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EFFECT OF SINTERING TEMPERATURE ON COMPRESSION STRENGTH AND MICROHARDNESS OF RECYCLING ALUMINIUM ALLOY AA6061 THROUGH BALL MILL PROCESS

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ABSTRACT

AA 6061 is used in the automotive, aircraft, marine and construction industries due to it is excellent properties such as noncorrosive, strength to weight ratio and rewards over than steel in ductility. Four groups of particle size were chosen (25, 63, 100, mix) µm. Each group has compacted by three specimens for various of Sintering temperature (487, 552, 617) ^{O}C, the compaction pressure and holding time were constant (9) tons, (20) min respectively. The mechanical properties of the four groups depend on the variations of sintering temperature. So, it is useful first to present and discuss the results of microstructure to understand the strengthening mechanism. In this study, compression strength value was increased with the increasing of sintering temperature value to (552) ^{O}C of all types of suggested groups due to the bonding between particles was stronger, in addition, the pores amount was decreased. After that, it was decreased due to the particles become big size lead to the barriers were decreased. The maximum value of compression strength was detected by mix group which was (160) MPa while the particle size (100) µm was the minimum value which was (115)MPa. Where as the groups (25) µm and (63) µm were (150) and (134)MPa respectively.

Keyword: AA6061, ball mill, sintering temperature, mechanical properties, recycling aluminium.

INTRODUCTION

Aluminium alloy AA6061 present a remarkable combination of outstanding physical and mechanical advantages, such as low density, high strength, fatigue resistance, low coefficient of thermal expansion and tribological properties, and are widely applied in spacecrafts, automobiles, bicycles and electronic components as high-temperature structural or electronic packaging materials [1-4]. Both theoretical and experimental results indicate that AA6061 has high strength and light weight [5]. In recent years, there was a significant increase in publications related to AA6061 powder reinforced metal matrix composites (MMCs). Considerable research on milling process has focused on matrix materials, such as Al [6-7].

The Effects of sintering temperature and duration on the structural was studied [8], Because of their large surface area, metal nano-particles display several unique properties, such as a low melting point and sintering temperature. The large surface area provides higher surface energy and reactivity to the nano-particles by which they can be sintered below the bulk melting point. This may be beneficial for semiconductor packaging because the low temperature could help avoid thermal stresses and reduce substrate warpage [9].

Recycle milled Aluminium is the most researched powder metallurgy material, but their potential applications have not yet been defined. The range of applications in which recycle milled Aluminium are used grows rapidly. Nano-structured cemented carbides are characterised by a unique combination of a very fine grained homogenous microstructure and good mechanical properties, which makes them the best choice for many areas of application. Mechanical properties are directly dependent on the developed microstructure in the sintered parts, which is governed by several factors such as WC crystallite size, mean free path of the binder phase, and the contiguity of WC grains [10]. The research work presented in this paper focuses on understanding the effect of the milling process of aluminium alloy chip and the influence of Sintering temperature on the obtaining a good compact sample for testing. Hence the Aluminium alloy compacted samples are compacted by hydraulic press. The value of sintering temperature and mechanical properties are studied on the green compact which clearly shows the outcome of a good compact for testing.

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EXPERIMENTAL WORK

Material

Aluminium metal AA6061 is a silver-white metal that has a strong resistance to corrosion and malleable. Then, it has a widely using in the industry. It is a relatively light metal compared to metals such as steel, nickel, brass and copper with a specific gravity of 2.7 gm/cm^3, the Chemical composition for Aluminium AA6061 is shown in Table-1.

Table-1. Chemical composition of Aluminium AA6061.

Component	Al	Cr	Cu	Fe	Mg	Mn	Si	Ti	Zn
Wt%	95.8-98.6	0.04-0.35	0.15- 0.4	Max 0.7	0.8-1.2	0.15	0.4-0.8	Max 0.15	Max0.25

Zinc stearate will be used as a binder to make the compaction process easier.

