

Evaluation of hardness strength and microstructures of recycled Al chip and powder AA6061 fabricated by cold compaction method.

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Abstract. The present study is aimed at investigating Mechanical properties of the milled recycling Aluminium type AA6061 according to the change of the volume fraction for the continents and the reinforcement material. In the study, high speed millings were used for producing the chip sizes of AA6061 and followed by a cold press forging process. Milling process was used to produce smaller particles of aluminium chips by the planetary ball mill. Three groups of specimens were taken according to the percentage of chip and powder, while, two groups were taken according to the mixture between different particle sizes of powders. Where, four types of particle size were chosen (25, 63, 100, mix of particles) μm . The results were showing that the Microhardness increased with increasing the percentage of chip, then the density was decreased due to a large amount of pores were found. By the experiments, it can be concluded, the mixture of powders is the best choice for all groups. On the other hand, the type D3 (78.5% (25 μm) + 21.5% (100 μm)) gave the best result for microhardness compare with others according to particle.

Keyword: Aluminium Alloy AA6061, recycling chip, cold compaction method, microhardness.

1. Introduction

The melting process of reuse for aluminium metal gives many pollution effects to the environment. Aluminium is the most heavily used nonferrous metals in the world [1, 2]. Aluminium alloys are very favourable for structural applications in military, aerospace and transportation industries due to their high specific strength, low density and resistance to corrosion, and especially as regards high energy cost [3]. Aluminium hybrid composites are a new generation 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]. The optimization of the mechanical properties of aluminium matrix composites is

largely dependent on the microstructure of the metal. Some parameters characterize this structure, i.e. size, shape and particle distribution, and to the matrix, such as precipitates, grain size, texture, and dispersoids [7]. Thorough characterization of the composite microstructure is required to understand the mechanical properties of aluminium matrix.

In metal industries, scrap and waste metals that residue after manufacturing processes are chip and discards. These waste metals are recycled by retreating them to smelters. However, during melting processes of metals for reusing, many metals are lost due to the costs of labor and occurring oxidation, energy and environmental protection expenditures.

The current research work focuses on understanding the effect of the volume fraction of aluminium alloy chip and powder for getting optimum mechanical properties of aluminum. There are some researches for powder metallurgy but there are not for recycling aluminum AA6061 until now.

2. Experimental setup

The main raw materials in this study were aluminium AA6061, zinc stearate ($C_{36}H_{70}O_4Zn$). In this study, AA6061 was mixed with zinc stearate as a binder. The mechanical properties for Aluminium AA6061 are shown in Table.1 were used this material in some research.

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 explains the experimental design to prepare the chip from the bulk. High-speed milling machine (Sodick-MC 430L) at UTHM was used to produce the chip from AA6061 ingot using the following constant set up parameter to obtain a chip with uniform size as shown in Table 2.

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

AA6061 chips need to be clean in order to remove oil and other contaminants that stick to the chips, so that it would not affect the obtained results. The cleaning process of the chips was performed by using an ultrasonic bath cleaner with duration of (1hr). During the cleaning process, acetone (CH_3COCH_3) was used as cleaning agent.

After the cleaning process the chip will be drying undergone by furnace type (KUITTHO Linn High Therm). The temperatures of drying and duration time were 75°C and 1h respectively. The next steps are chip

milling process or production of particle size. Smaller Aluminum particle size was formed by this process. The aluminum chip was milled by using the planetary ball mill type (Retsch PM 100).

In this process, the aluminum chip was milled in a stainless steel jar for the total duration of 20 hours. Aluminum chip was added to the machine for the rotation speed of 350 RPM. During this process, the machine was set to pause for 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 ball to powder ratio of this process was 20:1. A preventive measure such as ensuring the steel cup was clamped properly was taken into account in order to prevent the machine from damaging.

The sieving process was used to separate the various particle sizes. Three sizes were separated in this study (25, 63, 100 μm). The duration time was 30 min and the amplitude of vibration was 4.

