IMPROVEMENT OF MECHANICAL PROPERTIES OF ALUMINUM ALLOY BY ARTIFICIAL AGING TREATMENT FOR STRUCTURAL APPLICATION IN AUTOMOBILE

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I admit that have read this report and to my opinion this report fulfill in terms of scope and quality for the Bachelor of Mechanical Engineering (Design & Innovation).

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This report is submitted in partial fulfillment of the requirement for the Bachelor of Mechanical Engineering (Design & Innovation)

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I hereby declare that this project report is written by me and is my own effort and that no part has been plagiarized without citations.

Signature	: ………………………..
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Date	: ………………………..

For my beloved mother, Nor Haziah Bte Mohd Ali Hanapiah and my beloved father, Mohd Azhari B. Hj. Mohd Awal.

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ABSTRACT

The growing demand for more fuel efficient vehicles to reduce energy consumption and air pollution is a challenge for the automotive industry. The best way to increase fuel efficiency without sacrificing safety is to employ aluminum alloy in the body of cars due to its higher strengths to weight ratio than those of conventional steel. Aluminum Alloy 6061 T4 was selected as a material for this study. The re-solution heat treatment followed by artificial aging as well as natural aging was carried out at different conditions in terms of artificial aging temperature and times. Charpy impact testing and Brinell hardness testing were performed in order to study and analyze the energy absorption and the strength Aluminum alloy respectively. SEM and optical microscope were used to observe the microstructure characterization of heat treatment and artificial aging aluminum alloy. The particular strength of this study is in providing insight into the current use of aluminum alloy and its future potential in car manufacture.

ABSTRAK

Permintaan terhadap kenderaan yang lebih efisien dalam penggunaan minyak dan pencemaran udara adalah semakin tinggi dan memberi satu cabaran untuk industri automotif. Jalan terbaik untuk menambah kecekapan bahan api tanpa mengabaikan keselamatan pengguna ialah dengan menggantikan bahan asal iaitu keluli konvensional dengan aluminum aloi untuk membuat badan sebuah kenderaan disebabkan oleh kekuatan aluminum aloi yang lebih tinggi dan purata berat yang lebih rendah daripada keluli konvensional. Dalam laporan ini, aluminum aloi telah dikaji untuk mengukuhkannya kerana aluminum aloi ini telah banyak digunakan dalam industri-industri automotif. Aluminum aloi 6061 T4 telah digunakan dalam kajian ini. Kaedah rawatan haba dan diikuti penuaan tiruan serta penuaan semulajadi telah dijalankan pada keadaan yang berbeza-beza mengikut langkah-langkah yang telah ditetapkan. Dengan memahami sepenuhnya tentang kekuatan dan kekerasan aluminum aloi 6061 T4, charpy ujian kesan Charpy dan ujian kekerasan Brinell telah digunakan dengan tujuan menganalisis penyerapan tenaga dan kesan suhu. Daripada keputusan-keputusan, aluminum aloi yang menjalani penuaan tiruan dibanding dengan aluminum aloi menjalani penuaan semula jadi. SEM dan mikroskop optik digunakan untuk memerhati pencirian mikrostruktur rawatan haba dan penuaan tiruan aluminum aloi. Hasil daripada kajian ini menyediakan pengetahuan mengenai kekuatan dan keupayaan aluminum aloi yang bakal digunakan dalam pengeluaran kereta di masa akan datang.

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LIST OF SYMBOLS

v	= velocity, m/s.
g	= acceleration of gravity, 9.81 m/s^2
h	= initial elevation of the striker, m
h	= initial elevation of the striker, m.
S	= length of the pendulum distance to the center of strike, m.
β	= angle of fall, m
H	= height of rise, m
α	= angle of rise
e	= permanent increase in depth of penetration due to major load F1 measured in units of 0.002 mm
E	= a constant depending on form of indenter: 100 units for diamond indenter, 130
F_0	= preliminary minor load in kgf
F_1	= additional major load in kgf
F	= total load in kgf
HR	= Rockwell hardness number
D	= diameter of steel ball
D	= diameter of the ball
d_b	= diameter of the impression
F	= the imposed load in kg
F	= Load in kgf
d	= Arithmetic mean of the two diagonals, *d1* and *d2* in mm
HV	= Vickers hardness

CHAPTER 1

INTRODUCTION

1.1 Overview

Aluminum is a soft, durable, lightweight, malleable metal with appearance ranging from silvery to dull gray, depending on the surface roughness. Aluminum is nontoxic, nonmagnetic, and no sparking. Aluminum alloys with a wide range of properties are used in engineering structures. Alloy systems are classified by a number system (ANSI) or by names indicating their main alloying constituents (DIN and ISO).

