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INVESTIGATION OF THE FATIGUE LIFE FOR THE AA7001-T6 AT DIFFERENT TEMPERATURES UNDER VARIABLE LOADING

A thesis Submitted to the Council of College of Engineering, University of Diyala in Partial Fulfillment of the Requirements for the Degree of Master of Science in Mechanical Engineering

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بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

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COMMITTEE DECISION

We certify that we have read the thesis/ dissertation titled (**Investigation of the Fatigue Life for the AA7001-T6 at Different Temperatures under Variable Loading**) and we have examined the student (**Huda Salih Mahdi**) in its content and what is related to it, and in our opinion it is adequate as a thesis for the **Degree of Master of Science in Mechanical Engineering.**

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Date: / / 2023

Dedication

First and foremost, I Dedicate this effort that lasted months of unrivaled continuous work. I dedicate my success to my **Lord**, **the Greatest**, who included me with his care and compassion, who gave me countless blessings and more than I deserved.

Blessings were the reason for my success in life and this humble effort in particular. **Allah** gave me wonderful parents.

To my Beloved **family and friends**, their presence gave me the strength that guided me all the way through.

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ABSTRACT

Aluminum alloys are being utilized increasingly often in the automotive, transportation, marine, and aerospace industries. Due to their superior strength, resistance to wear, and fatigue resistance, The main goal of this study is to obtain experimentally the fatigue life of the selected alloy under different conditions fatigue life under elevated temperatures and variable loading the mechanical characteristics of AA7001-T6, including ultimate tensile stress (UTS), yield stress (YS), Young modulus (E), and ductility, the reduction percentages were recorded to be 37%, 37.2%, and 24% respectively while the ductility increased by 28.57%. Fatigue interaction have a large effect on fatigue strength and life. The endurance fatigue limit was recorded to 208 Mpa at 25°C and reduced to 184 Mpa at 330°C, about an 11.5% reduction occurred. Shot peening reduced the percentage to 32.2% and 36.7%, respectively. Shot peening treatment increased the improved fatigue limit at 330 °C from 217 MPa to 229 MPa, 5.24% improvement. The endurance fatigue limit (fatigue strength) was found to be 229 MPa at RT, but it increased to 237 MPa as a result of SP 3.37%. The cumulative fatigue damage under rotating bending loading and the stress ratio R = -1 were calculated. The experiments were carried out at (25°C), (330°C), and (SP+330°C), respectively. Use a modified damage stress model that has been developed to account for damage at different load levels to forecast the fatigue life under high temperatures. the output of the model was compared to experimental results as well as to an output from the fatigue damage model that was used to determine the greatest damage (Miner's rule). The results of the two models one for low-high loading and the other for high-low loading were suitable for extending fatigue life.

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LIST of ABBREVIATIONS

Abbreviations	Explanation	Unit
LCF	Low Cycle Fatigue	
Al	Aluminum	
AA	Aluminum Alloy	
FEA	Finite Element Analysis	
LSP	Laser Shock Peening	

SP	Shot Peening	
RT	Room Temperature	℃
CFET	Creep Fatigue Elevated Temperature	
CAF	Constant Amplitude Fatigue	
VAF	Variable Amplitude Fatigue	
MTS	Material Testing Systems	
FLRF	Fatigue Life Reduction Factor	
UIP	Ultrasonic Impact Treatment	
CNC	Computer Numerically Controlled	
UOT	University of Technology	
ASTM	American Society for Testing and Materials	
DIN	Deutsches Institut für Normung	
UTS	Ultimate Tensile Strength	MPa
YS	Yield Strength	MPa
E	Modulus of Elasticity	N/m^2
D	Ductility	%
CRS	Compressive Residual Stresses	
VL	Variable Loading	
C1, M	Material Constants	
L	Beam Length	mm

LIST of SYMBOLS

Symbols	Definition	Unit
σ_{max}	Maximum Tensile Stress	MPa
σ_{min}	Minimum Compressive Stress	MPa
$\Delta\sigma$	Simply the Difference between σ_{max} and σ_{min} Normally	MPa
R	The Ratio of Minimum and Maximum Stress	
σ_e	Endurance Limit	MPa
σ_u	Ultimate Tensile Strength	MPa
σ_1 , σ_2	Applied Stress	MPa
f_1 , f_2	Damage Histories in the Provide Stages	
N	Number of Cycles	Cycle
Ai	Variable Quantity Related to the ith Loading Level	
σ_f	Applied Stress at Failure	MPa
N_f	Fatigue Life at Failure	Cycles
α	Material Constant	
A	Material Constant	
X	Applied Load	N
$\boldsymbol{\beta}$	Inverted Slope of the S-N Curve	
D	Damage	

Chapter One

Introduction

CHAPTER ONE

INTRODUCTION

1.1 Preface

Aluminum alloys have been increasingly popular in recent years because of their great corrosion resistance and excellent weight-to-strength ratio. Wrought aluminum alloys are particularly popular in the aircraft, automobile, marine, and construction industries. Despite aluminum alloys' very strong corrosion resistance in chloride environments, localized corrosion does occur on occasion. Further surface treatment and protection of machine parts is necessary to extend their service life. Shot peening impact treatment has received a lot of attention in recent years due to its ability to increase both mechanical properties and corrosion resistance [1].

