tembakan pengepinan.

DEDICATION

I would like to dedicate this report to my loving mother, even more loving father and cheeky sister.

I am what I am because of them..

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TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

T6	-	Heat treatment; Solution heat treated and then artificially aged
Al	-	Aluminum
MPa	-	Mega Pascal
ksi	-	kilo-pound-force per square inch
psi	-	pound-force per square inch
min	-	minimum
N_t	-	The total fatigue life
N_i	-	Initiation life
N_p	-	Fatigue-crack-propagation life
R_a	-	Arithmetic Average Roughness
PSM	-	Projek Sarjana Muda

CHAPTER 1

INTRODUCTION

1.1 Background

The advance needs and requirements of technology and demand for quality material in structures has urged for many new manufacturing processes and methods for improving the physical and mechanical properties of materials. Many new materials with enhanced properties are also developed to cater for the increasing design requirement of the new age engineering usage and applications.

Among the new materials, 7000 series wrought Aluminum alloys and 2024 Aluminum alloys are used for structural applications because of their combination of high fatigue strength, stress-corrosion cracking resistance and toughness. The main usage of the 7000 series aluminum alloys are in aircraft structures especially the 7075 alloy which has been chosen for this study. Although 7075-T6 is stronger than 2024, it is more sensitive to notches and has a higher fatigue-crack propagation rate. However, structures designed and fabricated in 7075-T6 have somewhat less weight than in a 2024 structure having equivalent performance. (Carvalho, 2006). Due to the extended usage of Aluminum alloy, further research needs to be done.

Fatigue is important as it is the single largest cause of failure in metals, estimated to comprise approximately 90% of all metallic failures; polymers and ceramics (except for glasses) are also susceptible to this type of failure. Fatigue is the process of cumulative damage that is caused by repeated fluctuating loads and in the presence of aggressive environment. Fatigue failure is so named because of the nature of the failure that occurs after a prolonged period of cyclic stress or strain subjection (Callister, 2006).

Studies of the basic structural changes that occur when a metal is subjected to cyclic stress have found it convenient to divide the fatigue process into the following stages (Dieter, 1988):

1. Crack initiation
2. Slip-band crack growth
3. Crack growth on planes of high tensile stress
4. Ultimate ductile fracture

To improve the fatigue strength of the aluminum alloys, many methods are being used and researched among which are hot burnishing, chromium electroplating and shot peening. This study will be focusing on shot peening. One of the known ways to improve fatigue strength is by using shot peening process (Carvalho, 2006).

The crack initiation on a surface is very much influenced by the residual stress level near the surface. In shot peening, the workpiece surface is hit repeatedly with a large number of cast steel, glass, or ceramic shot (small balls), which make overlapping indentations on the surface. This shot process is done under certain pressure.

This research is conducted to investigate the affect of compressive residual stress that forms as a result of shot peening process on the fatigue life of Aluminum alloy. The evaluations are defined from the objectives of the experiment. The findings of this study will show that the fatigue life of aluminum alloy is increased through the implementation of the shot peening process.

1.2 Problem Statement

Repetitive or cyclic stress on a certain member causes it to fail in a stress level much lower than the stress level it can withstand under a static load. This is called fatigue failure and it has become a common problem today in automobiles, aircrafts and compressors that particularly use aluminum alloy because of its light weight and less corrosive properties. Huge amount of money is lost when equipments fail due to fatigue. Shot peening process is thus studied in detail to avoid this problem.

Although shot peening does improve fatigue life, when overdone, it brings reversed effect, where the dimples embedded through the bombardment of the shots can accelerate crack propagation (Carvalho, 2006). Thus the intensity of the shot peening process has to be studied

A side effect of shot peening is the increase in surface roughness. Besides acting as stress concentrators, increased surface roughness also increase friction in mating parts such as gears and shafts and lead to high wear rate.

1.3 Objectives

The objectives of carrying out this project are:

i. To study the fatigue failure of aluminum alloy after the shot peening process.
ii. To analyze the fatigue failure for different shot intensities by altering pressure level.
iii. To study the surface roughness of specimen after subjected to shot peening process.

1.4 Scope

This study is an experimental study on the effect of shot peening on fatigue life of 7075 T6 Aluminum alloy . The shot peening process is carried out in 3 different shot intensities.. The axial fatigue test is done on plate specimens with continuous radius between ends complying to ASTM E 466-96. The surface roughness is also measured before and after the shot peening process to analyze the extend of surface damage induced by the shot peening process. The shot media used is stainless steel shots with 90µm diameter with the shot distance of 6 inches. The total specimens that would be tested are nine specimens, where three specimens would be considered as 1 set. Thus a total of 3 sets of specimen would be tested. All three specimens in one set would be subjected to the same shot intensity during the shot peening process. These specimens are then tested at 3 different fatigue loads to obtain an S-N curve. Other parameters such as the standoff distance, the diameter of the stainless steel shots and the diameter of the nozzle are kept constant.

