PREPARATION OF RECYCLING CHIP ALUMINIUM (Al 6061) THROUGH POWDER METALLURGY ROUTE

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering Engineering Materials (Hons.)

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I hereby, declared that this report entitled "Preparation of Recycling Chip Aluminium (Al 6061) Through Powder Metallurgy Route" is the results of my own research except as cited in references.

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the Degree in Bachelor of Manufacturing Engineering (Engineering materials) (Hons.). The member of the supervisory is as follow:

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(Dr. Mohd Warikh bin Abd Rashid)

ABSTRAK

Laporan ini membentangkan penyediaan kitar semula cip aluminum melalui kaedah metalurgi serbuk. Bahan mentah yang telah digunakan ialah aluminum 6061. Salah satu keperluan utama dalam melaksanakan projek ini ialah untuk menilai prestasi cip aluminum dengan kelajuan ‘planetary ball mill’ yang berbeza. Sampel telah dikisar dengan tiga kadar kelajuan putaran yang berbeza iaitu 100, 150, dan 200 rpm selama satu jam. Satu lagi keperluan utama ialah untuk menganalisa kesan perbezaan suhu kepada kekerasan cip aluminum. Sejak kekerasan sampel meningkat selepas ia dirawat dengan haba, tiga suhu yang berbeza akan dikenakan dimulakan dengan 500, 550, dan 600 ^{o}C selama 40 minit. Dalam mendapatkan sampel yang mempunyai ciri-ciri yang baik, setiap sampel akan diuji secara mekanikal untuk menyiasat ketumpatan, dan kekuatan kekerasan setiap sampel. Pada masa yang sama, kesemua tiga sampel di analisis untuk mendapatkan taburan saiz dan mikrostruktur selepas disinter dengan menggunakan analisa saiz zarah dan mikroskop optik.

ABSTRACT

This report presents the preparation of recycling chip aluminium through the powder metallurgy route. The raw materials that have been used are aluminium 6061. One of the key requirements in doing this project is to evaluate the performance of aluminium chips with different speed of planetary ball mill. Samples were grind with three different rate of rotation speed which is 100, 150, and 200 rpm for an hour. Another key requirement is to analyze the effect of different temperature towards the hardness of recycling chips. Since sample increase it hardness after been treated to the heat, three different sintering temperatures will be introduced starting with 500, 550, and 600 ^{o}C for 40 minutes. In order to get which sample has better properties, each sample will be testing mechanically to investigate its density, and hardness strength properties of each sample. At the same time, all these samples are being analyzed to obtain its size distribution and microstructure after being sintered by using Particle Size Analyzer (PSA) and Optical Microscope (OM).

DEDICATION

To my parents and friends for their help and understandings,

To my supervisor, PM Dr. Mohd Warikh Bin Abdul Rashid for his support and guidance is enlightenment to me.

Thank you for everyone for every support, help, and cooperation until I manage to finish this report.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

Al	Aluminium
CO_2	Carbon dioxide
Al_2O_3	Alumina
AA	Aluminium Association
ANSI	American National Standard Institute
PSA	Particle Size Analyzer
ASTM	American Society for Testing and Materials
SAE	Society of Automotive Engineers
Mg_2Si	Magnesium silicide
PM	Powder Metallurgy
Cu	Copper
Si	Silicon
Mg	Magnesium
Zn	Zinc
rpm	revolution per minutes
OM	Optical Microscope

CHAPTER 1

INTRODUCTION

1.1 Background

Aluminium produced from bauxite ore where commonly used in industry after iron since its good recyclability as well as low density, good mechanical properties and corrosion resistance. Nowadays, the recycling of this waste material becomes a major issue. The waste of this material usually in the form of chips comes from the machining of semi-finished product. Usually, conventional method been used in recycling this type of scrap.

According to, Gronostajski et al., (2000), the waste and scrap then returned to melting, whereby some of the metal is recovered and reutilized in the production process. A lot of metal is lost as a result of oxidation and the cost of labour and energy as well as the expenditures on environmental protection increases the general cost of the process during the recycling of the waste been carried out.

Sherafat et al., (2009), states that in conventional method, it is difficult to recycle the chips due to their elongated spiral shape and small size in comparison with other scraps. Chips surface area is also relatively large and covered with oxides and oil emulsion, so that their recycling through re-melting process is not applicable. Under these conditions, it is estimated that on average about 46% of the metal is loss during the re-melting process. Besides, conventional recycling is characterized by high energy consumption, high operating costs, and a large number of operations. This means that the conventional process manage to recycle less of the aluminium scrap and lead to very significant problem because the amount of recycled aluminium has been growing from days to days.

