TENSILE STRENGTH VARIATION OF PRE-STRAINED ALUMINIUM ALLOY DUE TO ANNEALING

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ABSTRACT

The automobile is a self-propelled vehicle that travels on land. There are many different styles of cars. Today, the automotive industry is one of the biggest in the world. Body of car is a major component part in the automotive manufactured. Aluminium-Magnesium (Al-Mg) alloys have very good formability properties and have been used extensively for interior structural components of automotive body-in-white (BIW). However, at elevated temperatures, high diffusivity of Mg atoms allows easy dislocations rearrangements which lead to reduction of mechanical strength (softening/thermal recovery). Straining during press forming process also the problem in manufactured body of car. The two factors caused the components made out of Al-Mg alloy sheet to be susceptible to softening during paint bake cycle. During studies, softening behaviour is under the influences of time, temperature and pre-strain. The result of this investigation will be useful information for design and selection stages of Al-Mg sheet alloys because it reveals how much softening actually occurring as function of temperature and pre-straining.

ABSTRAK

Kereta adalah kenderaan yang bergerak diatas muka bumi. Kereta yang terhasil terdiri daripada pelbagai rupabentuk. Kini, industry automotif adalah industry yang terbesar di dunia. Badan dan rangka kereta merupakan bahagian penting dalam pembuatan automotif. Logam campuran yang terdiri daripada magnesium mempunyai kelebihan dari segi tujuan pembentukan, dan ianya digunakan secara meluas dalam industri automotif untuk pembuatan "body-in-white". Walaubagaimanapun, ketika peningkatan suhu, molekul-molekul atom magnesium dengan mudah tersebar dan membentuk atau menyusun semula atom-atom dalam keadaan baru. Disebabkan perkara ini, telah berlakunya potongan timah dari segi kekuatan mekanikal. Regangan juga merupakan masalah yang dihadapi ketika melakukan proses pembentukan dan penekanan juga. Kedua-dua faktor ini menyebabkan logam campuran ini mudah dipengaruhi ketika melalui proses pengeringan cat. Melalui sumber rujukan, diketahui bahawa perangai kelembutan ini dipengaruhi oleh masa, suhu dan kadar regangan. Keputusan yang diperolehi daripada penyiasatan ini, akan memberi maklumat yang berguna di samping membantu jurutera dalam pemilihan peringkat yang bersesuaian untuk logam campuran magnesium kerana ianya menunjukkan nilai sebenarnya berlakunya kelembutan pada suhu dan kadar regangan.

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SYMBOL

A_o	Area of the width specimen
W	Width
t	Thickness
ε	Engineering Strain
L_o	Original Length
L_1	New Length
σ	Engineering Stress
F	Force
V	Speed
x	Extension

LIST OF EQUATIONS

EQUATIONS

[1] Area (A_o) = Wt

[2] $$\text{Engineering Strain } (\varepsilon) = \frac{\text{Displacement}}{L_o} = \frac{L_1 - L_o}{L_o}$$

[3] $$\text{Engineering Stress } (\sigma) = \frac{\text{Force}}{A_o} = \frac{F}{A_o}$$

[4] $$\text{Speed } (V) = \frac{\text{Extension}}{t} = \frac{x}{t}$$

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CHAPTER 1

INTRODUCTION

1.1 Objective

To investigate the softening phenomena sensitivity to paint bake cycle temperature variation between 150°C to 225°C for pre-strain 5% to 20%.

1.2 Scopes

Study about the aluminium alloy. The type of the aluminium is aluminium magnesium alloy 5083 and aluminium alloy 1100. Beside that, investigate static recovery of the aluminium magnesium alloy is an important part. The variable in the experiments or test are temperature and percentage of pre-strain.

1.3 Project Aim

The aim of this project is to investigate softening behaviour which covers three important variables: namely time, temperature and pre-strain.

1.4 Project Background

The automobile is a self propelled vehicle that travels on land. It usually has four wheels. An engine provides the power to move the vehicle. The automobile or car carries people primarily for their transportation. Body car is the major component in a construction of the automobile.

Vehicle light-weighting not only enhances fuel efficiency, but also lowers vehicle emissions and improves driving performance. Lightweight subsystems such as hoods and deck lids are already employed throughout the industry to achieve small weight savings. However, significant improvements in vehicle efficiency will require larger changes in mass.

In body in white (BIW), the material used is aluminium magnesium alloy 5052 and 5083 (Al-Mg Alloy 5052 and 5083). These materials are used because to reduce the density or weight of the car construct. Furthermore, this material also can reduce air pollution. In that case, aluminium magnesium alloy 5052 and 5083 is having a little weight so it's just use a small quantity of fuel.