Production process for particle size

Firstly, chip was produced by using CNC milling machine, type HSM (SODICK - MC430l), Feed rate (1100 mm/min), Depth of cut (1.0 mm), cutting velocity (345.4 m/min). Then, aluminium chip particles were cleaned by ultrasonic bath apparatus. Type Fritsch (ultrasonic cleaner labarette 17). The duration was 1 hour for each patch. After that, it is treated with acetone solution for 20 min. Finally, the drying process was used by furnace type (Kuittho Linn High Therm) for 1 hour. Consequently, the chip was milled by planetary ball mill type (Retsch PM100) under conditions of the speed (350 r.p.m) and time (20) HR. The ratio of ball to powder (r.b.p) was 20:1. Finally, aluminium particles sieving was used by vibrator apparatus type (Fritsch analysette 3) with maximum interval time 5 second. Three sizes were classified (25, 63, 100) µm. Table-2 shows the classification of specimens according to particle size. So, Table-3 shows the classification of specimens according to applied to the Sintering temperature.

Table-2. Classification of specimens according to particle size.

AIII	Particle size (25 µm)
BIII	Particle size (63 µm)
CIII	Particle size (100 µm)
DIII	Mix (78.5% (25 µm) + 21.5% (100 µm))

Table-3. Classification of specimens according to applied to the Sintering temperature.

	Particle size (25 µm)	**Particle size** (63 µm)	**Particle size** (100 µm)	**Mix (78.5%** (25 µm) **+ 21.5%** (100 µm))
Applied for sintering temp. (487)ºC	AIII1	BIII1	CIII1	DIII1
Applied for sintering temp. (552)ºC	AIII2	BIII2	CIII2	DIII2
Applied for sintering temp. (617)ºC	AIII3	BIII3	CIII3	DIII3

Mixing and compaction

Ball mill machine was used for mixing the powders (1hr for time) and (300 r.p.m for speed) to make sure that the distribution was completed. The composition of mixture to produce the samples between (AA6061) and (Zinc stearate) was regular along the size that equal to 99% of AA6061 and 1% of zinc stearate.

Cold compaction of powder blends was performed in this study. Cold compaction was performed at room temperature (RT). In cold compaction, the mixed powder with a given amount of lubricant was pressed by uniaxial hydraulic operated press, the die was supported by two circular blocks of iron to allow uniform movement of the die during compaction, the cleaned surfaces of die wall and tools (upper and lower punch) were sprayed with a lubricant-saturated solution.

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Sintering process

Sintering process is to provide extra bonding between atoms. The atomic diffusion takes place and welded areas formed during compaction will increase the connection by sintering process. The sintering will be controlled over heating rate time; temperature and atmosphere are required for reproducible results.

The equipment used during sintering process is tube furnace. The inert gas used during the process is Argon gas. Then, enter the specimen metal (AA6061 specimen) into the tube furnace; the temperature used is followed by sintering profile Figure-1. Sintering Temperature was taken according to the rule.

Sintering Temperature = (0.7-0.9) Tm (1)

Hence: Tm = melting point

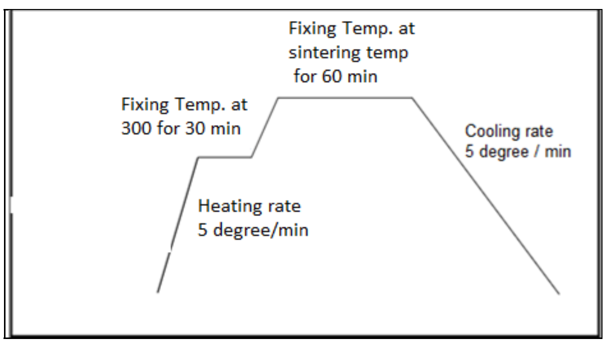

Figure-1. Sintering procedure.

