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Compression Strength and Microhardness of Recycling Milled Aluminium (AA6061) for Various Binder

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Abstract: **In this investigation, AA6061 milled particle size was fabricated by milling machine plus compacted by hydraulic press in room temperature. Finally, sintering in the temperature range of 552 ^{O}C. The samples were compacted by 9 tons. The holding time was 20 mins. Three groups of specimens were chosen (without binder, blended with zinc stearate binder and blended with polyethylene glycol 400 binder). Each group has tested by compression test , microhardness test and microstructure. The mechanical properties of the three groups depend on the type of binder. So, it is useful first to present and discuss the results of microstructure to understand the mechanical properties. In this study, the compression strength and microhardness values were increased with the using of zinc stearate binder due to the bonding between particles was stronger, in addition, the pores amount was decreased. On the other hand, the specimen (without binder) was decreased the compression strength and microhardness due to the particle size cannot slip well, it leads to more pores and the bonding was not stronge. An addition, polyethylene glycol has a value lower than the previous binder and better than without binder specimen.**

Keywords: **Binder, milling process, Micro-hardness, powder metallurgy, AA6061.**

I. INTRODUCTION

In the manufacturing technologies of P=M products, cold isostatic pressing (CIP) and die compaction are widely used. However, PM parts formed by die compaction have inhomogeneous density distributions due to the friction between the powder and the die wall [1]. Metal forming process, one of the most important parameters of metal products is the surface quality. Manufacturers always intend to improve the surface quality of metal products by employing all kinds of new technologies [2]. One of the common aluminium alloys used is the AA6061 alloy because of its high corrosion resistance, formability and strength. It is used in the automotive industry for body panels and bumpers, and in the aerospace industry for fuselage skins, among others [3]. Grinding mill circuits are the most energy and cost intensive unit processes in the mineral processing industry and therefore the study of the control systems for grinding circuits remains important[4] [5][6].

Grinding in ball mills is an important technological process applied to reduce the size of particles which may have different nature and a wide diversity of physical, mechanical and chemical characteristics. Typical examples are the various ores, minerals, limestone, etc. The applications of ball mills are ubiquitous in mineral processing and mining industry, metallurgy, cement production, chemical industry, pharmaceutics and cosmetics, ceramics, different kinds of laboratory studies and tests. Besides particle size reduction, ball mills are also widely used for mixing, blending and dispersing, amorphisation of materials and mechanical alloying [7] [8] [9].

Binder treatment or bonding has been well established in the PM industry and is currently used for a variety of applications. Binder treatment has progressed from simply reducing segregation and improving flowability to a process that can be engineered to improve green strength, green density and dimensional change, as well as improving the pressing and ejection of parts. Bonding is used to prevent segregation of powder premixes by attaching smaller additives such as graphite, metallic alloying elements, and lubricant to the base iron [10].

The purpose of this research was to study the influence of the binder on the compression strength during the cold compaction process. The research was conducted at Metallurgy Laboratory, UTHM, Malaysia.

II. EXPERIMENTAL WORK

A. 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 (ASTM B308/B308M)

Ele.	Wt %	Ele.	Wt %	Ele.	Wt %
Si	0.59	Mn	0.08	Zn	0.031
Fe	0.092	Mg	0.975	Ti	0.1
Cu	0.289	Cr	0.2	Al	Rem

Zinc stearate and polyethylene Glycol 400 ($HO(C_2H_4O)_nH$) will be used as a binder to make the compaction process easier.

B. Chip production:

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).

C. Chip cleaning and drying:

Milled aluminium 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.

D. Milling process:

After that, 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.

E. Aluminium particles sieving:

Aluminium particles sieving was used by vibrator apparatus type (Fritsch analysette 3) with maximum interval time 5 second. Three sizes were classified (25,100) µm.

F. Mixing theory:

The high performance of the percentage of particle size is referred to as milled particle size bulk having mechanical properties exceeding that of normal strength of milled particle size. This is a type of particle size specially designed to meet a combination of variable particle size to achieve the requirements which specifically include high strength. The figures 1 & 2 illustrate the concept of mixing method for particle size.