1.5 Structure of Study

This study would be segregated into few chapters. The structure of the study is described below:

a) Chapter 1: Introduction

This chapter covers the background of the fatigue failure and aluminum alloy, the objectives of study, problem statement, scope of study and the structure of the study.

b) Chapter 2: Literature Review

This chapter explains Aluminum alloy in common and then describes the 7075-T6 alloy in particular. The fatigue of metals is also covered along with the fatigue testing methods. Shot peening process is described and the fatigue life enhancement through shot peening is also covered.

c) Chapter 3: Methodology

Generally, this chapter covers the process flow for the whole study. The shot peening process is explained in detail along with the rotary bending fatigue test.

d) Chapter 4: Results and Discussion

The findings obtained through the experiments run according to Chapter 3 are discussed in this chapter. The result of surface roughness measurement and the S-N curve obtained from the axial fatigue test is discussed in detail.

e) :Chapter 5: Conclusion and Recommendations

The findings of the study are concluded in this chapter. The conclusion would project to the objective of this study. A few recommendations are also given in this chapter on techniques for further study of the shot peening process.

CHAPTER 2

LITERATURE REVIEW

2.1 Aluminum and its Alloys

Recent attention has been given to alloys of aluminum and other low density metals as engineering materials for transportation, to affect reductions on fuel consumption. An important characteristic of these materials is specific strength, which is quantified by the tensile strength-specific gravity ratio. Aluminum alloys have relatively low densities in comparison to a more dense material (such as steel), nevertheless, on a weight basis it will be able to sustain larger load (Callister, 2006).

Aluminum is a non ferrous material with FCC crystal structure. It has many superior properties such as high electrical and thermal conductivity and resistance to corrosion in common environments including, ambient environment. Pure aluminum is too soft for most structural applications and therefore is usually alloyed with several elements to improve its corrosion resistance, inhibit grain growth and increase the strength. The optimum strengthening of aluminum is achieved by alloying and heat treatment that promote the formation of small, hard precipitates which interfere with the motion of dislocations.

Aluminum alloys that can be heat treated to form these precipitates are considered heat treatable alloys. Aluminum is usually formed by virtue of high ductility; this is evidenced by the thin foil sheet into which the relatively pure material maybe rolled. The main limitation of aluminum is its low melting temperature 660°C, which restricts the maximum temperature at which it can be, used (Callister, 2006). Nearly all high voltage transmissions wiring is made of aluminum. In its structural loading (load bearing) components, 82% of a Boeing 747 aircraft and 79% of Boeing 757 aircraft is aluminum (Kalpakjian, 2001). Properties of selected aluminum alloys at room temperature are shown in Table 2.1.

Table 2.1: Properties of Aluminum Alloys at Room Temperature (Kalpakjian, 2001).

Alloy (UNS)	Temper	Ultimate Tensile Strength (MPa)	Yield Strength (MPa)
1100 (A91100)	O	90	35
1100	H14	125	120
2024 (A92024)	O	190	75
2024	T4	470	325
3003 (A93003)	O	110	40
3003	H14	150	145
5052 (A95052)	O	190	90
5052	H34	260	215
6061 (A96061)	O	125	55
6061	T6	310	275
7075 (A97075)	O	230	105
7075	T6	570	500

Several processes can be made upon aluminum to increase mechanical properties which include cold working and alloying. But these processes can reduce the resistance to corrosion. Elements that are usually alloyed into aluminum include copper, magnesium, silicone, manganese and zinc. Generally, aluminum alloys are classified as cast or wrought (Callister, 2006). Since this study is focusing on 7075 alloy which is a wrought aluminum alloy, the cast aluminum alloy would not be discussed further.

2.1.1 Wrought Aluminum Alloys

Aluminum alloys produced in the wrought form (i.e. sheet, plate, extrusions, rod and wire). A four-digit number that corresponds to a specific alloying element combination usually designates wrought aluminum alloys. The first digit indicates the alloy group that contains specific alloying elements. The last two digits identify the aluminum alloy or indicate the aluminum purity (Smith, 2004). Table 2.2 shows the numbering of wrought aluminum alloys corresponding to the major alloying element.

Table 2.2: Wrought Aluminum Alloy Groups (Smith, 2004).

Aluminum, 99.00% minimum and greater	1XXX
Aluminum alloys grouped by major alloying elements:	
Copper	2XXX
Manganese	3XXX
Silicon	4XXX
Magnesium	5XXX
Magnesium and silicon	6XXX
Zinc	7XXX
Other elements	8XXX
Unused series	9XXX

To develop strength, heat-treatable wrought alloys go through various heat treatments. During heat treatment, the aluminum alloys are solution heat treated, then quenched and precipitation hardened. Solution heat treatment consists of heating the metal, holding at that elevated temperature to bring the hardening constituents into solution, then cooling to retain those constituents in solution. Precipitation hardening after solution heat treatment increases strength and hardness of these alloys (Smith, 2004).

While some alloys age at room temperature, others require precipitation heat treatment at an elevated temperature (artificial aging) for optimum properties. Aging is where the Aluminum alloys are reheated and maintained at the proper tempering temperature to increase strength. However, distortion and dimensional changes during natural or artificial aging can be significant. In addition, distortion and residual stresses can be introduced during quenching from the solution heat-treatment cycle. These induced changes can be removed by deforming the metal (for example, stretching).