Aluminium alloy are produced in the wrought form sheet, plate, extrusion and others. It's classified according to the major alloying element they contain. However aluminium magnesium has softening behaviour under the heat treatment. Therefore compromise the actual strong.

Aluminium magnesium alloy 5052 and 5083 are been chosen because it have very good formability properties and have been used extensively for interior structural components of the automobile body in white (BIW). An addition, other characteristics this alloy is good weld ability and corrosion resistance.

The principal alloying element is magnesium (Mg). Chemical composition in percentage are using on Al-Mg Alloy 5083 for magnesium is 4.4, 0.7 for manganese (Mn) and 0.15 for chromium (Cr). In the annealed condition alloy 5083 has a tensile strength about 290 MPa and for the Al-Mg Alloy 5052, which contain about 2.5 percent magnesium (Mg) and 0.2 percent chromium (Cr). In the annealed condition alloy 5052 has a tensile strength of about 28ksi or 193MPa.

CHAPTER 2

LITERATURE REVIEWS

2.1 Introduction

For many years the biggest end-use market for aluminium has been the transportation sector with a major share of it going into car manufacturing. There has therefore been a long history of co-operation between the car industry and the aluminium industry.

The car producers' continual efforts to reduce car weight are furthered by aluminium developments. Weight reduction is not only based on the need to reduce emissions by requiring less fuel, but also on the need to meet consumer demands, since the trend for new options and safety equipment, such as air-conditioning, anti lock brakes, airbags etc. combined with the increasing popularity of light trucks as substitutes for conventional cars, is actually making vehicles heavier.

Accordingly, the forecast for the amount of aluminium used in each car is set to increase from about 100 kg in 2000 to 150 kg in the year 2005.

Pure aluminium is soft, ductile, and corrosion resistant and has a high electrical conductivity; more detail information can see Table 2.1. In consequence it is widely used for foil and conductor cables, but alloying with other elements is necessary to provide the higher strengths needed for other applications.

Alloys fall into two main groups. The work-hardening alloys, where strength is achieved by the amount of ***cold work*** applied to the alloy, such as rolling. For heat-treatable alloys, it can be precipitation-strengthened by ***heat treatment***.

Table 2.1: Typical properties for aluminium

Property	Value
Atomic Number	13
Atomic Weight (g/mol)	26.98
Valency	3
Crystal Structure	Face centered cubic
Melting Point (°C)	660.2
Boiling Point (°C)	2480
Mean Specific Heat (0-100°C) (cal/g.°C)	0.219
Thermal Conductivity (0-100°C) (cal/cms. °C)	0.57
Co-Efficient of Linear Expansion (0-100°C) ($x10^{-6}$/°C)	23.5
Electrical Resistivity at 20°C (μΩcm)	2.69
Density (g/cm^3)	2.6898
Modulus of Elasticity (GPa)	68.3
Poisson's Ratio	0.34

[7 http://Azom.com-Aluminum Alloys Designations]

2.2 Wrought Aluminium Alloys

Usually ingot shapes such as sheet and extrusion ingots are produced through semi continuously cast by the ***direct-chill*** method.

For the sheet ingots, about the ½ inch of metal is removed from the ingot surface. Where the surface is contact with the hot-rolling mill rolls. This operation called ***scalping.*** Effect from this operation we can get the smooth surface for the fabricated sheet or plate.

Then the ingots are preheated or homogenized at a high temperature for about 10 to 24 h to allow atomic diffusion. In that case, its will make the composition of the ingots become uniform. The important thing during the preheated process is the preheating must be done at a temperature below the melting point of the constituent with the lowest melting temperature.

Lastly, after the ingots through the reheating process, ingots must go to hot-rolled by using a four-high reversing hot-rolling mill.

2.3 Classification Wrought Aluminium Alloys

Aluminium alloys are classified according to the major alloying elements they contain. A four digit numerical designation is used to identify aluminium wrought alloys. The first digit indicates the alloys group that contains specific alloying elements. The last two digits identify the aluminium purity. The second digit indicates modification of the original alloy or impurity limits. For example, the fifth digit in a 5000-series aluminium alloy indicates magnesium as the principal alloying addition. 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. Detail information about wrought aluminium alloy is shown in appendix B and C.