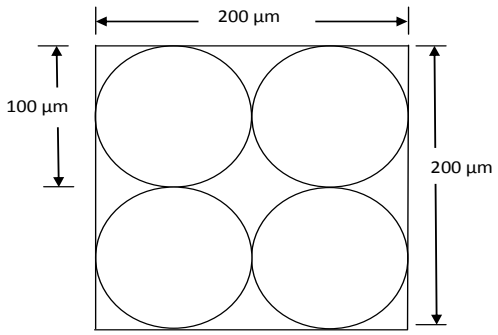

Figure. 1 The Concept Of Mixing Method For Particle Size

Figure. 1 shows the relationship if the particle size is 100 µm has been taken. Thus, The area of particle size is ($A = \pi r^2$) (7850 µm^2). The the area of all four particles is (31400 µm^2). The area of the square is (40000 µm^2).

The ratio of particle size to the square $= \frac{The\ area\ of\ particle\ size}{The\ area\ of\ square}$

$$= \frac{31400}{40000}$$

$$= 78.5\%$$

In this sample, the content is (78.5% (100µm) + 21.5% (25µm))

But in this paper, the volume fraction of the particle size was (50% (25µm) + 50% (100µm)). Then, three samples were taken. The first one was as compacted. The second was mixed with polyethylene glycol as a binder. The last one was mixed with zinc stearate powder as a binder.

G. 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, polyethylene glycol) were regular along the size that equal to 99% of AA6061 and 1% of the binder.

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

H. 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 as shown in Figure. 2, the inert gas used during the process is Argon gas. Then, enter the specimen metal (Aluminium and metal carbide) into the tube furnace, The temperature used is followed by sintering profile

Sintering Temperature = (0.7-0.9) Tm

Hence: Tm = melting point

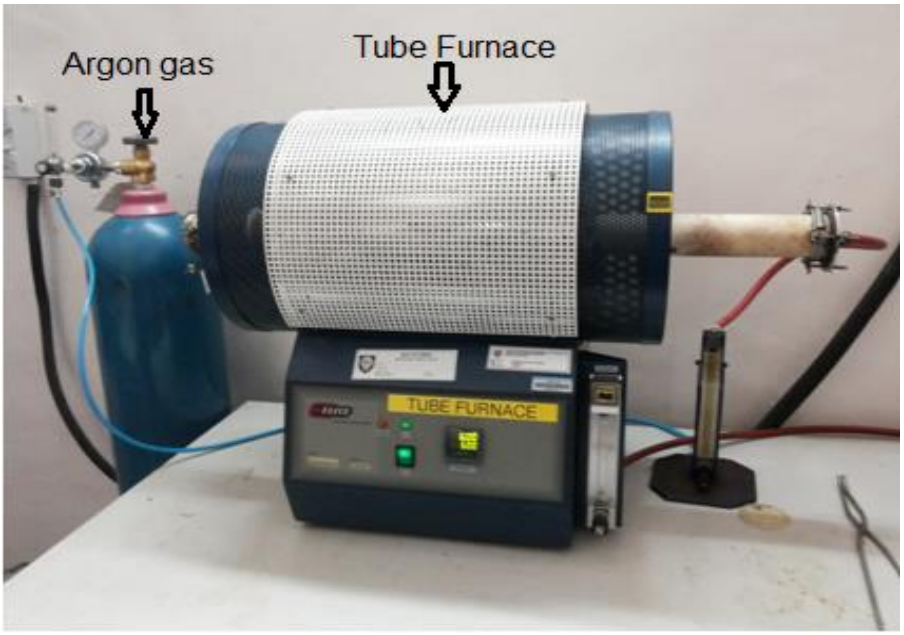

Figure. 2 Sintering Furnace

III. RESULTS AND DISCUSSION

It is possible to accomplish the process of pressing the powder on many of the powders at various pressing conditions without relying on optimal conditions with compression strength. But in this case, the compaction piece is of durability is weak and there is a high probability of exposure to failure when it is used due to the various problems take place during the compaction process such as pores and weak bonding. Therefore, compression strength has been studied in this paper.

A- The effect of binder content on compression strength:

Binder treatment or bonding has been well established in the PM industry and is currently used for a variety of applications. Binder treatment has progressed from simply reducing segregation and improving flowability to a process that can be engineered to improve green strength, green density and dimensional change, as well as improve the pressing and ejection of parts. Three specimens were taken to prove the effect of binder on the compression strength (A, B, C) as shown in the table-2.

