



**EFFECT OF HEAT TREATMENT ON MECHANICAL PROPERTIES  
OF EQUAL CHANNEL ANGULAR PRESSING (ECAP) PROCESSED  
A356 ALUMINIUM ALLOY**

Submitted in accordance with the requirement of the University Teknikal Malaysia Melaka  
(UTeM) for the Bachelor Degree of Manufacturing Engineering (Hons.)

by

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**Tajuk: EFFECT OF HEAT TREATMENT ON MECHANICAL PROPERTIES OF EQUAL CHANNEL  
ANGULAR PRESSING (ECAP) PROCESSED A356 ALUMINIUM ALLOY**

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I hereby, declared this report entitled “Effect of Heat Treatment on mechanical properties of Equal Channel Angular Pressing (ECAP) processed A356 Aluminium Alloy” is the results of my own research except as cited in reference.

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## **APPROVAL**

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Process) (Hons).

The members of the supervisory committee are as follow:

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(Principal Supervisor) – Signature & Stamp

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## ABSTRAK

Proses saluran sama matra (ECAP) adalah kaedah pemprosesan di mana logam ditekan kedalam acuan dengan menggunakan daya ricihan tanpa sebarang perubahan dalam dimensi fizikal pada keratan sampel. Prosedur ini boleh digunakan untuk menghasilkan mikrostruktur yang lebih kecil dan bebas dendritik. Tujuan kajian ini adalah untuk mengkaji evolusi struktur mikrostruktur dan sifat mekanikal ECAP. Struktur mikrostruktur A356 aluminium aloi dikaji dengan menggunakan mikroskop optik (OM) dan mikroskopi pengimbasan elektron (SEM) untuk menentukan ukuran ira aloi aluminium. Proses ECAP membuktikan bahawa ia mampu untuk menghasilkan struktur ultra pada keratan sampel apabila rawatan haba T6 dijalankan. Ujian tegangan telah dijalankan dengan menggunakan Mesin Tegangan Semesta (UTM) bagi mendapatkan menilai kekuatan bahan yang bersesuaian dengan beban yang digunakan. Sampel ECAP yang terawat haba T6 memperoleh nilai yang tertinggi iaitu 290 MPa diikuti dengan dengan sampel ECAP tanpa rawatan haba T6 dengan nilai 267 MPa, diikuti pula dengan sampel acuan tuangan yang dikenakan rawatan haba T6 iaitu sebanyak 243 MPa dan akhir sekali ialah sampel acuan tuangan tanpa rawatan haba T6 dengan nilai terendah sebanyak 188 MPa. Selepas itu, ujian kekerasan telah dijalankan untuk mengetahui kekerasan sampel. Sampel ECAP dengan rawatan haba T6 mempunyai kekerasan 93.09 HV, diikuti dengan sampel ECAP tanpa rawatan haba T6 82.02 HV, sampel acuan tuangan dengan rawatan haba T6 sebanyak 77.96 HV dan akhir sekali ialah sampel acuan tuangan tanpa rawatan haba T6 dengan memperoleh 76.17 HV. Semua sampel telah melalui proses rawatan haba T6 yang terdiri daripada rawatan haba serakan, pelindapkejutan dan penuaan semulajadi. Rawatan haba T6 berguna untuk meningkatkan sifat-sifat mekanikal aloi aluminium. Evolusi mikrostruktur dan penilaian sifat mekanikal dapat ditentukan melalui sifat sebenar aloi yang boleh digunakan dalam pelbagai aplikasi.

## ABSTRACT

Equal-channel angular pressing (ECAP) is a processing method in which a metal is subjected to an intense plastic straining through simple shear without any corresponding change in the cross-sectional dimensions of the sample. This procedure may be used to introduce an ultrafine grain size into polycrystalline materials. The aim of this study is to investigate the microstructure evolution and mechanical properties of ECAP. The microstructure of A356 aluminium alloy was examined by using optical microscope (OM) and scanning electron microscopy (SEM) to determine the grain size of the aluminium alloy. ECAP proved that it is able to produce ultra-refine grain boundary and it can be enhanced by heat treatment. Tensile test was conducted using Universal Tensile Machine (UTM) with purpose of to evaluate the strength of the material which correspond to the load applied. From the test, ECAP with T6 heat treatment achieved the highest value of UTS 290.027 MPa, compared to ECAP non heat treated that obtained 267.027 MPa, while for as-cast with heat treatment is 243.189 MPa and last but not least is as-cast with value of 188.731 MPa. After that, hardness test had been conducted in order to know the hardness of the sample. ECAP with heat treated obtained the highest hardness with 93.09 HV, followed by ECAP which is 82.02 HV, 77.96 HV for as-cast with heat treated and lastly as-cast with value of 76.17 HV. All of the samples went through T6 heat treatment processes that were solid solutioning, quenching and natural aging. T6 heat treatment was useful to increase the mechanical properties of the aluminium alloy. The microstructure evolution and mechanical properties evaluation were determined due to actual properties of the alloys that can be used in various applications.

