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# Microstructural Analysis and Mechanical Properties of Direct Recycling Aluminium Chips AA6061/Al Powder Fabricated by Uniaxial Cold Compaction Technique

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**Abstract**

Aluminium alloy AA6061 recycling benefits to the current and future generations by conserving energy and other natural resources. Thus with the current approach of processing technique by cold compaction technique solid state recycling made it possible for fabrication of direct recycling chips. In this research, AA6061 chips and powder were fabricated to form a sample by using uniaxial cold compaction at 9 tons for 20 minutes and sintering process at temperature of 552°C. The microstructural behaviour of the recycled AA6061/Al powder samples were distributed non-homogeneously and randomly between the chips and powder region. The density of sample full chips and full powder shows the closest value to theoretical at 2.47 g/cm$^3$ and 2.43 g/cm$^3$ respectively. The hardness and compression strength examined shows the same reaction with the increasing amount of Al powder content. The full Al chips showed the highest hardness at 65.6 Hv and gradually decreased with increasing Al powder. Whereas, the maximum compression strength was at fully chip content at 307.7 MPa. The compression strength decreases with increasing amount of Al powder content due to the weak bonding between the particles.


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*Keywords:* Recycled aluminium chips; AA6061; powder metallurgy; cold compaction; microstructures; hardness; and compression strength

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## 1. Introduction

Aluminium production has been widely used for many application thus recycling of aluminium leads to a huge number of economic and environmental benefits. In comparison with other materials, aluminium production has one of the largest energy differences between primary and secondary production at 186 MJ/kg and 10–20 MJ/kg respectively [1]. From this reason numerous manufacturers have now focuses of expanding the usage of secondary materials [2]. Aluminium chips produced by machining are the most standout amongst all sorts of scrap to reuse by remelting, as the oxidation of the material is heightened because of the high surface to volume proportion of the chips [3]. A direct conversion of aluminium alloy machining chips into a new product is an alternative approach to overcome the issue of material loss during remelting of aluminium chips and to further develop the energy balance of the aluminium production [4-6].

Chips from aluminium and its alloy are particularly derived from machining operation are commonly characterized by its spiral and elongated shape, thus, making them unfit to recycle through conventional methods. In making them into a more specific size and shape chips, many kinds of milling processes will be involved to obtain a smaller and regular shape particles of the recycled aluminium. This process will cause more time consumption and cost. Therefore, plenty of studies were made to avoid the hassles of conventional recycling process by directly conversion method through pressing [7-10].

Numbers of studies have reported that the solid state recycling of aluminium alloys have been positively carried out using powder metallurgy method. Schikorra et al. [11] studied the recycling of AA6060, AA6082 and AA7075 aluminium chips and their mixtures by cutting, compaction and hot extrusion into a rectangular bar shape. Meanwhile, a new approach was used by Fogagnolo et al. in which the aluminium chips is directly cold or hot pressed and then hot extruded [8]. AA7075 chips with addition of pure Al powder was recycled through powder metallurgy method was conducted by Sherafat et al. [12]. Significantly, all the mentioned studies had avoided the milling process in resulting more economic recycling process and huge area of application. With the high demand of aluminium, thus, made the study of aluminium recycling becoming more and more interesting [10].

Powder metallurgy is described as the technique used to create metal powders by packing the metal with or without addition of other material and heating them just beneath the melting temperature to strengthen the material. Fundamentally, powder metallurgy comprises of straightforward technique beginning with production of powder, powder blending or mixing with binders, trailed by compaction process into required shape, sintering process, and end with optional secondary machining or finishing in producing a special property or improving the precision of powder metallurgy product [13].

Thus this paper aims to investigate the sample works on recycled AA6061 chips and Al powder by combination of powder metallurgy and compaction technique in order to study the characteristics of physical and mechanical properties of composites body.

## 2. Working Procedures

### *2.1. Materials*

In this study, AA6061 alloy with a theoretical density of 2.7 g/cm$^3$ was used as the metal matrix material. The AA6061 alloy blocks and Al powder with particles size of 25 microns were supplied by the Newspark Technology and Chengdu Best New Materials Co., Ltd., China. The chemical composition (in wt.%) of the aluminium alloy AA6061 are Si (0.59), Fe (0.092), Cu (0.289), Mn (0.08), Mg (0.975), Cr (0.2), Zn (0.031), Ti (0.1), and Al (remnant). Only 1 wt.% of zinc stearate was used as a binder to make the compaction process easier [14].

### *2.2 Preparation of chips*

Firstly, chips were produced by using CNC milling machine, type HSM (SODICK – MC430L) as shown in Fig. 1. The feed rate (1100 mm/min), depth of cut (1.0 mm), cutting velocity (345.4 m/min) were used as the parameters of machine to produce the chips. The milled chips were then cleaned by ultrasonic bath apparatus type Fritsch. The duration taken for each batch was about 1 hour. The liquid used to treat the chips was acetone solution in order to