IMPROVEMENT OF STRENGTH AND FORMABILITY OF ALUMINUM ALLOY SHEET BY ARTIFICIAL AGING TREATMENT (APPLICATION FOR CAR BODY PANEL)

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Laporan ini dikemukakan sebagai
memenuhi sebahagian daripada syarat penganugerahan
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‘Saya akui bahawa telah membaca karya ini dan pada pandangan saya karya ini adalah memadai dari segi skop dan kualiti untuk tujuan penganugerahan Ijazah Sarjana Muda Kejuruteraan Mekanikal (Rekabentuk & Inovasi)’

Tandatangan :…………………….

Nama Penyelia I :…………………….

Tarikh :……………………

"Saya akui laporan ini adalah hasil kerja saya sendiri kecuali ringkasan dan petikan yang tiap-tiap satunya saya telah jelaskan sumbernya"

Tandatangan :…………………….

Nama Penulis :……………………

Tarikh :…………………….

To my beloved parents

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ABSTRACT

Nowadays, the demands for high fuel-efficiency to reduce energy consumption and weight of vehicles become a challenge in industries especially in automotive industry. The selection of materials used in vehicles is the most important factors that need to be considered. This study is basically to do improvement on formability and hardness of aluminum alloys 6061-T4 as a choice of material for industries to fulfill the demands. The special properties or characteristics of aluminum alloys 6061-T4 such as lightweight and high corrosion resistance have put them among the best chosen materials to be used as automotive body sheets. Heat treatment processes are the best ways to improve its formability and hardness as aluminum alloys 6061-T4 are the heat-treatable wrought aluminum alloys and thus chosen in this project. The processes were performed by re-solution heat treatment, quenching, artificial aging and paint baking. The re-solution heat treatment was performed at 530^0C for 2 hours and followed by quenching in water at room temperature to retain or freeze its microstructure in α-phase. While, artificial aging treatment was carried out at 170^0C for 8 hours in order to strengthen the material. The formability and strength of aluminum alloy were determined by uniaxial tensile test and three-point bending test respectively. The value of strain-hardening exponent (*n*-value) and plastic strain ratio (*r*-value) indicates the formability of aluminum alloy. The flexure stress also was observed to clearly prove the results. The results were compared between sequences of conventional and present processes of car body panel.

ABSTRAK

Pada zaman sekarang, permintaan terhadap kenderaan yang lebih ringan dan dapat menjimatkan penggunaan minyak telah meningkat dari semasa ke semasa dan ia telah menjadi satu cabaran kepada mereka yang terlibat dalam industri automotif. Dalam memenuhi permintaan ini, pengeluar perlu mengambil kira faktor pemilihan bahan yang sesuai dalam mencipta sesebuah kenderaan. Oleh sebab itu, kajian ini telah dijalankan ke atas satu bahan iaitu aloi aluminium 6061-T4 dalam usaha untuk memenuhi permintaan tersebut. Ciri- ciri istimewa yang terdapat pada campuran aluminium 6061-T4 seperti ringan dan daya tahan terhadap hakisan yang tinggi telah meletakkan campuran aluminium 6061-T4 antara bahan yang digunakan secara menyeluruh untuk menghasilkan badan kereta. Pemanasan ke atas bahan ini akan dapat meningkatkan kekerasan dan kelenturannya dan dipilih sebagai proses dalam projeck ini. Proses- proses yang dijalankan ialah rawatan haba ulangan di mana ia dijalankan pada suhu 530^0C selama dua jam. Selepas pemanasan, bahan tersebut disejukkan secara pantas di dalam air yang sejuk untuk mengekalkan struktur di dalam bahan tersebut. Proses seterusnya ialah penuaan buatan di mana proses ini dijalankan pada suhu 170^0C selama lapan jam untuk menambah kekuatan dan kekerasan bahan tersebut. Kelenturan dan kekuatan campuran aluminium 6061-T4 ditentukan dengan menjalankan ujian tegangan dan ujian kelenturan tiga titik. Nilai-nilai *n* dan *r* bahan tersebut menunjukkan kelenturan campuran aluminium 6061-T4 tersebut. Bacaan yang didapati kemudian dibandingkan di antara proses yang digunakan dahulu dengan proses terbaru untuk menghasilkan badan kereta.

