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CORROSION-BUCKLING INTERACTION OF 2014-T4 ALUMINUM ALLOY UNDER SHOT PEENING AND ULTRASONIC TREATMENTS

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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بسم الله الرحمن الرحيم

﴿ اقْرَأْ بِاسْمِ رَبِّكَ الَّذِي خَلَقَ (1) خَلَقَ الْإِنْسَانَ مِنْ عَلَقٍ (2) اقْرَأْ وَرَبُّكَ الْأَكْرَمُ (3) الَّذِي عَلَّمَ بِالْقَلَمِ (4) عَلَّمَ الْإِنْسَانَ مَا لَمْ يَعْلَمْ(5) ﴾

سورة العلق

الاية (1-5)

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We certify that we have read the thesis/ dissertation titled (**Corrosion-Buckling Interaction of 2014-T4 Aluminum Alloy under Shot Peening and Ultrasonic Treatments**) and we have examined the student (**Salam Nihad Naji**) in its content and what is related with 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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The thesis was ratified at the Council of College of Engineering/University of Diyala.

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Date: / / 2020

DEDICATION

I dedicate this work to ….

My parents and brothers

My friends

Whom supported me

With their

Love, Care, and Prayers

Acknowledgement

Above of all, I would like to express my deeply thanks to the Almighty, **ALLAH**, for His generosity and guidance, and without Him I cannot even begin with this work. Secondly, I would like to thank, our prophet **MUHAMMAD** (peace be upon him and his family).

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ABSTRACT

The present work involves the corrosion buckling interaction behavior of 2014-T4 aluminum alloy with corroded time of 120 days. The effects of shot peening (SP) combined with ultrasonic impact treatment (UIT) on the surface properties of 2014-T4 aluminum alloy were investigated based on mechanical properties and hardness. Comparison between the corroded columns in (soil and water) with as received columns before and after (SP+UIT) is achieved. Euler, Johnson, Peery-Robertson, Rankine, and ANSYS (V.18) formulas are used to evaluate the experimental results. The behavior of the axial compressive buckling column has been studied experimentally, theoretically and numerically. Comparison is made between the above classical theories methods and experimental results for both long and intermediate columns. SP and UIT surface treatment techniques are used and provide suitable methods to improve the mechanical and buckling properties of both long and intermediate columns of AA 2014-T4. Test results for mechanical properties show that after (SP+UIT), the mechanical properties (ultimate tensile strength (UTS) and yield stress (YS)) are noticeably improved. The improvements in UTS and YS are (2.84%, 3.07%), (2.42%, 2.87%), and (2.39%, 3.17%) for as received at (RT), soil corrosion (SC), and water corrosion (WC) respectively. The critical buckling loads ($P_{cr)}$ where reduced under corrosion media for both water corrosion (WC) and soil corrosion (SC). The reduction percentage (R%) of (WC) was (6.24%) and (10.1%) for (SC) for long columns. But (R%) for intermediate columns was (3.16%) for (WC) and (4.77%) for (SC). The results showed that (Euler, Johnson, Perry Robertson and Rankine) formulas give a good agreement with experimental results with factor of deviation of (1.8), (2.5), (1.5), and (1) and (1.8), (2.4), (1.5), and (1) for long and intermediate columns before and after (SP+UIT) respectively. While for ANSYS it was (2.2) and (2.7) before (SP+UIT) for long and intermediate columns respectively, and (1.9) and (2.7) after (SP+UIT) for long and intermediate columns respectively.

TABLE OF CONTENTS

Chapter V: Results and Discussions

Chapter VI: Conclusions and Suggestions

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

Abbreviations	Meaning	Unit
σ_{comp}	Critical Buckling Stress	MPa
σ_{cr}	Ultimate Stress	MPa
σ_{y}	Yield Stress	MPa
δ_{in}	Initial Deflection of Column	mm
δ_{cr}	Critical Deflection of Column	mm
ω	Angular velocity	rad/sec

LIST OF ABBREVIATIONS

Symbol	Definition	Units
A	Cross – sectional area	mm^2
C_c	Column constant	
d	diameter of hydraulic pump delivery rod	mm
D	Diameter of column	mm
E	Modulus of elasticity	GPa
F_{comp}	Applied compression load on column	N
DF	Deviation Factor	
G	Modulus of rigidity	GPa
I	Moment of inertia of cross section	mm^4
K	End-fixity factor	
L	Length of column	mm
L_e	Effective length of column	mm
P_{cr}	Critical buckling load	N
$P_{exp.}$	Experimental critical buckling load	N
r	Radius of gyration	mm
SR	Slenderness Ratio	
APDL	ANSYS Parametric Design Language	
ASM	American Society for Metals	
FEM	Finite Element Modeling	
ASTM	American Society for Testing and Materials	
D	Dry	
WC	Water Corrosion	
SC	Soil Corrosion	
FEA	Finite Element Analysis	
R %	Reduction percentage	
RS	Residual stresses	
CRS	Compressive Residual stresses	
RT	Room temperature	C°
AA	Aluminum alloy	
YS	Yield strength	MPa
UTS	Ultimate tensile strength	MPa
SP	Shot peening	
UIT	Ultrasonic impact treatment	

CHAPTER ONE
INTRODUCTION

1.1 Introduction

Stability is one of the critical limit states for structures during construction and through their service life. One of the difficult challenges in the stability of the structure is determining the critical load under which the structure breakdown due to loss of the stability, this is because of the complexity of this phenomenon and the many properties of the material that are affected by geometric, material imperfections and material nonlinearity [1].