2. RESULTS AND DISCUSSIONS

Compression strength, Microhardness and Microstructure were investigated in this study, the surface of a manufactured part generally has properties and behaviour that is considerably different from those of its bulk. Although the bulk material generally determines the component's overall mechanical properties, the component's surface directly influences several important properties and characteristics of the manufactured part. The compressive strength is the capacity of a material or structure to withstand loads tending to reduce size. It can be measured by plotting applied force against deformation in a testing machine. Some materials fracture at their compressive strength limit, others deform irreversibly, so a given amount of deformation may be considered as the limit for compressive load. Compressive strength is a key value for design of structures.

The effect of sintering temperature on compression strength

Figure-2 shows the relationship between compression pressure and the value of temperature for each group of selected powder. It can be seen that the value of compression pressure for the lower selected temperature was (150) Mpa For the powder (AIII1) while this value was (134) Mpa for (BIII1) that attributed to that the increasing at grain size cuases decreasing in grain boundaries (Barriers against crack growth), So the value was (117) Mpa at (CIII1) due to the particle size was (100 µm) .Whereas the (DIII1) was the bigger one which was (160) Mpa the attributed to particle size was varied ,therefore the barriers against crack growth were affected. On the other hand, the cracks were little amount at (DIII1) while were the more amount of the others.

The same figure shown is the relation between the sintering temperature and compression strength, Then, three values of sintering temperature were used which were (487, 552, 617) ºC. The value of compression strength on (487 ºC) was (134) Mpa. When the sintering temperature increased, the compression strength increased due to that the aluminium particle was more flexible and the bonding was stronger. Therefore, the compression strength on (552 ºC) was (160)Mpa. while the increasing of Sintering Temperature will be decreasing the compression strength.Hence, It is showed in Figure (2),then, the value of compression strength on (617 ºC) was (127)Mpa.

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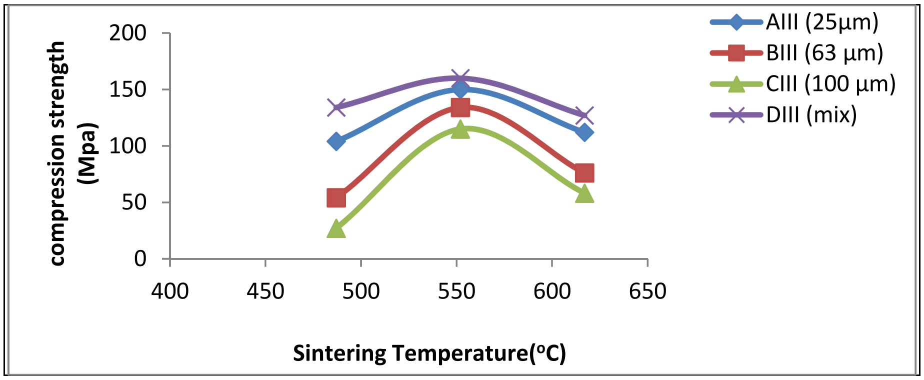

Figure-2. Relation between sintering temperature and compression strength.

Effect of sintering temperature on microhardness

Figure-3 shows the relation between sintering temperature and Microhardness. Four groups were taken for different particle sizes which were (AIII, BIII, CIII, DIII). Three sintering temperatures were used for each group. It can be seen that the Microhardness will be decreased with the increasing of sintering temperature. So, the Microhardness was related to the particle sizes. Therefore, the type (AIII) has Microhardness (63 Hv) is bigger than the types (BIII) and (CIII) which were (56.58Hv) and (49.55Hv) respectively, these results are attributed to the particle size of powder, while the type (DIII) has the biggest value which was (68.72Hv) due to the cracks were a little amount.