TABLE-2 CLASSIFICATION OF SPECIMENS

Specimen	Percentage of particle size	Compacting pressure (tons)	Holding Time (Min)	Sintering Temp. (^{o}C)	Binder
A	50% (25µm) + 50% (100µm)	9	20	552	Zinc stearate
B	50% (25µm) + 50% (100µm)	9	20	552	Without
C	50% (25µm) + 50% (100µm)	9	20	552	Polyethylene glycol 400
D	25µm	9	20	552	Zinc stearate
E	100µm	9	20	552	Zinc stearate

Two specimens were taken for this test. Figure-4 illustrates the effect of binder existence in constituents of the specimen on compression strength. It can be seen that the specimen type (G) has bigger value, compare with the specimen (H). So, compression strength was (161.61) for specimen (G) while it was (122.32) for specimen (H). The increasing percentage of compression strength value for specimen (G) is 32% of the value of specimen (H).

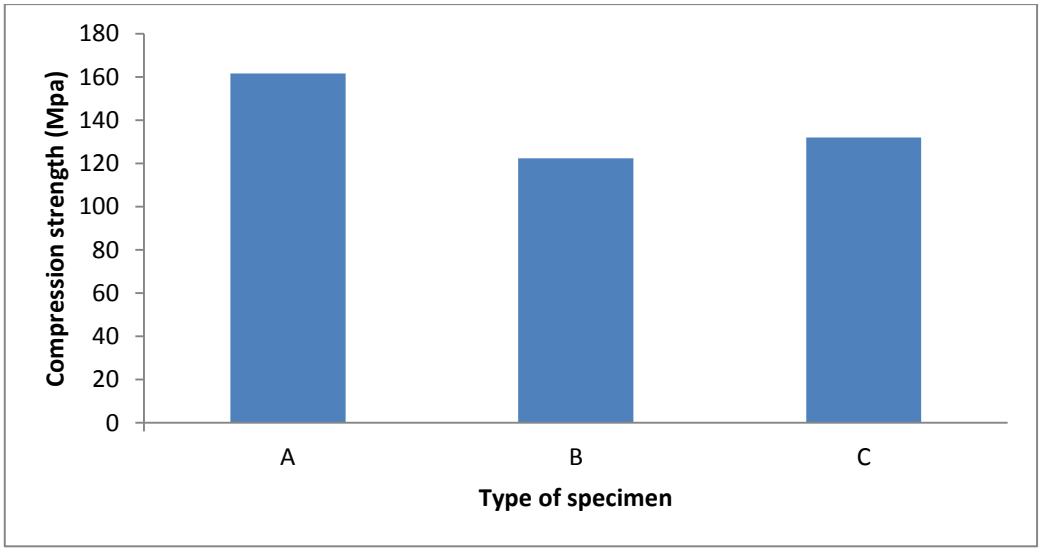

Figure-4 The Effect Of Binder Existence In Constituents Of Specimen Of Compression Strength

Three samples were chosen to discover the relation between particle size and compression strength. Figure-5 shows the relation between particle size and compression strength for specimens A, D and E. It can be seen that the small size of particle size was better than large size which were (150 and 115) MPa respectively. So, the specimen of mix between 50%

of 25 µm and 50% of 100µm was better than the others which were 161.6 MPa. The increasing of strength attributed to that the various of particle size of specimen will be decreased the volume of pores. Therefore, it will be increased the bonding between the particles that lead to increasing the compression strength.

