UNIVERSITI TEKNIKAL MALAYSIA MELAKA

STUDY ON MECHANICAL PROPERTIES AND MICROSTRUCTURE BEHAVIOR OF ALUMINIUM ALLOY 6061

This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Manufacturing Engineering Technology (Process and Technology) with Honours.

by

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This report is submitted to the Faculty of Mechanical and Manufacturing Engineering Technology of Universiti Teknikal Malaysia Melaka (UTeM) as a partial fulfilment of the requirements for the degree of Bachelor of Manufacturing Engineering Technology (Process and Technology) with Honours. The member of the supervisory is as follow:

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ABSTRAK

Aluminium 6061 aloi digunakan secara meluas dalam banyak aplikasi kerana ciriciri kekuatan yang baik, haba yang boleh dipemproseskan, rintangan kakisan, ringan, dan lain-lain. Pelbagai aplikasi struktur dan perhimpunan dikimpal seperti bahagian automotif, komponen trak, landasan kereta api, kereta telah menggunakan bahan Aluminium Aloi 6061. Bahan ini biasanya terdedah kepada pelbagai kadar ketegangan semasa penggunaan. Dalam siasatan semasa, percubaan telah dibuat untuk mengkaji kesan kadar ketegangan yang berlainan. Dan telah dapati bahawa kemuluran bahan menurun apabila kadar ketegangan meningkat dengan kekuatan bahan meningkat. Di samping itu, rayap sentiasa berlaku semasa komponen beroperasi pada suhu tinggi atau tahap tekanan tinggi. Oleh itu, cubaan telah dibuat untuk menganalisis kelakuan aloi aluminium 6061 di bawah tekanan dan suhu yang berbeza. Dan hubungan telah ditubuhkan antara suhu dan pemanjangan bahan. Fraktografi bahan juga dianalisis dengan menggunakan SEM.

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ABSTRACT

Aluminium 6061 alloy is widely used in many applications due to the characteristics of good strength, heat treatable, corrosion resistance, lighter, etc. A broad range of structural applications and welded assemblies such as automotive part, truck component, railroad cars use the material Aluminium 6061 alloy. The material is usually exposed to various strain rates during use. In the present investigation an attempt has been made to study the effect of different crosshead speed. And it has been found that as the crosshead speed increases along with the strength of the material increases but the ductility decreases. Though creep always happen during component operating at high temperature or high stress level. Therefore, an attempt has been made to analyze the behavior of Aluminium 6061 alloy under different stress and temperature. And a relation has been established between the temperature and the elongation of material. The fractography of material is also being analyzed using SEM.

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DEDICATION

This thesis is dedicated to my beloved parents, supervisor and friends in helping and guiding me throughout the project.

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LIST OF SYMBOLS

℃	-	Celsius
$\mathbf{T_M}$	-	Absolute Melting Temperature
K	-	Absolute temperature in kelvins
mm/min	-	Millimetre per minute
kg	-	Kilogram
T	-	Temperature
$\boldsymbol{\varepsilon_0}$	-	Instantaneous elasto-plastic deformation upon loading, not associated with creep
$\boldsymbol{t}$	-	Time
$\boldsymbol{\varepsilon_P}$	-	Stress-dependent parameters associated with the magnitude and duration of primary creep
$\boldsymbol{\varepsilon_T}$		Temperature-dependent parameters associated with the magnitude and duration of primary creep
$\boldsymbol{\epsilon^C}$	-	Equivalent creep strain
A	-	A constant, depends on problem
n	-	Creep stress index, $1 \leq n \leq 10$
m	-	Time index, $0 < m \leq 1$
k	-	Creep strain index
C	-	Material specific constant (often approximated as 20)
$\boldsymbol{\sigma}$	-	Stress
F	-	Internal force
$\boldsymbol{A_0}$	-	Cross sectional area of body
$\boldsymbol{\Delta L}$	-	Elongation of length
$\boldsymbol{L_0}$	-	Original gauge length
$\boldsymbol{l}$	-	Length after elongate

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P_{max}	-	Maximum load
K	-	Slimness ratio
F	-	Fahrenheit
in	-	inches
psi	-	Pound-force per square inch
MPa	-	Megapascal
NaOH	-	Sodium hydroxide
H_2O	-	Water

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LIST OF ABBREVIATIONS

SEM	Scanning Electron Microscope
TEM	Transmission Electron Microscopy
OM	Optical Microscopy
OIM	Orientation Imaging Microscopy
LMP	Larson-Miller parameter
UTS	Ultimate Tensile Strength
EDM	Electrical Discharge Machining
DXF	Drawing Interchange Format/ Drawing Exchange Format
VDAS	Versatile Data Acquisition System
MVC	Microvoid coalescence

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CHAPTER 1

INTRODUCTION

1.1 Background Study

In this era of modern industry, aluminium is a type of non-ferrous metal with light weight and low strength in comparison to the steel. In order to strengthen the material, aluminium is combined with other metal-type element and later, it is known as aluminium alloy. According to Davis (2013), aluminium alloys are economical in many applications such as automotive industry, aerospace industry, in construction of machines, appliances, and structures as cooking utensils, covers for housings for electronic equipment, pressure vessels for cryogenic applications and in countless other areas. Aluminium alloys also are widely used in aircraft because of their high strength-to-weight ratio. On the other hand, pure aluminium is too soft for aircraft as it does not have a good tensile strength which is required by them. Thus, Aluminium 6061 alloy has been widely used due to its better characteristic such as a good strength, lighter, formability, weldability, heat treatable and corrosion resistance. Additionally, Aluminium 6061 alloy is also being used for a broad range of structural applications and welded assemblies in many fields including the truck components, railroad cars, pipelines, marine application, automotive part, etc.