Failures because of the instability phenomena can occur suddenly and may cause the whole structure to breakdown. It's therefore in the engineer's interest to have good knowledge about this phenomenon. Column buckling is one of the most common examples of instability phenomena [2].

Structural failure due to buckling is still of interest to researchers. Study the buckling behavior of the columns is an important step to understanding and evaluating the reliability of the structures that have more complex designs [3].

The column is a structural member that experiencing compressive loading at one end, the dimensions of the cross-section are considerably smaller than the length that will be the direction in which the load is applied. Buckling is the phenomenon that occurs when a column is subjected to an axial load and deflects because of the loading that is big enough. Buckling failure happens mainly to the loads that are smaller than the yield strength. For engineers it is very important to predict the buckling levels due to how dangerous, destructive and sudden it can occur. The critical load of the column is defined as the maximum axial load that the column can support before its failure [4].

Structures can fail due to a number of conditions such as when members or the complete structure reach yield or ultimate strength, override the maximum deflection, or when fracture of members or collapse happens. Buckling is a broad term that describes several of mechanical behaviors, it is generally referred to an event whereby a structural element in compression deviates from a behavior of elastic shortening within the original geometry and undergoes large deformations involving a change in member shape for a very small increase in load [5].

Buckling phenomenon can be described as bending of structural members under axial compressive load. Columns are slender members that support the axial compressive load. If the compressive load excessive, a column may fail due to the instability of the structure called buckling. Hence, the problem of the buckling of the columns is a very important issue. Underestimation of this effect may lead to disastrous results or unjustified factors of safety [6].

Calculating the stability of the structures has always been important engineering attention. Especially the estimation of the critical buckling load of the structure has been a subject for study since Euler in 1744 calculated the critical buckling load for the simply supported column. Buckling can be defined as the phenomenon, where the construction changes from an equilibrium status to another one suddenly. It is very important to evaluate the buckling loads of the structure, because of the possibility of the sudden failure of the structure, if the critical load is reached. Some members of the structure might lose stability when reached the buckling load [7].

The increasing growth in use of the aluminum alloy in the structural application due to its several advantages over conventional carbon steel, good strength to weight ratio, satisfactory corrosion resistance, and excellent formability, it also offers low maintenance costs, comparable ease of manufacture and superior aesthetics [8].

Corrosion is defined as the degradation of the material due to the reaction with its environment. Degradation means deterioration of the physical properties of the material. This can be affected negatively the material due to a loss of cross-sectional area, it can be destroying the metal due to hydrogen embrittlement. The corrosion is dominant in offshore and marine structures because of the well-known fact that the water of the sea is an aggressive corrosive environment [9].

Elements of many structures are exposed not only to loads and temperatures, but also to a various corrosive environment. These factors often appear in bad combinations, reducing the load carrying capacity and the service life of the structure. Neglecting the corrosive environments in the analysis may lead to premature and often emergent stopping of the system operation, causing a big damage to the environment and economy [10].

1.2 Problem Statement

Buckling is one of the important subjects studied by researchers since Leonhard Euler in 1744 till now. Many structures are exposed to a corrosive environment (when members buried in soil or immersed in water), members of the structure will affect negatively and decrease their resistance to the critical loads and increase the chance of buckling and may lead to the collapse of the whole structure. Therefore, it was necessary to study the buckling loads of the long and intermediate columns without corrosion (Dry), further to study the effect of the water corrosion (WC) and soil corrosion (SC) on these columns when it is exposed to these corrosive environments for a period of time. With an opportunity of the suitable formula to be more compatible with the experimental results and approved in the future for researchers and engineers.

1.3 Objectives of the Study

The objectives of this research work are:

1) Investigating the buckling behavior of the column with the fixed-pinned state.

2) Investigating the influence of the corrosion (WC and SC of 120 days) on the buckling behavior of AA 2014-T4 specimens.

3) Investigating the effect of the surface treatments (SP and UIT) on the buckling behavior of AA 2014-T4 specimens.

4) Measuring the initial deflection of AA 2014-T4 columns by using a digital dial gauge indicator.

5) Theoretically, using (Euler, Johnson, Perry, and Rankine) formulas to estimate the critical load of the columns.

6) Numerically, using ANSYS 18.2 (APDL), to evaluate the buckling load.

7) Comparing between the results obtained experimentally with the formulas of Euler, Johnson, Perry, Rankine, and ANSYS with a statement of which formula is more acceptable with the practical results.

8) Determining the deviation factor for the five methods that allow to design a column can resist buckling load without referring to the practical work.

1.4 The Layout of the Study

Chapter (1) consists of an introduction of the thesis and the basic reason of the study, including the purpose and objectives of the present work.

Chapter (2) presents a survey of the published works regarding the buckling behavior of the column and the effects of corrosion. Also, the influence of the surface treatments on the mechanical properties of the material.

Chapter (3) includes the theoretical considerations of buckling phenomenon under axial compression load and the influence of corrosion on buckling resistance of the specimens. Also, buckling theories (Euler, Johnson, Perry, Rankine, and ANSYS) are presented.

Chapter (4) introduces the experimental work regarding the buckling of columns without and with corrosion, and before and after (SP+UIT).

Chapter (5) includes the theoretical and experimental results with their discussion.

Chapter (6) presents conclusions, also suggestions for works in the future.