OPTIMIZATION OF THE MILLING SPEED FOR AN RECYCLING AA6061 ALLOY TO PRODUCE SMALL PARTICLE SIZE

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ABSTRACT: *The present study aimed to investigate the effect of milling speed on the size of the particle, by using a mechanical milling process followed by sieving process. The chip sized of AA6061 that fabricated by high speed milling machine (CNC) were used. The milling process used to produce smaller particles of aluminum chips by the planetary ball mill. Three values of speed were taken, which are 300, 350, and 400 RPM, to produce smaller particle size. The Shape and size of the milled recycled chip of AA6061 were investigated. Four types of particle size were tested (25, 63, 100,and mix µm). The results indicated that the particle size was depended on the milling speed and time used, therefore, we concluded that the reasonable time observed is suggested to be 20 hrs, as well as, the speed of 350 RPM is given the best results for milling efficiency according to the particle size.*

Key word: AA6061, Ball mill, powder metallurgy, particle size, milling speed.

1. INTRODUCTION

The melting process of reuse for aluminium metal gives many pollution effects to the environment. Aluminium alloys were the most heavily used nonferrous metals in the world [1,2]. They are very favorable for structural applications in military, aerospace and transportation industries due to their high low density, resistance to corrosion, specific strength and especially as regards high energy cost [3]. Aluminium hybrid composites are new creations of metal matrix composites that have the potentials of pleasing the recent requests of advanced engineering applications which have a high specific modulus, a tailorable coefficient of thermal expansion and good wear resistance [4,5,6]. The optimization of the mechanical properties of aluminium matrix composites are predominately dependent on the microstructure of the metal. Some parameters characterize this structure, i.e. size, particle distribution, shape and to the matrix, such as precipitates, grain size, texture, and dispersoids [7]. A thorough characterization of the composite microstructure is required with a view to understand the mechanical properties of aluminium matrix [8]. The current study aimed to investigate the effect of the milling speed and the milling time of aluminium alloy chip for getting smaller particles size of aluminum. Although, recent studies have tried the powder metallurgy but none has focused on the recycling of aluminum AA6061 until now.

2. EXPERIMENTAL SETUP

Main raw materials used were aluminum AA6061 and zinc stearate ($C_{36}H_{70}O_4Zn$). Recently aluminum alloys, exclusively AA6061, used in automotive, marine, aircraft and construction industries due to its excellent properties, such as strength to weight ratio, noncorrosive and rewards over than steel in ductility. Aluminum AA6061 mixed with zinc stearate as a binder. The mechanical properties of AA6061 (Table 1) were indicated by some other researchers [9,10].

Table 1: Mechanical Properties of Aluminum AA6061 (ASTM B308/B308M)

Yield Strength (MPa)	Tensile Strength (MPa)	Density g/cm^3	Hardness (Vickers)
240	260	2.7	107

The first part of the study focused to prepare the chip from the bulk. High-speed milling machine used (Sodick-MC 430L, at UTHM) to produce the chip from AA6061 ingot, using constant setup parameters (illustrated in table 2) to obtain the chip with a uniform size.

Table 2: Chip Production Specification

Machine name	HSM (SODICK – MC430l)
Tool	Ø 10 mm carbide 2 flute
Feed rate	1100 mm/min
Depth of cut	1.0 mm
Number of cycles	11000
Speed	345.4 m/min
Feed	0.1

AA6061 chips needed to be clean, so that a cleaning process of the chips was performed using an ultrasonic bath cleaner with duration of 1 hr. During the cleaning process, acetone (Ch_3CoCh_3) was used as cleaning agent in order to remove oil and other contaminants that stick to the chips. The next step was the chip drying. This process undergo by the furnace type KUITTHO Linn High therm. The temperature of drying and duration time were 75^{o}C and 1 hr respectively.

Then after, the chip milling process or production of particle size has started to figure out the smaller aluminum particle size formed. The aluminum chip was milled using planetary ball mill (Retsch PM 100). In this process, the aluminum chip milled in a stainless steel jar for total duration of 20 hrs. Aluminum chip added to the machine at rotation speed of 300, 350, and 400 RPM. During this process, the machine has set to pause every 15 minutes to ensure that the aluminum chips in the ball mill were not cold welded due to high energy collision subjected in the ball mill. The ratio of the ball to the powder of this process was 20:1. A preventive measure, such as ensuring the steel cup was clamped properly, was taken in order to prevent machine damage.

Sieving process used to separate various particle sizes. Three sizes (25, 63, 100 µm) were separated and studied, at duration time of 30 minutes and amplitude of vibration as 4.

3. RESULTS AND DISCUSSION

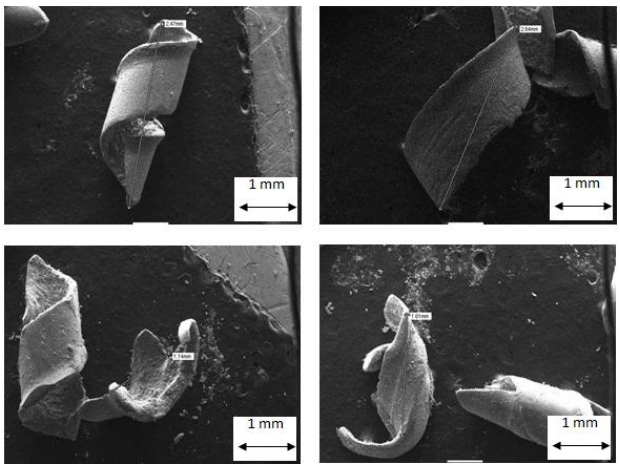

Figure 1: Chip Shape

Aluminium metal has produced as a chip under certain constant parameters. Then milled under variable speeds (300, 350, 400 RPM). Each speed has classified according to the particle size (25, 63, 100, mix µm), and some specimens were fabricated for testing to obtain the optimum condition for compaction process.