## **DEDICATION**

Only

My beloved father, Aziz bin Bakar

My appreciated mother, Norlia binti Hj. Yusoff

My adored brothers, Nor Azman and Nor Azlan

My dedicated master student, Nurul Naili binti Ishak

My supportive friends, Muhammad Hafizzudin, Sofia Mulyani, Fatin Nur Amira, Puteri  
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## LIST OF ABBREVIATIONS

ASTM	-	American Society for Testing and Materials
Al-Si-Cu	-	Aluminium Silicon Copper
ECAP	-	Equal Channel Angular Pressing
HT	-	Heat Treatment
HPDC	-	High Pressure Die Casting
OM	-	Optical Microscope
RE	-	Uncommon Earth Component
RT	-	Room Temperature
SPD	-	Severe Plastic Deformation
SSM	-	Semi-Solid Metal
SHT	-	Solution Heat Treatment
UTeM	-	Universiti Teknikal Malaysia Melaka
UTM	-	Universal Tensile Machine

## LIST OF SYMBOLS

$\text{n/mm}^2$	-	Newton Per Millimeter Square
$^{\circ}\text{C}$	-	Degree Celcius
gr.	-	Grain
kN	-	Kilo Newton
$\sigma$	-	Stress
$\epsilon$	-	Strain
%	-	Percentage
wt. %	-	Weight Percentage
vl. %	-	Volume Percentage
$\phi$	-	Inner Angle
$\Psi$	-	Outer Angle
M	-	Meter
$^{\circ}$	-	Degree
$\mu\text{m}$	-	Micrometer
nm	-	Nanometer
mm	-	Millimeter
h	-	Hour
d	-	Diameter
MPa	-	Mega Pascal
K	-	Kelvin

HVN	-	Hardness Vickers Nunmber
F	-	Fahrenheit
mtr/min	-	Meter Per Minutes
mm/min	-	Millimeter Per Minutes

# CHAPTER 1

## INTRODUCTION

This section clarifies about the background, objective, problem statement and the scope of the final year project. Then followed by the organisation of the final year report. The background discusses about the Equal-channel Angular Pressing (ECAP) and T6 heat treatment. Next, the objective indicates about the mission needed to be achieved for this project. Lastly, the scope mentions about what is supposed to be accomplish in this project.

### 1.1 Background of Research

Equal-channel angular pressing (ECAP) is a severe plastic deformation process (SPD) that use to obtain ultrafine grain material. According to (Langdon, 2017) ECAP is a severe plastic deformation technique that capable of presenting severe plastic strain bulk metals, leading to substantial grain refinement to submicrometer or even to nanometer level. A simple shear force is apply when a metal is subjected to an intense plastic straining. The force apply is not create any changing in cross-section dimension of the sample. ECAP introduce ultrafine grained microstructure at low homologous temperature.

A356 Aluminium alloy can be classified into hypoeutectic Al- Si alloy group. This kind of group is extensively used in avionic and automotive industry due to its advantages of good castability owing to the greater volume of Al- Si eutectic and good fluidity instead of able to achieve near net shape product. The most vital cast aluminium alloy system is Al– Si, where the elevated amounts of silicon add to give great throwing attributes. Casting made up from A356 aluminium alloy offer lots of advantages such as wear and corrosion resistance, hot tearing resistance, weldability and height strength of weight ratio (Zhang *et al.*, 2008).

Table 1.1 Chemical composition of A356 aluminium alloy (Pio, 2011)

Elements	Si	Fe	Cu	Mn	Mg	Ti	Al
Composition weight (%)	7.14	0.39	0.06	0.25	0.35	0.02	1.79

According to (Johnsinit, 2011) heat treatment is a process that involve heating and cooling of metal by changing or alter their physical and mechanical properties but without changing their shape. For example, improving formability or machining. Heat treatment also known as method for strengthening materials. There are examples of heat treatment process such as hardening, annealing and tempering. Usually extreme temperature is required for the treatment as we want to achieve the required result. Heat treatment is not only support manufacturing process but also can improve product, its performance and characteristics in several ways.

## 1.2 Problem Statement

Usually, ECAP samples is used to fabricate the automotive parts. There is a strong requirement for this sample to undergo T6 heat treatment in order to enhance the structural integrity and mechanical properties of the samples Microstructure is one of the important analysis that can be prove the properties of the sample by observing their structural composition.

ECAP process is the first trial process of cold work. ECAP is a process that does not involve any heat and conducted in room temperature which is 23° C. So that not many researchers do the research regarding this process since it is new to industry. Other than that, regarding the parameter of the ECAP, there is no information on the 1 pass procedure of ECAP in the literature, Thus the investigation is needed to determine the mechanical properties of A356 aluminium alloys on 1 passes of ECAP parameter.

Heat treatment is well known as it can give rise properties of the material. But, since ECAP is the first cold work process, there are no further information regarding ECAP with heat treatment. Due to that, Lack of data and information are available regarding the heat

treatment of A356 alloy fabricated using ECAP processing. It is crucial to carry out this research due to get more detail about the enhancement of heat treatment.

### **1.3 Objective**

The objectives are as follows:

1. To investigate the microstructure evolution of ECAP processing technique.
2. To analyse the mechanical properties of ECAP processed A356 aluminium alloy.
3. To investigate the effect of T6 heat treatment on mechanical properties of ECAP processed A356 aluminium alloy.

### **1.4 Scope**

In this research the material that will be use is only aluminium alloy A356. This material will be process from raw material until the end of the finding.

Besides that, several method and technique are apply while carrying this research which are Equal-channel angular pressing (ECAP) and heat treatment. ECAP is a trustworthy method to achieve ultrafine-grained material. For heat treatment only focus on T6 heat treatment with parameter of solution temperature and aging temperature.

In order to analyse the mechanical properties of ECAP processed aluminium alloy (A356), several tests have been conducted including tensile test, and hardness test. All the test are conducting follow all the steps and requirement in detail. Furthermore, microstructure of the sample is observed to identify the grain of the sample.