The strength and durability of aluminum alloys vary widely, not only as a result of the components of the specific alloy, but also as a result of heat treatments and manufacturing processes. A lack of knowledge of these aspects has from time to time led to improperly designed structures and gained aluminum a bad reputation.

The low melting point of aluminum alloys has not precluded their use in rocketry; even for use in constructing combustion chambers where gases can reach 3500 K. The Agene upper stage engine used a regenerative cooled aluminum design for some parts of the nozzle, including the thermally critical throat region.

Aluminum can absorb nearly twice as much crash energy as steel. During a crash, aluminum can be designed to fold predictably by allowing the vehicle (not its passengers) absorb most of the crash forces. Since aluminum alloy is lighter than steel, it can be used to maintain or even increase the size and strength of a vehicle's critical front- and back-end crumple zones without increasing overall weight. In most cases, aluminum also benefits from the same high-productivity manufacturing infrastructure that has evolved to serve the automotive industry with today's conventional materials. This is why implementing heat treatment to aluminum alloy is the best options in automotive industries.

Aluminum has increasingly become the desired automotive application for engineers and designers for two simple reasons. First, engineers know that aluminum builds a better car due to its added strength and low weight. Constructing a vehicle from aluminum allows more features to be added without adding excessive weight while improving the vehicle's braking, handling and acceleration rates. That's why military aircraft and NASA's spaceships have used aluminum extensively for years. Second, designers prefer aluminum metal when constructing interior vehicle design plans. Similar to leather seats and walnut trim; brushed aluminum interior trim has become the innovative option consumer's demand because of its cutting edge style and high-performance (www.autoaluminum.com).

1.2 Objective

The objectives of this project are:

a) To investigate the effect of artificial aging conditions on the impact toughness and hardness of aluminum alloy.
b) To study the microstructure characterization of the re-solution heat treatment aluminum alloy followed by re-artificial aging.

1.3 Scope

The scopes of this project are.

a) Using Aluminum alloy 6061 T4 as the main material for this research.
b) All the experiment that been done in this research are according to American Society for Testing and Material (ASTM).
c) Charpy impact testing and Brinell hardness testing were the mechanical testing used in this research.
d) Temperature for re-solution heat treatment is 530^{o}C for 2 hours and temperature for artificial aging is 150^{o}C, 170^{o}C and 190^{o}C for 2 hours, 5 hours and 8 hours.

1.4 Problem Statement

Increase in world oil price caused problems to car user. Manufacturer tries to find other alternative for a vehicle to reduce its oil consumption. The demand for more lightweight, fuel efficient and enhanced performance automobiles has stimulated research and development in high-strength and high formability aluminum alloys. Aluminum alloy is the green choice for automotive materials. It’s proven to safely lighten vehicles for better economy and reduce green house emissions. Nowadays, many people are more interested looking for a safer vehicle. The objective of heat treatment is to create in a heat-treated alloy a dense and fine dispersion of precipitated particles in matrix of deformable metal. Besides, heat treatment is done to increase the strength of a material or in other way to improve the mechanical properties of aluminum alloy.

CHAPTER 2

LITERATURE REVIEW

This chapter will discuss the entire main component that involves in this project such as type of aluminum alloys, heat treatment, hardness test, impact test and microstructures characterization of aluminum alloy.

2.1 Aluminum Alloys

Aluminum alloys with various elements improves its mechanical properties, strength, density and strength to weight ratio (www.asminternational.org). There are two types of aluminum alloys which are wrought alloys and cast alloys.