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n	= Strain Hardening Exponent
r	= Plastic Strain Ratio
ϵ	= True Strain
σ	= True Stress, Pa
K	= Strength Coefficient
S	= Engineering Stress, Pa
e	= Engineering Strain
P	= Load, N
A	= Area, m^2
L	= Length, m
N	= Number of Data Pairs
SD	= Standard Deviation
ϵ_w	=Width Strain
ϵ_t	= Thickness Strain
l_0	= Original Gage Length, m
l_f	= Final Gage Length, m
t_0	= Original Thickness, m
t_f	= Final Thickness, m
w_0	= Original Width, m
w_f	= Final Width, m
υ	= Coefficient of Variation

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CHAPTER I

INTRODUCTION

1.1 Overview

At the present time, technological demands for materials having high strength to weight ratio, high specific modulus, low coefficient of thermal expansion, good wear resistance, low density and good thermal conductivity are constantly increasing. In automotive application, material competition has been traditionally intensive. The increasing requirement to improve fuel economy triggered by concerns about global warming and energy usage has a significant influence on the choice of materials. Aluminum alloys offers one answer for the combinations of such attractive properties which can be applied in various types of industries.

This study is basically to do an improvement on strength and formability of cold-rolled aluminum alloy sheet 6XXX series (6061-T4) by artificial aging treatment, thus investigate the tensile strain hardening exponent (*n*-values) and plastic strain-ratio (*r*-values) by conducting tensile test. The processes involved are re-solution heat treatment, machining the sheets into dog-bone shape, artificial aging treatment, paint baking and finally tensile test in order to prove the results obtained after carrying out those treatments. This aluminum alloy 6061-T4 was chosen in this study because of its special properties and applicable in various industries, not only limited in automotive industry.

1.2 Problem Statement

a) The increased in oil price has caused the economical problems to car users.

b) The alternative solution to replace the present material is important to reduce weight of vehicles and energy consumption.

c) Aluminum alloys are the best choice because of its lightweight properties, but its formability and hardness need to be improved to make it suitable to be applied in industries especially in automotive industry.

1.3 Objective

To investigate the tensile strain-hardening exponents (*n*-values) and plastic strain-ratio (*r*-values) of product rolled from aluminum alloy sheet produced by sequences of conventional and present processes.

1.4 Scopes

This project is more to material and design engineering. The scopes of this project are:

a) Material: Aluminum alloy 6061-T4
b) Standard: American Standard for Testing Method (ASTM)
c) Mechanical testing:
    i. Tensile test
    ii. Bending (Flexure) test
d) Variables: Time duration from re-solution heat treatment to artificial aging treatment
e) Modified heat treatment from ASTM B918-01

CHAPTER II

LITERATURE REVIEW

2.1 Aluminum Alloys

Aluminum is categorized as a light metal besides magnesium, titanium and beryllium and its lightweight characteristic positions aluminum among the most widely used materials in industries. Currently, the needs for light metals have been the predominant consideration by manufacturers in choosing materials especially in automotive field and for this reason, aluminum offers the best answer compared to other metals such as iron, copper and nickel.

Basically, pure aluminum is soft, ductile, corrosion resistance and high electrical conductivity and these properties are most suitable to be applied for coil and conductor cable. However, aluminum is identified to have a low tensile strength of about 90 MPa and this constraint has limited its usage in industries (nonferrous.keytometals.com). By working the aluminum, as by cold rolling will give improvement in tensile strength for approximately doubled. To gain higher or marked increases in mechanical properties, the best way to be taken is by alloying the aluminum with small percentages of one or more other elements for example magnesium, silicon, copper, zinc and manganese. For aluminum alloys, they are also made stronger by cold working. Some alloys can be further hardened and strengthened by performing heat treatments to give a very large increase in tensile strength for almost 700MPa (nonferrous.keytometals.com). Generally, aluminum and its alloys have a self-protecting characteristic in which they are capable in forming a thin visible oxide skin immediately whenever its surfaces are exposed to atmosphere. This special characteristic gives aluminum and its alloys their high resistance to corrosion as well as to many acids. Alkalis are among the few substances that attack the oxide skin and therefore are corrosive to aluminum.