The second part explains the experimental design to produce a recycled aluminum sample. The aluminum particle size from the previous part was then compacted into standard ASTM (E9-89a) shaped and compacted at pressure 9 ton and held at holding time 20 min and sintered at 552 ° C due to optimum sintering temperature [8].

3. Result and Discussion

The Aluminium alloy AA6061 was produced as a chip under constant parameter. It was then milled under speed 350 RPM and classified according to the particle size (25, 63, 100, mix) μm . After that, some specimens were fabricated for several testing to obtain enough data for microhardness behaviour for compaction process.

3.1. Chip and powder production

This paragraph discusses on producing of the aluminium chip AA6061. The chips were produced from aluminium block by using high speed CNC milling machine (SODICK – MC430I). Chip length, chip width and the shape of the chip were observed using scanning electron microscopy at lowest magnification possible. Figure 1 illustrates the several of chips sizes and shapes according to the parameters used for milling process

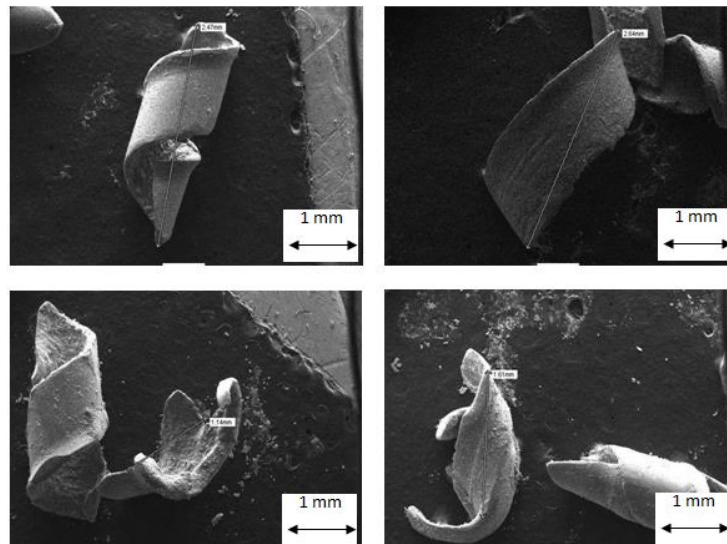


Figure 1. Image of different chip shapes.

Meanwhile, ball milling process was used to produce smaller particle size of aluminium chips into powder form. One speeds of milling was used which was 350 RPM. The duration time for milling process was 20 hours. The ball to powder ratio (b.p.r) of this process was 20:1. Smaller particle size was obtained by this process and three particle sizes were sieved at 25 μm , 63 μm and 100 μm .

3.2 Classification of the specimens

There are many variables considered in the selection, in this paper parameter that considered were the different volume fraction of aluminium chip and particle sizes of powder. The denotations of each composition were as follows in Table.3.

Table 3. Classification of specimens

Symbol	Sub-sym	Chip %	Powder %
A	A1	90	10 (one size 25 μm)
B	B1	70	30 (one size 25 μm)
C	C1	50	50 (one size 25 μm)
D	D1	0	21.5% (25 μm) + 78.5% (100 μm)
	D2	0	50% (25 μm) + 50% (100 μm)
	D3	0	78.5% (25 μm) + 21.5% (100 μm)
E	E1	0	21.5% (25 μm) + 78.5% (63 μm)
	E2	0	50% (25 μm) + 50% (63 μm)
	E3	0	78.5% (25 μm) + 21.5% (63 μm)

3.3 Effect of volume fraction on microhardness

Hardness gives a good idea of the durability and coherence of the material mass by using small loads. In this test which is non-destructive, the instrument consists of a hard and accurate head for easing the penetrating in the material. The material will usually suffering from elastic deformation and follows by the plastic deformation. In this test, two groups were taken, the first group was mixture between aluminium chip and aluminium powder (25 μm). The second group was mixture between aluminium powders 25 μm , 63 μm and 100 μm .