3.1. Chip Production

Blocks of aluminum AA6061were used to produce the chip. The HSM (SODICK–MC430l) machine, and milling (CNC) machine used to fabricate the chip. The chip length, width, and shape were observed (Figure 1).

3.2. Milling process

Milling process used to produce smaller particle sizes of aluminium chips. Three speeds of milling (300, 350, 400 RPM) were used. The duration time for milling process has set up to 20 hrs, with pause time every 5 hrs (to collect samples of the chip). The ball to powder ratio (b.p.r) of this process was 20:1. Particles sizes for each speed and duration of time illustrated in Table 3. The relation of speed of the milling machine to the particle size shown in Figure 2.

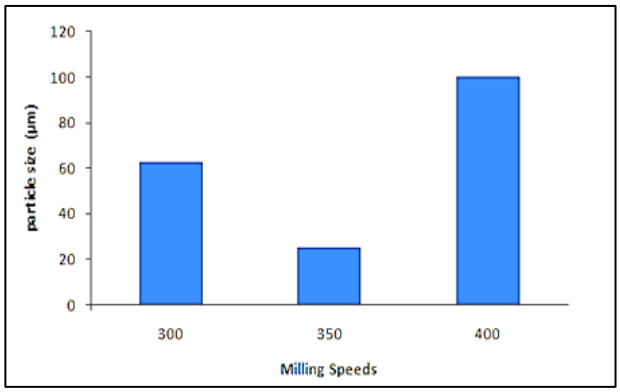

Figure 2: Particle Size after 20 Hours for Each Speed

Table 3: The Relation Between Time and Particle Size under Various Speeds

Time (HR) \ Speed (RPM)	300	350	400
5	2220 µm	2300 µm	2250 µm
10	1400 µm	900 µm	1630 µm
15	700 µm	40 µm	900 µm
20	63 µm	25 µm	100 µm
25	Stopped	25 µm	Stopped

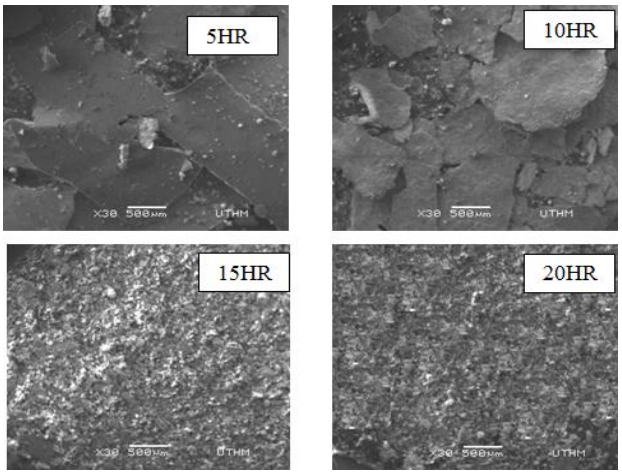

Figure 3: Relation Between Particle Size Length with Duration Time at Speed 350 RPM

The results indicated that the best speed used to give the smaller size of particles was 350 RPM (Figure 3), because it came with a high impact energy, whereas the speed of 400 RPM is the longest for particle size, due to the low impact energy. Anyhow, the particle size for 300 RPM has a reasonable value (Figure 4). The percentage of particles sizes for each speed, up to the end of duration time of 20 hrs, illustrated in Table 4.

Table 4: The Percentage of Particle Size for Each Speed Tested

Speed	25 µm%	63 µm%	100 µm%	200 µm%	250 µm%	500 µm%
300	35.6	45.4	19	0	0	0
350	51.4	39.2	9.4	0	0	0
400	0	0	1	2	3	94

These results agreed with a previous study that investigated the production of aluminium AA6061 material matrix composite reinforced with Ti_3Al particles by powder metallurgy techniques and hot extrusion. The process used ball milling and b.p.r of 6:1 for 18 hrs, to produce particles

sized 75 µm [11].

4. CONCLUSION

This work studied the recycling of aluminum chip, which is successfully done. The chip sizes of AA6061 that produced from high speed milling were used and the milling process of

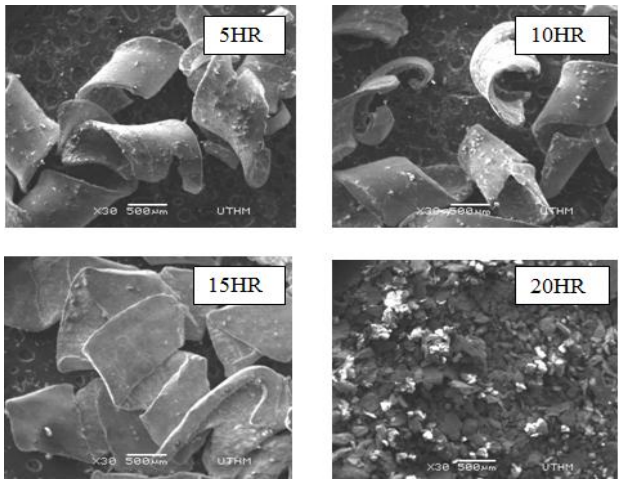

Figure 4: Relation Between Particle Size Length with Duration Time at Speed of 300 RPM

the recycled chip of AA6061 has investigated. Three values of milling speed were performed 300, 350, and 400 RPM, The smaller size was produced by using 350 RPM. Three sizes of particle were sieved for this study (25, 63, and 100 µm). We concluded that the smaller size of particle can be produce by using 350 RPM with earlier time 20 hrs compared to others.

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