Table 2.2 : Aluminium alloys grouped by major alloying elements

Major Alloying Element	**Wrought**
None (99%+ Aluminium)	1 X X X
Copper	2 X X X
Manganese	3 X X X
Silicon	4 X X X
Magnesium	5 X X X
Magnesium + Silicon	6 X X X
Zinc	7 X X X
Lithium	8 X X X

1st is alloy group

2nd indicates modification of base alloy

Last two identify alloy or purity

[9 http://aluminium.matter.org.uk/content/html/eng/default.asp]

2.3.1 Alloys Numbers

These numbers refer to a specific chemical composition of the aluminium alloy - the **recipe** of the metal. Pure aluminium is not a very useful product in any structural work - aluminium products almost without exception are produced from batches of pure aluminium mixed with a number of alloying elements that have been carefully specified by metallurgists in order to maximize particular characteristics of the finished metal. For example, an aluminium alloy that is easily extruded, may be difficult to machine, or an alloy that machines well, may be difficult to weld and others.

2.3.2 Non Heat-Treatable

Non heat-treatable alloys gain increased strength when cold worked. The principle strength is acquired through alloying and then further enhanced by the strain hardening, such as the rolling process. Alloy elements are added to the pure aluminium in order to contribute to strength, corrosion resistance and machine ability.

2.3.3 Temper Designation Systems

The temper designation system is used for all forms of wrought and cast aluminium and aluminium alloys except ingot. It is based on the sequence of basic treatments used to produce various tempers. The temper designation follows the alloy designation with the two separated by a hyphen. More explanations are in appendix D.

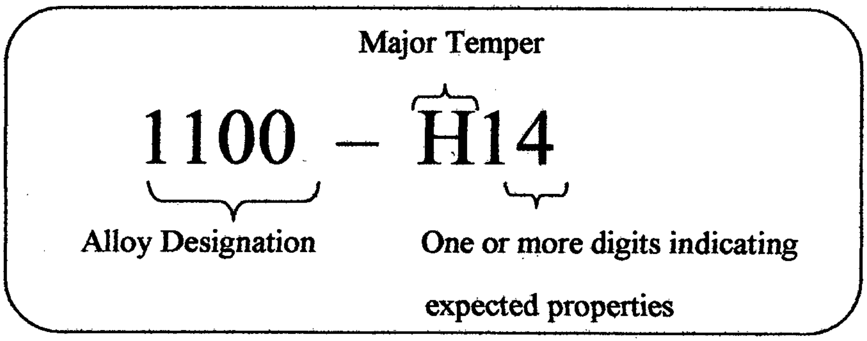

Figure 2.1 : Example designation in temper system.

[7 http://Azom.com-Aluminum Alloys Designations]

2.4 Aluminium Alloy

2.4 .1 Aluminium Alloy 1100 (AA1100)

This grade is commercially pure aluminium. It is soft and ductile and has excellent workability. It is ideal for applications involving intricate forming because it works hardens more slowly than other alloys. It is the most weldable of aluminium alloys, by any method. It is non heat-treatable. It has excellent resistance to corrosion and is widely used in the chemical and food processing industries. It responds well to decorative finishes which make it suitable for giftware.

Table 2.3 : Aluminium Alloy 1100

1100-O	Annealed (soft and bendable condition)
1100-H14	Strain hardened

For this group, series 1XXX, minimum aluminium content is 99%. And there is no major alloying element. Its contain 99 min percent of aluminium and 0.12 percent copper (Cu).

2.4 .2 Aluminium Magnesium Alloy 5083 (AA5083)

According to the wrought aluminum alloys designation system, alloys of this series are designated 5xxx. This group includes magnesium (Mg) as the major alloying element (up to 5.6%). Magnesium is used in the alloys for solid solution hardening. Beside that, manganese (Mg), chromium (Cr), titanium (Ti), vanadium (V), beryllium (Be) and gallium (Ga) may be added to the alloys of 5xxx series as minor alloying elements.

Aluminum-magnesium alloys are non-heat-treatable and may be strengthened by cold work (strain hardening). Effectiveness of cold work hardening increases when magnesium content is increased. Hot working temperature of 5xxx alloys is 500-950 °F (260-510 °C). Alloys of this series have moderate to high mechanical strength combined with relatively high ductility in annealed condition (up to 25%), good corrosion resistance and weldability.

Aluminium alloy 5083 contains 5.2% magnesium, 0.1% manganese and 0.1% chromium. In the tempered condition, it is strong, and retains good formability due to excellent ductility. AA5083 has high resistance to corrosion, and is used in marine applications. It has the low density and excellent thermal conductivity common to all aluminium alloys. Typical applications require a weldable alloy of high to moderate strength, with good corrosion resistance.