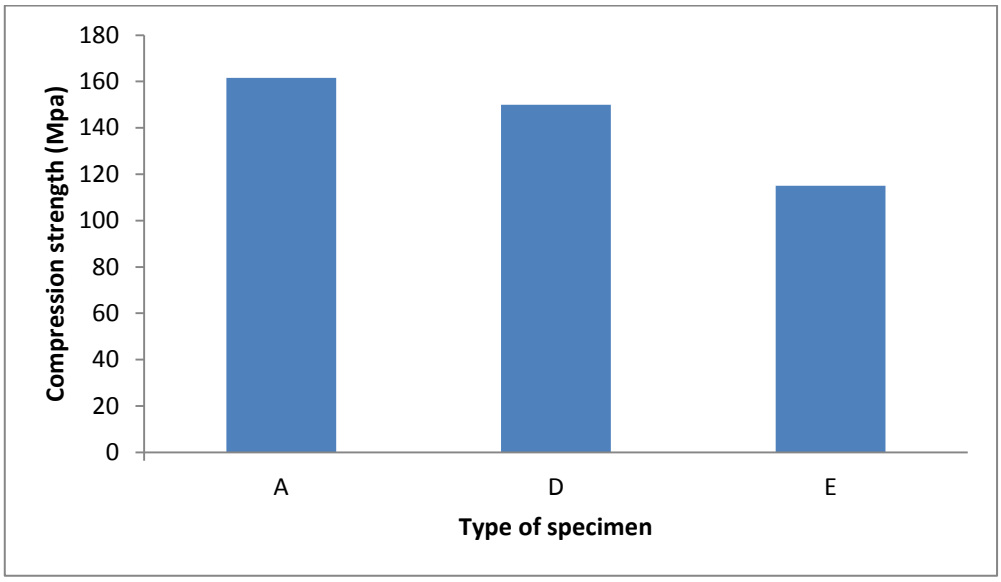

Figure-5 The Relation Between Particle Size And Compression Strength For Specimens A, D And E

B- Effect of the percentage of particle size on Microhardness:

The Vickers method is based on an optical measurement system. The Microhardness test procedure, ASTM E-384, specifies a range of light loads using a diamond indenter to make an indentation which is measured and converted to a hardness value. It is very useful for testing on a wide type of materials as long as test samples are carefully prepared. A square base pyramid shaped diamond is used for testing in the Vickers scale. Typically loads are very light (a few grams). The test force was applied for this test was (980.7 mN). So, three times of the test were examined for each specimen. Then, the average was taken of these results.

Three samples were chosen to measure the effect of particle size with zinc stearate binder. Figure-6 shows the relation between particle size with zinc stearate as a binder and microhardness.

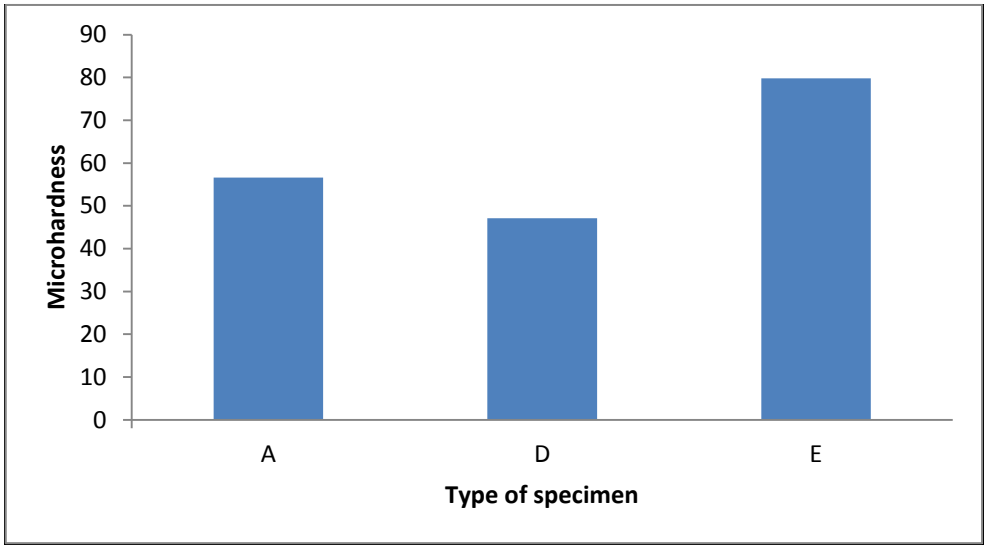

Figure-6 Shows The Relation Between Particle Size With Zinc Stearate As Binder And Microhardness.

It can be seen that the small size of particle size was better than large size, which were (56.6 and 47.09) Hv respectively. So, the specimen of mix between 50% of 25 µm and 50% of 100µm was better than the others which were 79.79 Hv. The increasing of hardness attributed to that the various of particle size of the specimen will be decreasing the volume of the pores. Therefore, it will be increased the bonding between the particles that lead to increasing the microhardness value.

C- Effect of binder on Microstructure:

Figure-7 shows the microstructure of the specimens A, B and C. Two types of binder were taken (Zinc stearate and polyethylene glycol). It is observed from the figure, the specimen B has more pores and it has concluded lowest compression strength, so the specimen A can be seen on microstructure has lower pores, higher bonding and higher compression strength. That means, the using of zinc stearate binder leads to an increase in the strength and Microhardness of compacted metal.