In recent years, powder metallurgy (PM) method been suggested as an alternative way in recycling the aluminium chips followed by the hot extrusion. This method results in lower hardness properties of the recycled materials than metallurgically produced material due to hot extrusion process where it causes residual porosity and imperfect bonding. Now, recycling of aluminium scrap without melting phase are tried to be fabricate so that the properties of the recycled aluminium can be improved.

1.2 Problem Statement

Recycling aluminium chips to the structural component becomes important for the reduction in CO_2 emission. Therefore, recycling of these light metals is an important issue nowadays. The recycling of aluminium alloy scraps is mostly carried out by the melting process and it require enormous heating energy in order to melt the scraps.

According to, Samuel (2003), by using conventional method, only 75-81% of conventional recovery obtained with high energy consumption required for re-melting scrap which is 6000 kcal/kg. It required high operation cost due to the large number of operations and lead to high pollution that mainly due to the fumes and dross generated during re-melting of the scrap.

Gronostajski et al., (2000) states that about 10% on average of the metal burnt and about 10% of it lost in the melting process of aluminium and aluminium alloy. The losses are irreversible and can reach about 35% if melting takes place in gas or oil-fired furnaces instead of induction furnaces. In the process of melting, the main cause of losses of aluminium scraps during these conventional recycling is its low density which causes it to stay for a long time on the surface of the molten metal and oxidize intensively.

In this research, powder metallurgy method is used in order to recycle the aluminium chips. This reduces the emission of CO_2 into the air that lead to air pollution by eliminating the melting phase during the processing.

1.3 Objectives

a) To analyze the effect of different particle size towards the hardness of aluminium 6061.

b) To investigate the performance of aluminium 6061 after been sintered at different range of temperature.

1.4 Scope

The scope of this research is to study the effect of different particle size of powder obtain from different speed rotation of planetary milling towards the hardness of aluminium 6061. Microstructure change after sintering process with temperature of (500, 550, 600) ^{o}C are observed using optical microscope. Lastly, the distribution of the particle will be analysed using Particle Size Analyzer (PSA).

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will discuss on the fundamental of this project, mainly about the basic of aluminium 6061. Next, the production of the chips through the powder metallurgy also will be discussed since it is the important part in this project.

2.2 Aluminium and Aluminium Alloy

Aluminium and aluminium alloys have many outstanding attributes that lead to a wide range of applications. Aluminium is light, ductile, has good electrical and thermal conductivity, and can be made strong by alloying. An advantageous chemical property of aluminium is its reactivity with oxygen, which leads to the formation of a dense layer of Al_2O_3 on the surface that shields the base metal from further environmental interaction (Starke, 2001).

All aluminium products belong to one of eight alloy series. They are available as wrought and casting alloy. Wrought alloys are used as basic material for mechanical forming such as extrusion, rolling, deep drawing and forging. These alloys have a comparatively small quantity of alloying elements. Alloying element that added to wrought alloys in quantities ranging from 1 to 7%, and in higher quantities, up to 20% silicon to casting alloys. These elements are copper, magnesium, manganese, silicon, and zinc.

Good cast-ability, particularly with regard to modern die-casting machines and considering the very complex structure of casting for the automotive industry, low shrinkage during solidification of the cast and good thermal stability are essential for casting alloys.

Alloying element is actually one of the common industrial alloys. Other two things are additive and impurities. Additive are added in smaller quantities usually less than 1% which purpose to improve certain properties. The traditional additions are chromium, manganese, nickel, titanium, beryllium, zirconium, lead, etc. Alloy can contain more than one additive, and their concentration may exceed 1% in certain cases.

As for impurities, the main impurities of unalloyed aluminium in the 1000 series; their total concentration determines the purity of the metal, are iron and silicon. The concentration of impurities can vary depending on the alloy. Aluminium and its alloy appear to have increasing applications and to be competitive to ferrous alloys due to their important advantages such as, low density, high specific strength, high corrosion resistance, good formability and weld-ability.

2.2.1 Wrought Alloy

Wrought alloys consist of two types: non-heat treatable of the 1XXX, 3XXX, 4XXX, and 5XXX series, and heat treatable of the 2XXX, 6XXX, and 7XXX series. Strengthening is produced by strain hardening which can be increased by solid solution and dispersion hardening for the non-heat treatable alloys.

This aluminium classification numbering system has been established by American National Standard Institute (ANSI) and the Aluminium Association (AA). This classification system uses an alpha-numeric code to identify major alloying element and heat treating condition of the material. The primary alloy groups are designated by a four digit code as shown in Table 2.1.