Table 2.4 : Aluminium Magnesium Alloy

Designation	Mn,%	Mg,%	Cr,%	Ti,%	Others,%
5005	0.2 max	0.5-1.1	0.1 max	-	-
5050	0.1 max	1.1-1.8	0.1 max	-	-
5052	0.1 max	2.2-2.8	0.15-0.35	-	-
5056	0.05-0.2	4.5-5.6	0.05-0.20	-	-
5083	0.4-1.0	4.0-4.9	0.05-0.25	0.15 max	-

[14 http:// substech_wrought_aluminum-magnesium_alloy_5083.txt]

2.5 Mechanical Properties of Metals

2.5.1 Introduction

During the processing and fabrication of metals and alloys, its necessary to reheat a cold-worked metal to soften it, and at the same time the ductility will increase. If the metal is reheated to a sufficiently high temperature for a long enough time, the cold-worked metal structure will go through a series of changes called recovery, recrystallisation and grain growth. This reheating treatment that softens a cold-worked metal is called annealing.

2.5.2 Recovery

Usually occurs at certain temperature range below the recrystallisation temperature. During recovery, sufficient thermal energy is supplied to allow the dislocations to rearrange themselves. This recovery process is called polygonisation. Where that's mean the subgrain boundaries begin to form. The electron micrograph may show the change in structure that accompanies advanced recovery. During the process the strength of a cold-worked metal is reduced only slightly but is ductility is usually significantly increased.

2.5.3 Recrystallisation

Recrystallisation occurs within a certain temperature range, where the new strain-free grains are nucleated in the recovered metal structure and begin to grow forming a recrystallised structure. The absolute temperature range approximately between 0.3 – 05 Tm. Tm means the melting points of the metal. Its also refer to the scale. The important factors that affect the recrystallisation process in metals and the alloys are:

1. Amount of prior deformation of the metal.
2. Temperature.
3. Time.
4. Initial grain size.
5. Composition of metal or alloy.

2.5.4 Grain Growth

Occurs when the temperature raise, where the grains begin to grow. The size may eventually exceed the original grain size. Effect from the grain growth process is its produce the rough surface ***(orange peel).***

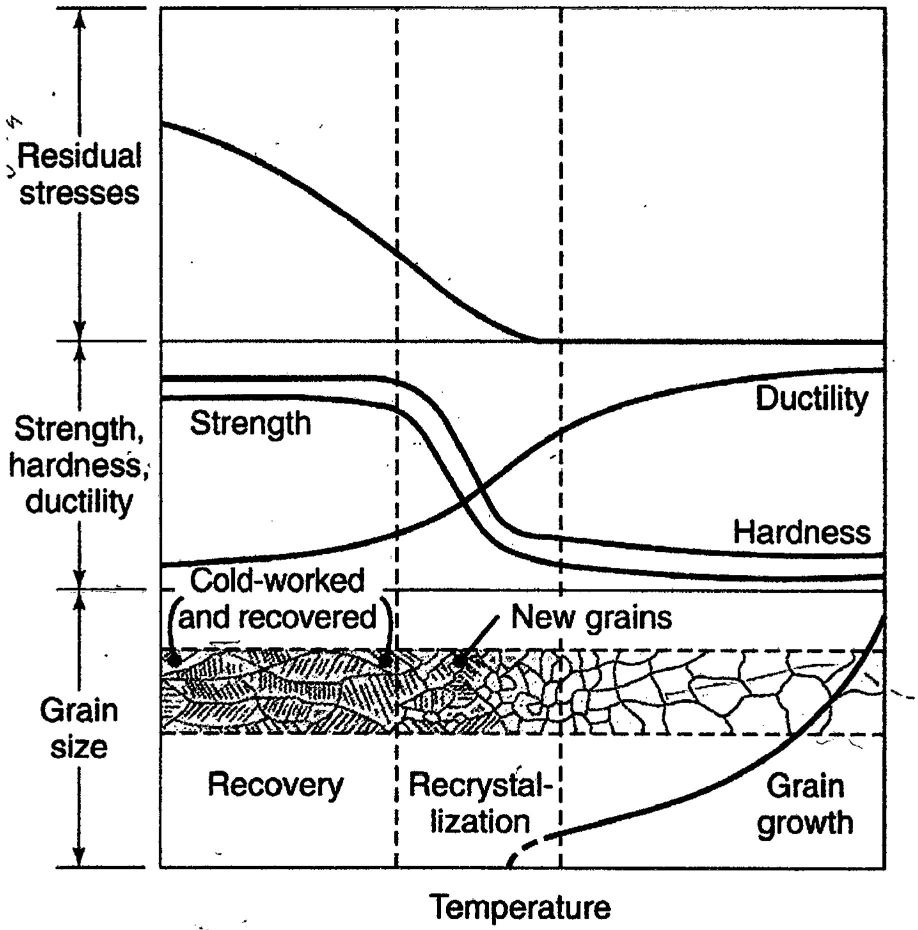

Figure 2.2 : Effect of annealing on the structure.

[2 Z.D Jastrzebski, "The Nature and Properties of Engineering Materials," 2d ed., (Wiley, 1976), pp 228]