Eight values for each sample were inspected to calculate the average. Figure 2 shows the relationship between volume fraction aluminium chip and microhardness for the sample A, B, and C. It can be seen, that the biggest value of microhardness was sample A1 due to it has a little amount of pores formation (5.67%), therefore it has higher value of hardness which was 61.003 Hv. While sample C1 has a lower value of microhardness 49.031Hv due to it has large percentage of porosity (7.69%). Whereas, sample B1 between A1 and C1 gave hardness value of 56.87Hv, whilst, resulting porosity at 6.33%. Generally, the relationship between volume fraction of aluminium chip and powder and hardness is directly proportional.

On the other hand, the value decreased from A1 to C1 due to it has insufficient amount of powder and thus gives the possibility of it particles to rearrange in the voids formation from the large size of chips. By the previous data, it can be concluded that the using of powder will improve the performance of the mixture and next the mixture of powder was studied in this paper. Figure 1 shows the relationship between the type of specimen and microhardness.

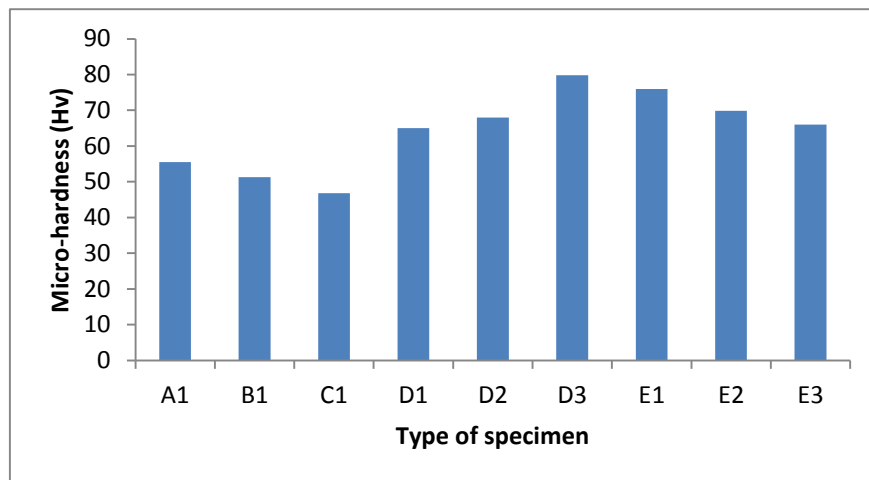


Figure 2. Relationship between type of specimen and microhardness

It can be seen that the specimens with mixture between powders gave higher values of micro-hardness due to these specimens have little amount of pores. The higher value obtained was for the specimen D3 (78.5% 25 μ m + 21.5% 100 μ m), while the lower value was from the specimen C1 (50% chip +50% powder with size of 25 μ m) due to it has a large amount of porosity.

3.4 Microstructural analysis

The microstructure was obtained by using optical microscopy to for better analysis between chip-powder and powder-powder mixtures. The images were magnified at 50 and 200 times for good comparison between chip-powder and 200 magnifications were used at powder-powder mixture samples (D and E). Thus, Figure 3 shows microstructure for the specimen C1 and Figure 4 shows micro-structure for the specimen D3. The specimen sample of C1 illustrated the different structure of chips and powder. The image shows clear view and separation of chip and powder, whereby, the powder resulted in filling up voids formation due to the large size of chips.