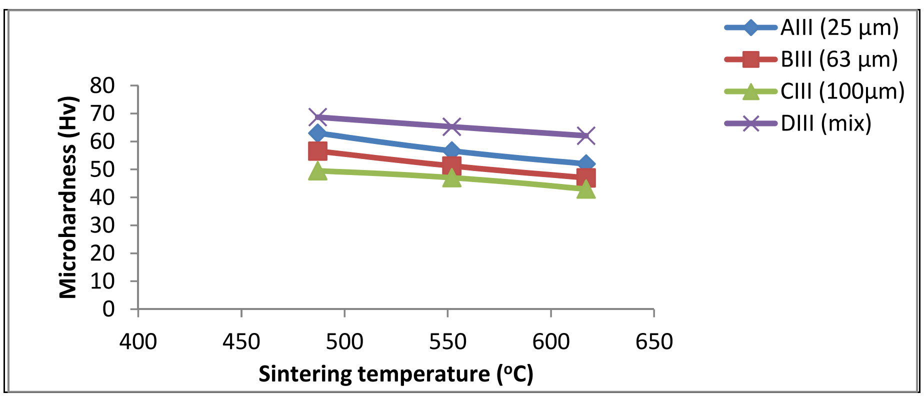

Figure-3. The relation between sintering temperature and Microhardness.

Effect of sintering temperature on microstructure

Overview and extensive knowledge have been given by Microstructure inspection. Every previous sample was inspected. Figures 4, 5, 6, 7 show the bonding and pores for every sample was tested. At sintering temperature equal to (487)°C, It can be seen many of pores due to the particle of aluminium didn't reach to enough temperature which it leads to bond the particles. While at sintering temperature (552) °C, it can be seen the pores become less than the previous temperature and the bonding becomes stronger. whereas at (617) °C, although the bonding becomes more but the crack becomes longer, therefore the strength becomes smaller.

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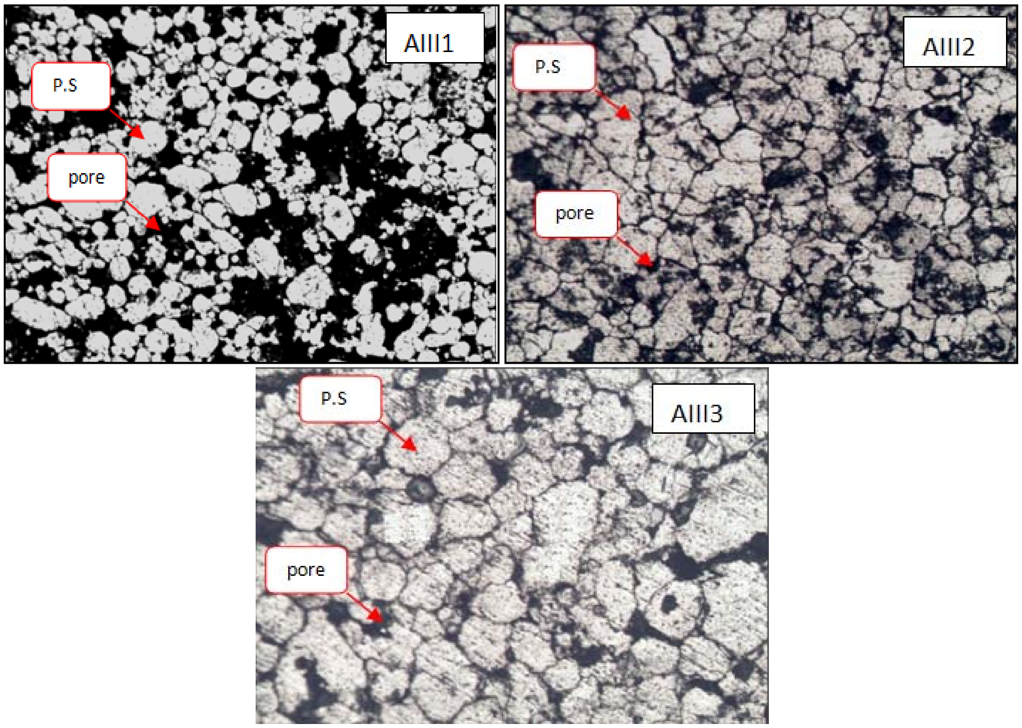

Figure-4. Effect sintering temperature on microstructure of AIII (25 µm powder).