Creep is a deformation of material which stress is applied on it under constant temperature or constant load. Creep can be progress in high temperature (thermal creep), or at room temperature for certain material. Tension is another type of material's deformation which stress is applied on it with load increasing until failure of material occur. A failure mode may not be formed if the material relieves the tensile stress that may cause cracking.

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The fracture behavior of material can be investigated if fracture is formed. Therefore, the study applied in this work takes different temperature around specimen and load into consideration to analyze the creep deformation of Aluminium 6061 alloy. While different crosshead speed is also taken as consideration to analyze the properties of Aluminium 6061 alloy in the study. Furthermore, the microstructure and composition of material will be studied in order to investigate the relationship between different process parameter.

1.2 Problem Statement

Mechanical failure often occurs in certain component during process operating high stress level, high speed of loading and even at high temperature. Torsion and creep are the mechanical failures that often are a concern of engineer and metallurgist when evaluating part that is operating at high stress or high temperature. In this work, Aluminium 6061 alloy which is widely used is tested with creep by using different loads and temperature to determine the fracture behavior, while tension test is also tested on the same material by using different crosshead speed. Thus, it is believed that the microstructure and composition of material could solve the problem of mechanical failure.

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1.3 Objectives

The objective of this project is shown in the following points:

i. To analyze the behavior of Aluminium 6061 alloy under different stress and temperature via creep deformation
ii. To investigate the effect of Aluminium 6061 alloy with different crosshead speed via tension test
iii. To analyze the microstructure of Aluminium 6061 alloy after creep deformation or tension test

1.4 Scope of Study

In this study, creep deformation and tension test employed to generate the fracture behavior on aluminium alloy. The study can be divided into three main scopes which are the process of specimen, testing process and performance. In the scope of specimen's process, the material for the specimen is Aluminium 6061 alloy sheet with thickness of 1.0mm. Laser cut machine was used to cut alloy sheet by following the dimension of specimen which inserted into the program. After the specimen preparation, the specimens experienced creep test in order to determine the effect of stress and temperature and tensile test to determine the effect of crosshead speed on aluminium alloy. In creep test, the numerous parameters of temperature around specimen of 18, 23 and 28°C were applied to probe the effect of different temperature to the alloy. While the load apply in the process were 0.5, 1.0, 1.5 and 2.0 kg which load represent the stress that applied to the specimen. Meanwhile, the numerous parameters of crosshead speed in tensile test were 1, 2, 3, 4, 5, 10, 15, 20 and 25 mm/min.

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Lastly, the study of microstructure and fracture surface also developed as well by exploring the porosity and drain growth. The machine that was used to develop this study is Scanning Electron Microscope (SEM). The observed microstructure obtained from the microscope to analyze the fracture behavior of the specimen.

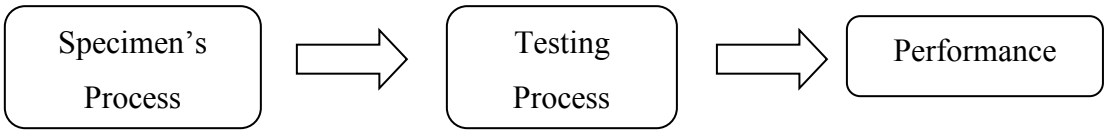

Figure 1.1: Main scope of study

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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

On this chapter, literature review will be discussed in term of the overview of a creep deformation and fracture behavior. The aim of literature review is to establish a theoretical framework with substantive findings and methodological contribution to this project which include all the current knowledges. Based on literature review, the general knowledge regarding the tool to be used, the process to be applied and the findings from previous works will be documented in this chapter.

2.2 Creep Deformation

Creep is slow, continuous deformations that depend not only on stress, but also on temperature and time. With increasing temperature, loads give no permanent deformation at room temperature (approximately 23°C) will cause creep of the material. According to Spigarelli (1999), creep can be observed in all metals, with the operating temperature exceeds 0.3 – 0.5T_M, where T_M is the absolute melting temperature. The lower limit temperature which creep phenomena can be obliterated is show at the table below. According to Ashby *et al.* (2012), for the melting or softening point of aluminium alloys is 750 – 933K. Therefore, Aluminium 6061 alloy is subject to creep. Creep is consulted under constant stress or even constant load by tension, compression or even torsion test.

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Table 2.1: Temperature limit above which creep is a limit factor in design

Materials	Limit of temperature
Aluminium	T > 0.54Tм
Titanium	T > 0.30Tм
Low alloyed steel	T > 0.36Tм
Austenitic stainless steels	T > 0.49Tм
Superalloys	T > 0.56Tм

2.2.1 Creep Curve

Creep curve can be obtained during a constant load test. The strain increases monotonically with time up to rupture (ε_R) after a momentary deformation upon loading(ε_0). The generic form of overall deformation after loading can be written as:

$$\varepsilon = \varepsilon_o + \varepsilon(\sigma, T, t) \qquad (1)$$

The ε (σ, T, t) component of total strain consist of three regions:

i. Primary Stage
ii. Secondary Stage
iii. Tertiary Stage

The primary stage is also called the transient curve. The strain rate ($\varepsilon_{\&} = \partial_\varepsilon/\partial_t$) decrease with time; as the strain increases, deformation also become more difficult. In this stage, material is experiencing strain hardening. The secondary stage or steady state of the creep curve has a strain rate which is constant($\varepsilon_{\&} = \varepsilon_{\&ss}$). The existence of constant strain-rate regime is generally explained in terms of a balance between strain hardening and structure recovery (a softening process determined by high temperature). At tertiary stage,

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