Aluminum alloys also can be cast into any form and provides good surface finish. It can be rolled, stamped, drawn, spun, roll-formed, hammered and forged. Beside that, it can be riveted, welded, brazed or resin-bonded. In automotive industry, the demands to produce the lightweight components and enhance the fuel efficiency have increased and the best solutions to meet the needs are aluminum alloys.

For manufacturers, the needs to produce lightweight vehicles for improving fuel economy are significant in order to compute in today's market and for customers' satisfaction. Current research (Smerd *et al.* 2005), claims that aluminum intensive space frame that reduce body weight up to 40% has been employed successfully and the advantage of aluminum lying in its strength-to-weight ratio.

Previous research (Miller *et al.* 2000) shows that the usage of aluminum in automotive applications has grown more than 80% in the past 5 years. The usage of aluminum is predicted to be used in hoods, trunk lids and doors hanging on a steel frame.

Among the characteristics of aluminum alloys that make it suitable for a variety of automotive applications are (Source: www.autoaluminum.org):

(a) Strong: the entire vehicle body can be aluminum
(b) Durable: good resistance to corrosion and fatigue
(c) Conductive: both thermal and electrical-for efficient engine and electrical components
(d) Nonmagnetic: useful in electronics
(e) Nontoxic: important in any material used in cars
(f) Abundant: adequate supply worldwide
(g) Recyclable: saves energy, benefits the environment

(h) Workable: uses well understood metalworking process

(i) Available: aluminum's many product forms offer design flexibility

Table 2.1 below is the applications of several types of aluminum alloys:

Table 2.1: Applications of Aluminum Alloys

(Source: www.autoaluminum.org)

Types/Designations	Applications
1100	Trim, nameplates, appliqués
2008	Outer and inner body panels (also suitable for structural applications)
3004	Interior panels and components
4004	Cladding for brazing sheet
5052	Interior panels and components, truck bumpers and body panels
6010	Outer and inner body panels, seat shells and tracks
7003	Seat tracks, bumper reinforcements

2.1.1 Types of Aluminum Alloys

There are two types of aluminum alloys available in industries and can be identified according to their designations. Those types are:

2.1.1.1 Wrought Aluminum Alloys

Wrought aluminum alloys are used in the shaping processes such rolling, shaping, extrusion, pressing and stamping. The examples of wrought products are rolled plate (>6 mm thickness), sheet (0.15 mm- 6 mm), foil (<0.15 mm), extrusions, tube, rod, bar and wire (Polmear 2006). They are normally identified by four digit figures which every digit explains the characteristic of particular alloy, followed by a dash that contains a letter and a digit. The letter indicates the heat treatment process that has been performed on the alloys and the digit denotes the temper designation of the specific alloys, e.g. 6061-T4.They are divided into two groups: heat-treatable and non-heat-treatable alloys. Table 2.2 below lists the general characteristics of wrought aluminum alloys according to its series.

Table 2.2: General Characteristics of Wrought Aluminum Alloys Series (Source: www.substech.com)

Series	Characteristics
1xxx	Strain hardenable Exceptionally high formability, corrosion resistance, and electrical conductivity Typical ultimate tensile strength range: 70 to 185 MPa (10–27 ksi) Readily joined by welding, brazing, and soldering
2xxx	Heat treatable High strength, at room and elevated temperatures Typical ultimate tensile strength range: 190 to 430 MPa (27–62 ksi) Usually joined mechanically, but some alloys are weldable
3xxx	High formability and corrosion resistance with medium strength