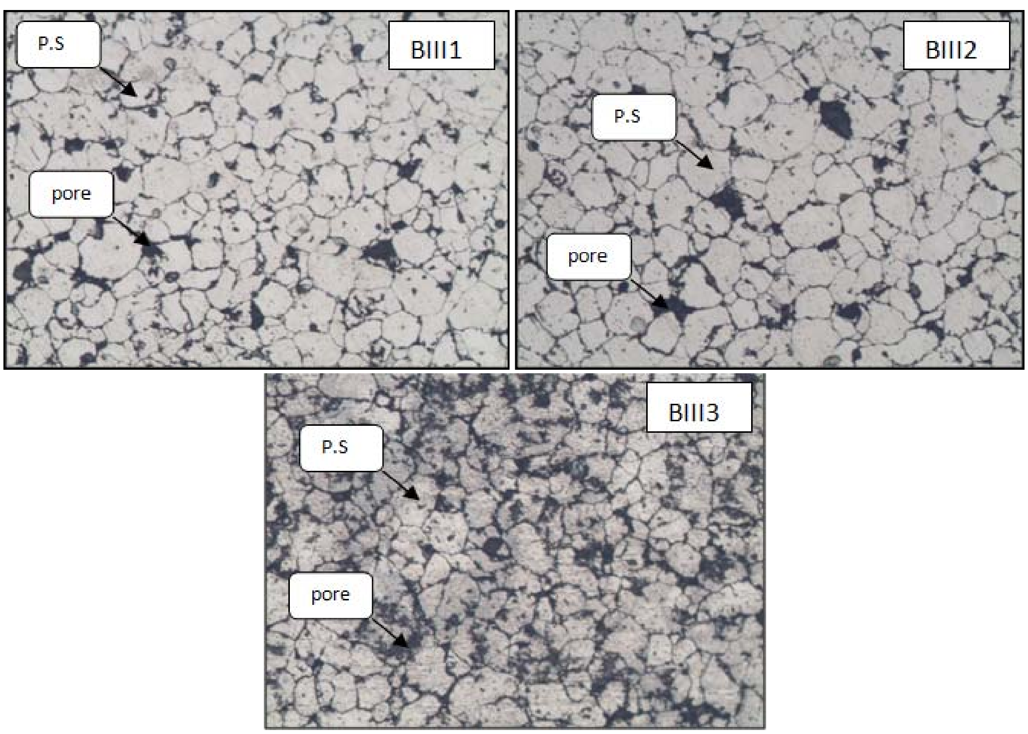

Figure-5. Effect sintering temperature on microstructure of BIII (63 µm powder).