2.1.1 Wrought Alloys

Wrought aluminum is defined by the fact that they are given some mechanical deformation in production. The first of four-digits used to identify a wrought aluminum alloy signifies the principal alloying element. The second digit refers to some particular modification of the original alloy composition. A suffix consisting of a dash followed by a series of letters and numbers define the temper, indicating certain properties and the process used to obtain them (www.asminternational.org).This family also falls into one of two groups:

a) Heat treatable (HT) which gain their mechanical properties by thermal processes.
b) Non-heat treatable (NHT) which gain their mechanical properties from cold working.

These suffixes begin with three possible letters:

- T - indicates a heat-treatable alloy
- H - indicates a non-heat-treatable alloy with final properties achieved instead by mechanical working such as cold rolling
- O - indicates annealed material (not heat treated)

2.1.1.1 1xxx, Pure Aluminum.

The major characteristics of the 1xxx series are:

a) Strain harden able
b) Exceptionally high formability, corrosion resistance, and electrical conductivity
c) Typical ultimate tensile strength range: 70 to 185 MPa (10–27 ksi)
d) Readily joined by welding, brazing, and soldering

The 1xxx series represents the commercially pure (CP) aluminum, ranging from the baseline 1100 (99.00% min Al) to relatively purer 1050/1350 (99.50% min Al) and 1175 (99.75 % min Al). The 1*xxx* series of alloys are strain harden able but would not be used where strength is a prime consideration.

2.1.1.2 2*xxx*, Aluminum-Copper Alloys.

The major characteristics of the 2*xxx* series are:

a) Heat treatable
b) High strength, at room and elevated temperatures
c) Typical ultimate tensile strength range: 190 to 430 MPa (27–62 ksi)
d) Usually joined mechanically, but some alloys are wieldable

The 2*xxx* series of alloys are heat treatable and possess in individual alloys good combinations of high strength (especially at elevated temperatures), toughness, and, in specific cases, weld ability. They are not as resistant to atmospheric corrosion as several other series and so usually are painted or clad for added protection.

2.1.1.3 3*xxx*, Aluminum-Manganese Alloys.

The major characteristics of the 3*xxx* series are:

a) High formability and corrosion resistance with medium strength
b) Typical ultimate tensile strength range: 110 to 285 MPa (16–41 ksi)
c) Readily joined by all commercial procedures

The 3*xxx* series of alloys are strain harden able, have excellent corrosion resistance, and are readily welded, brazed, and soldered.

2.1.1.4 4*xxx*, Aluminum-Silicon Alloys.

The major characteristics of the 4*xxx* series are:

a) Heat treatable
b) Good flow characteristics, medium strength
c) Typical ultimate tensile strength range: 175 to 380 MPa (25–55 ksi)
d) Easily joined, especially by brazing and soldering

2.1.1.5 5*xxx*, Aluminum-Magnesium Alloys.

The major characteristics of the 6*xxx* series are:

a) Strain harden able
b) Excellent corrosion resistances, toughness, weld ability; moderate strength
c) Building and construction, automotive, cryogenic, and marine applications
d) Representative alloys: 5052, 5083, and 5754
e) Typical ultimate tensile strength range: 125 to 350 MPa (18–51 ksi)

Aluminum-magnesium alloys of the 5*xxx* series are strain harden able and have moderately high strength, excellent corrosion resistance even in salt water, and very high toughness even at cryogenic temperatures to near absolute zero. They are readily welded by a variety of techniques, even at thicknesses up to 20 cm (8 in.).

2.1.1.6 6*xxx*, Aluminum-Magnesium-Silicon Alloys.

The major characteristics of the 6*xxx* series are:

a) Heat treatable
b) High corrosion resistance, excellent extrudibility; moderate strength
c) Typical ultimate tensile strength range: 125 to 400 MPa (18–58 ksi)
d) Readily welded by GMAW and GTAW methods

The 6*xxx* alloys are heat treatable and have moderately high strength coupled with excellent corrosion resistance. A unique feature is their great extrudability, making it possible to produce in single shapes relatively complex architectural forms, as well as to design shapes that put the majority of the metal where it will most efficiently carry the highest tensile and compressive stresses. This feature is a particularly important advantage for architectural and structural members where stiffness criticality is important.