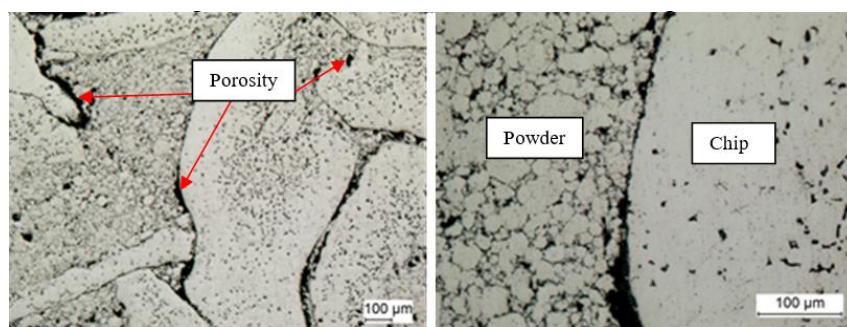


Figure 3. Microstructure for the specimen C1 (50X and 200X magnifications)

Meanwhile, Figure 4 shows the microstructure between powder-powder specimens (D and E). The microstructures illustrate that specimen D1, D2 and D3 show larger grain sizes due to the particles mixture between 25 μ m (smallest particles used) and 100 μ m (largest particles used). Besides, the specimen of E1, E2 and E3 provide better bonding between each particles due to smaller size of pore formation. But both groups illustrates fair amount of porosity due to the implementation of powder metallurgy route in the study. With smaller particle size powder use may help in the formation of grain boundary thus relatively filling up the pores surrounded by the larger particle size.

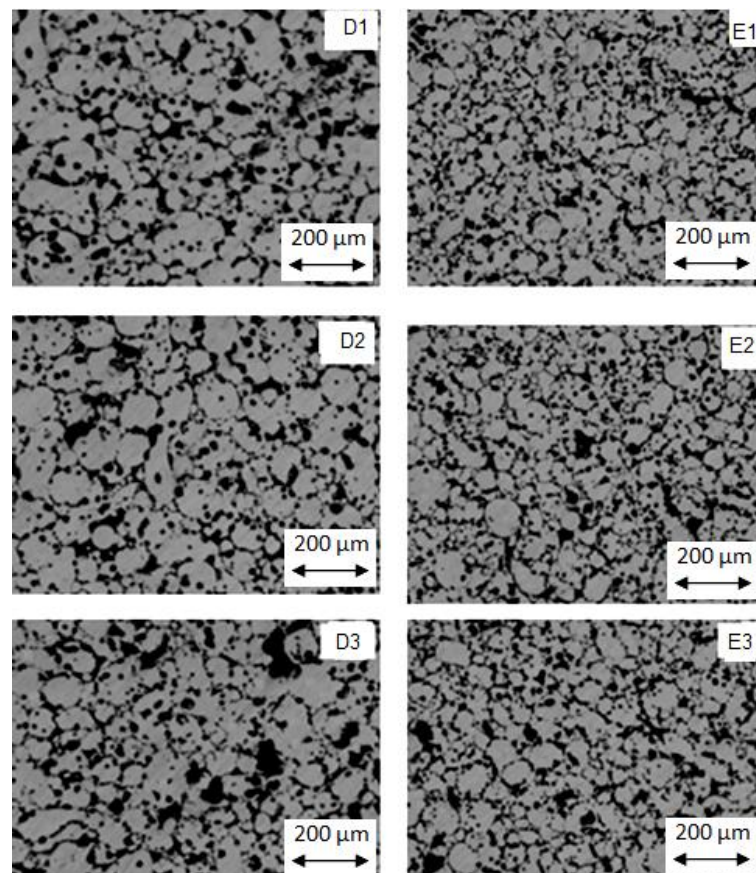


Figure 4. Microstructure for the specimen D and E

4. Conclusion

In this work, the study of recycling aluminium chip was successfully done. The chip sizes of AA6061 that produced from high speed milling were used and the mechanical property of the recycled chip of AA6061 was studied. The smaller size of powder particles was produced by using ball milling was achieved at 350RPM speed. Micro-hardness test was used to the specimen for different particle size and different mixture. Five groups were used for this study, three groups were mixed between chip and powder and two groups were mixed between powder and powder. It can be shown that the mix group D (78.5% 25 μ m + 21.5% 100 μ m) has a bigger value for this study due to relatively smaller porosity and well distributed mixture compared to others. Direct proportional relationship was found between the hardness and the percentage of chip.

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