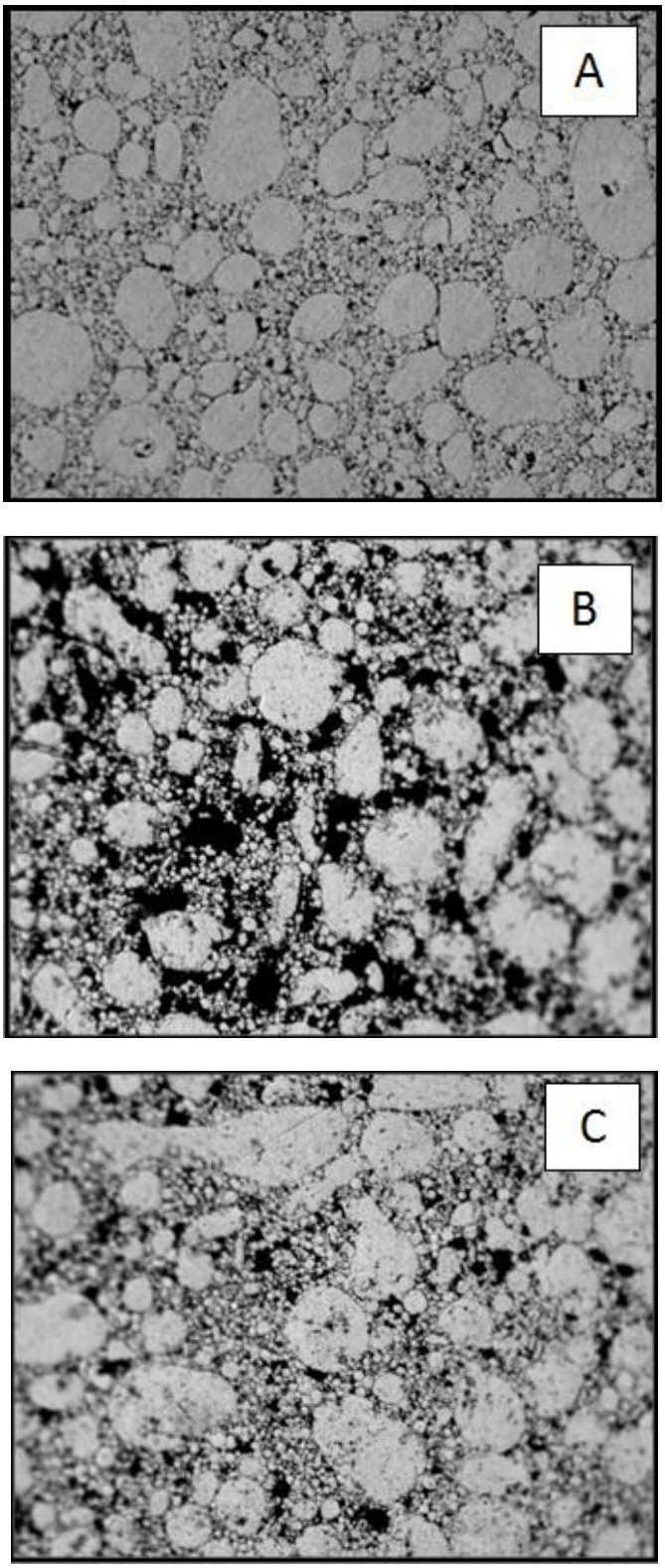

Figure-7 Microstructure For Specimen A, B AND C (50% (25µm) + 50% (100µm))

IV. CONCLUSIONS

According to investigations, it is revealed that the selection of binder type designed experiments was successfully conducted. So, we can be concluded the relationship between the selection of binder type and compression strength is so important to discover about the strength of the specimen. In this study, the maximum value for compression strength was detected in 50% (25µm) and 50% (100µm) (specimen type A).

On the other hand, high Microhardness value was given by the same specimen (50% (25µm) and 50% (100µm)) (specimen type A). Whereas, the others have been given lower value.

V. FUTURE SCOPE

AA6061 is an important metal in the industry. Many of parts were fabricated by it in many applications. Mechanical properties should be invested. The creep and fatigue life is so important to investigate. On the other hand, particle size and other parameters for compaction method are also important to investigate.

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