Table 2.1: Wrought designation system

Alloy Numbering Designation	Main Alloying Element
1XXX	Pure Aluminium (99% and greater)
2XXX	Copper
3XXX	Manganese
4XXX	Silicon
5XXX	Magnesium
6XXX	Magnesium and silicon
7XXX	Zinc
8XXX	Other element
9XXX	Unused series

1000 Series – Aluminium of 99% or higher purity has many applications, especially in the electrical and chemical fields. These alloys are characterised by excellent corrosion resistance, high thermal and electrical conductivity, low mechanical properties, and excellent workability. Moderate increase in strength may be obtained by strain hardening. Iron and silicon are the major impurities.

2000 Series – Copper is the principal alloying element in this group. These alloys require solution heat treatment to obtain optimum properties: in the heat-treated condition mechanical properties are similar to and sometimes exceed those of mild steel. In some instances artificial ageing is employed to further increase the mechanical properties. This treatment materially increases yield strength, with attendant loss in elongation; its effect on ultimate tensile strength is not as great. The alloys in the 2000 series do not have as good corrosion resistance as most other aluminium alloys and under certain conditions they may be subject to the inter-granular corrosion.

3000 Series – Manganese is the major alloying element of alloys in this group, which are generally non-heat treatable. Because only a limited percentage of manganese, up to about 1.5% can be effectively added to aluminium, it is used as a major element in only a few instances. These, however, are popular and are widely used general-purpose alloys for moderate strength applications requiring good workability.

4000 Series – The major alloying element of this group is silicon which can be added in sufficient quantities to cause substantial lowering of the melting point without producing brittleness in the resulting alloys. For these reasons aluminium-silicon alloys are used in welding wire and as brazing alloys where a lower melting point than that of the parent metal is required. Most alloys in this series are non-heat treatable, but when used in welding heat-treatable alloys they will pick up some of the alloying constituents of the latter and so respond to heat treatment to a limited extent. The alloys containing appreciable amount of silicon become dark grey when anodic oxide finishes are applied.

5000 Series – Magnesium is one of the most effective and widely used alloying elements for aluminium. When it is used as the major alloying element, or with manganese, the result is a moderate to high-strength non-heat treatable alloy. Magnesium is considerably more effective than manganese as a hardener. Alloys in this series possess good welding characteristic and good resistance to corrosion in marine atmospheres.

6000 Series – Alloys in this group contain silicon and magnesium in approximate proportions to form magnesium silicide, thus making them capable of being heat-treated. Though less strong than most of the 2000 or 7000 alloys, the magnesium-silicon (or magnesium-silicide) alloys possess good formability and corrosion resistance, with medium strength.

7000 Series – Zinc is the major alloying element in this group. When coupled with a smaller percentage of the magnesium, it results in heat-treatable alloys of very high strength. Usually other elements such as coppers and chromium are also added in small quantities.

8000 Series – Used for alloys not covered by the above series.

9000 Series – Unused series.

The material designation for wrought aluminium alloy is:

7	0	7 5

- ‘7’ refer to the major alloy element.
- ‘0’ refer to the modification of the original alloy.
- ‘7, 5’ is assigned when the alloy is registered.

Advantages of wrought aluminium alloys are:

a) Corrosion resistance: Alloys that which favorable in this respect is 1xxx, 3xxx, 5xxx, and 6xxx.

b) Thermal conductivity: Aluminium and its alloy are good conductors of heat.

c) Electrical conductivity: Pure aluminium and some of its alloy have exceptionally high electric conductivity, second only to copper among common metals as conductors.

d) Strength/weight ratio: This characteristic combined with the excellent corrosion resistance and recyclability has led to aluminium's broad use in containers, aircraft, and automotive applications.

e) Fracture toughness and energy absorption capacity: Many aluminium alloys are exceptionally tough and excellent choices for critical applications where resistance to brittle fracture unstable crack growth are imperatives.

f) Workability: Aluminium alloys are readily workable by a great variety of metal-working technologies and especially amenable to extrusion. This enables aluminium to be produced in a remarkable variety of shapes and forms in which the metal can be placed in locations where it can most efficiently carry the applied loads.

g) Ease of joining: Aluminium alloys may be joined by a very broad variety of commercial methods including welding, brazing, soldering, riveting, and bolting.

h) Recyclability: Aluminium and its alloys are among the easiest to recycle of any structural materials. It may be recycled directly back into the same high quality products like rigid container sheet (cans) and automotive components.