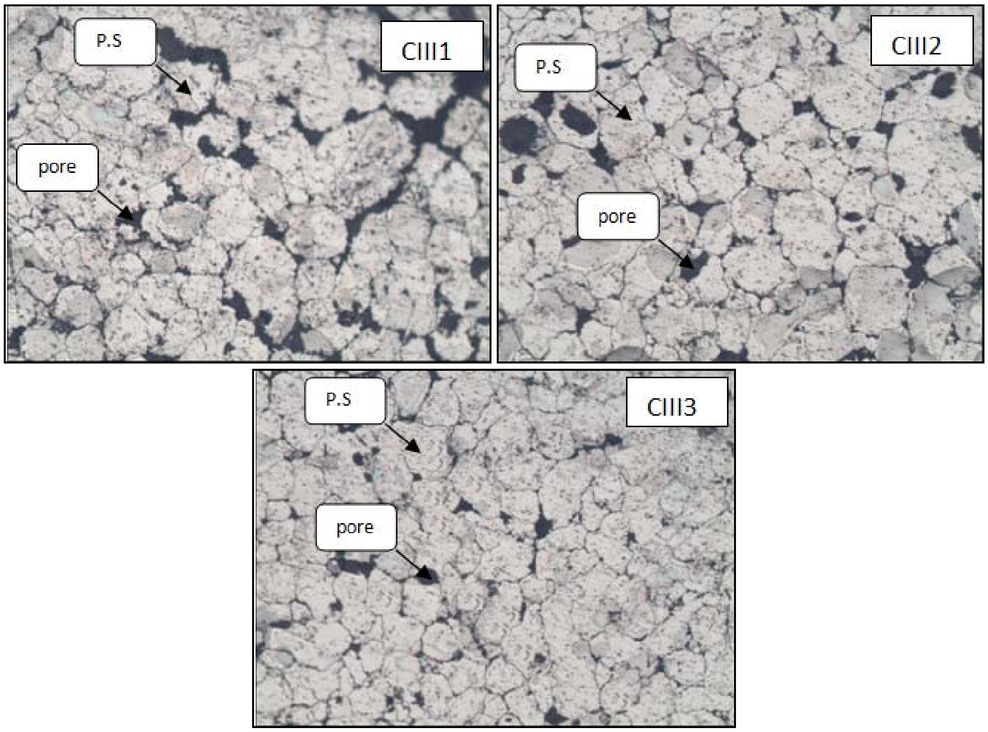

Figure-6. Effect sintering temperature on microstructure of CIII (100 μm powder).

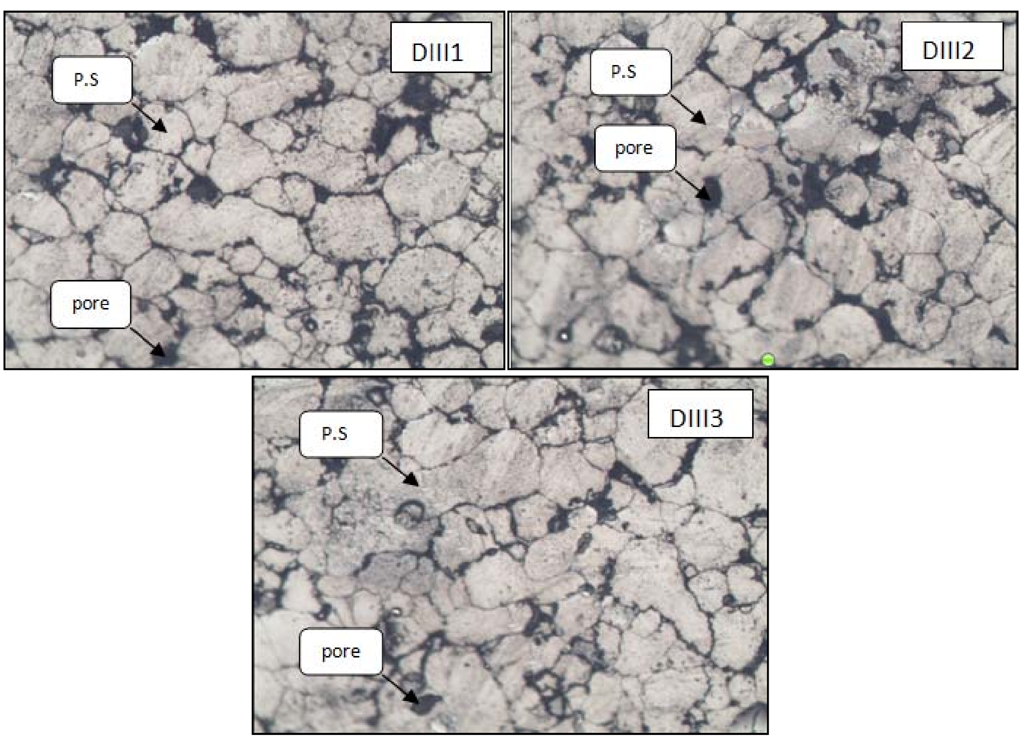

Figure-7. Effect sintering temperature on microstructure of DIII (mix powder).

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CONCLUSIONS

In this work, the chip sizes of AA6061 that produced from high speed milling are used and the mechanical property of the recycled chip of AA 6061 was studied. The mechanical properties test was used to maximize the ultimate compression strength for different particle size. Four groups were used for this study (25, 63, 100, mix of them) µm. It can be shown that the mix group (DII) has a bigger value for this study. On the other hand, three specimens were used for each group (487, 552,617) ^{O}C. It can be concluded that the Sintering temperature (552)^{O}C will be higher the Ultimate compression strength value and higher Microhardness value.

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