At high temperatures, the fatigue behavior of aluminum alloys is investigated. Fatigue failure is a common failure mode when a cyclic charge is applied to the machine element. Aluminum alloys have been widely employed in a variety of sectors, including transportation, aviation, and minor manufacturing, due to their non-corrosive characteristics and lightweight. The fatigue strength of the aluminum alloy 2024-T4 at higher temperatures is found to be diminished by a factor of 1.2–1.4 when compared to its dry fatigue strength. At both low and high temperatures, this aluminum alloy's fatigue behavior is studied[2].

1.2 Aluminum and Aluminum Alloys

Materials are now more effective than they were decades ago, and new forms have significantly advanced science and technology. Without the application of increasingly effective materials, advances in physics and technology are challenging. Researchers are always learning about, investigating, and experimenting with new, cutting-edge materials in the field of technology. Additionally, the requisite scientific investigation into the aspects influencing and improving mechanical qualities has been conducted [3]. The strongest alloys are commercial heat-treatable aluminum alloys from the 7xxx class, which have the maximum strength among them. It also has a passable resistance to corrosion. Aircraft manufacturing companies have a significant demand for this alloy for structural components and other highly stressed applications [4]. it has become increasingly important to enhance these alloys' mechanical characteristics. Actually, this has been accomplished by a number of studies in this field. By combining several nanomaterial's in specific ratios, With the anticipated increase in aluminum use in various applications where high strength and low weight are required, improving wear resistance is now urgently needed [5]. One of the aluminum alloys with silicon and magnesium is called A6061. Plates, circular bars, and pipes are the most common shapes of A6061. Light structures, machine parts, rail transit parts, and airplane structures are all frequently made with it [6].

1.3 Fatigue

Fatigue is defined as the gradual loss of a material or structural component's strength, allowing failure to occur at significantly lower stress rates than the ultimate load. An estimated 90% of all mechanical service failures are attributed to fatigue. As we've seen, fatigue is a complicated phenomenon that starts as tiny (micro) cracks in a material or component and leads them to grow into much larger (macro) fissures; if they are left unnoticed, they could cause catastrophic failure. Damage to tiredness may be caused by a variety of factors. Cyclical fatigue is brought on by often fluctuating loads. Corrosion fatigue is a type of fatigue brought on by internal corrosion that permeates the material's surface and reduces structural strength. Thermal fatigue is brought on by stress variations brought on by thermal expansions and contractions, whereas fretting fatigue is induced by little rubbing motions and the abrasion of nearby components[7].

1.4 Fatigue Interaction

All Engineering Components exposed to increased loading temperature and may be sensitive to damage effects in quasi-static loadings and to damage effects in cyclic loadings. All metallic materials and polymers share this characteristic. According to the lifespan, these impacts can be divided into

- Short-range impacts in rocket components where the lifetime is a few minutes or in the metallurgy of coating the steel ladles steel fabrication with a lifespan of only 200 to 500 service hours.
- Medium-range effects in gas turbines found in automobiles or airplane engines with lifetimes of between 5000 and 10,000 hours.
- large-scale effects in the chemistry sector and in thermal or nuclear power facilities with lifetimes of between 10 and 50 years[8].

The majority of engineering components that operate at high temperatures under cyclic loading fail due to a complex process that includes not only fatigue but also creep and the influence of hostile surroundings. These procedures might function alone or jointly. While fatigue damage is brought on by cyclic stress and is predominantly influenced by time-independent plastic strain, creep damage is a time-dependent process that is primarily influenced by the component's history of applied stress and temperature. When the two damage factors cooperate, there is a creep and fatigue interaction[9].

1.5 Shot Peening

Shot peening is a cold work technique that incorporates residual compressive stresses of materials on the surface to reinforce mechanical properties. With enough force, a shot of glass, ceramic, or metallic rounding is fired, deforming the specimen's surface in a way known as plastic deformation. The remaining compressive stress is produced in a peened surface by plastic deformation, tensile stress, and internal tension. As the tensile stress on the surface is not a significant problem, the tensile stress within the component is not a significant issue because cracks typically do not begin in the interior. In aircraft repair, shot peening is necessary to alleviate tensile stresses created during the grinding process and swap them out for advantageous compressive stresses. Shot peening will extend fatigue life by 0–1000%, depending on the part's material composition, geometry, and shot material type. Shot intensity, shot quality, and shot coverage depends on the type of material used for the part[10].

1.6 Problem Statement

In view, the exposure of aluminum alloys to high temperatures during their use affects the mechanical properties of these alloys and thus loses their service life, and to extend this life only, use (Shot Peening) as a means to improve the surfaces of this alloy and thus increase its operational life.

1.7 Objective of the Research

The main goal of this study is to obtain experimentally the fatigue life of the selected alloy under different conditions fatigue life under high temperature and variable loading.

1.8 Thesis Outline:

This thesis consists of six chapters they are :

- **Chapter One: Introduction**

This chapter explains the general concepts of the whole project and the aim of the study.

- **Chapter Two: Literature Survey**

This chapter introduces the literature review on fatigue, the summary of this literature, and the position of the current research from previous studies.

- **Chapter Three: Theoretical Considerations**

This chapter presents the theoretical concept, some fatigue theories, and models, the proposed damage model of the present work, and a summary of theories and models.

- **Chapter Four: Experimental Work**

This chapter illustrates the plan of the work, the description of specimen geometry, and the mechanical properties of the materials used.

Chapter Five: Results and Discussion

This chapter contains the experimental and theoretical results and their discussion.

- **Chapter Six**: **Conclusions and Recommendations**

This chapter reveals the important remarks of the project and suggestions for future work.