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EFFECT OF COMPACTION PRESSURE ON MECHANICAL PROPERTIES OF ALUMINIUM PARTICLE SIZES AA6061Al ALLOY THROUGH POWDER METALLURGICAL PROCESS

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ABSTRACT

Recently Aluminium alloy, exclusively 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 compacted pressure (5, 7, 9) tons, the holding time and sintering temperature were constant (20) min, (552) ºC respectively. The result of mechanical properties shows that the compression strength increase with increasing compaction pressure for all groups and the various of particle size (mix) will be given the best compression strength (134Mpa) due to it will be given a smaller amount of pores. Whereas the others have less value due to the large amount of pores. Micro-hardness has been getting the large value of the mix group (61HV), while the others have less value. Therefore, it can be concluded that, cold press forging for powder metallurgy could be one of the alternative production process instead of the conventional method that has been carried out melting phase, which contributes to a sustainable manufacturing process technology in the future.

Keywords: powder metallurgy, MMC, mechanical properties, cold compaction.

INTRODUCTION

The melting process of reuse for aluminium metal give many pollution effects to the environment. Aluminium is the most heavily used nonferrous metals in the world [1].

Aluminium alloys are very favourable for structural applications in aerospace, military, and transportation industries due to their low density, high specific strength and resistance to corrosion, and especially as regards high energy cost [2]. In comparison with the unreinforced aluminium alloys, aluminium matrix composites reinforced with ceramic phases exhibit higher strength and stiffness, improved tribological characteristics, and increased resistance to creep and fatigue [3]. 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 [4]. Aluminium Matrix Composites (AMCs) refer to a class of lightweight, high performance aluminium centric material systems. In the present script, aluminium is the one of the most popular matrix for the metal matrix composites. Predicting composite behaviour continues to improve with promoting scientific understanding and modelling capability, allowing much more effective and reliable use of these complex materials [5]

Current engineering applications require materials that are stronger, lighter and less expensive. A good example is the current interest in the development of materials that have good strength to weight ratio suitable for automobile applications where fuel economy with improved engine performance are becoming more critical [6]. In-service performance demands for many modern engineering systems require materials with a broad spectrum of properties, which are quite difficult to meet using monolithic material systems [7], Metal matrix composites (MMCs) have been noted to offer such tailored property combinations required in a wide range of engineering applications [6,7]. Some of these property combinations include: high specific strength, low coefficient thermal expansion and high thermal resistance, good damping capacities, superior wear resistance, high specific stiffness and satisfactory levels of corrosion resistance [8]. Aluminium alloy is used in many applications due to light weight, excellent weld ability, and corrosion resistance. The use of aluminium alloys in automotive structural application is rapidly growing. In terms of fatigue strength, aluminium alloys still offer lower fatigue strength than high strength steel. On the other hand, as an alternative to steel, aluminium is potentially increasing the efficiency of vehicles by providing a lower weight [9].

Cold compaction is a chipless metal-forming process, which employs an incremental compact pressure technique. To meet the structural strength requirements, components for aerospace applications are usually manufactured through cold working [10]. Many process factors affect the effectiveness of the compaction process. The main purpose of this paper is to establish the effect of

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compaction pressure on compression strength and surface integrity that influence the plastic deformation of AA6061 particles during the compaction process. This can be determined through a series of experiments by using optical electron microscope.

EXPERIMENTAL WORK

Material

The material used in the present investigation is AA6061 alloy. The alloying elements are shown in Table-1. AA6061 has moderate strength, excellent corrosion resistance and high plane strain fracture toughness. The main components of the heat treatable AA6061 alloy are Mg and Si. The alloy derives its strength from the precipitation-hardening phase Mg_2 Si. AA6061 has an ultimate tensile strength of (310) MPa, yield strength of (275) MPa and hardness of around (106) Hv.

Table-1. The alloying elements for AA6061.

Cu	Fe	Mn	Si	Mg	AL
0.20	0.40	0.07	0.54	0.80	Bal

Zinc stearate was used as a binder in this research. Therefore, four types of particle sizes were used. Table-2 shows the classification of specimen.

Table-2. Classification of specimens.

P.S / Load (Tons)	A (25μm)	B (63 μm)	C (100 μm)	D(mix*)
5	A1	B1	C1	D1
7	A2	B2	C2	D2
9	A3	B3	C3	D3

Mix = 78.5% (100 μm) + 21.5% (25 μm)
P.S = particle size (μm)

Aluminium powder compaction

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 of Acrawax C in acetone (10 g of Acrawax C and 100 ml of acetone), prior to each compaction event.

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 , 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 Figure. Sintering Temperature was taken according to the rule.

Sintering Temperature = (0.7-0.9) Tm
Hence: Tm = melting point

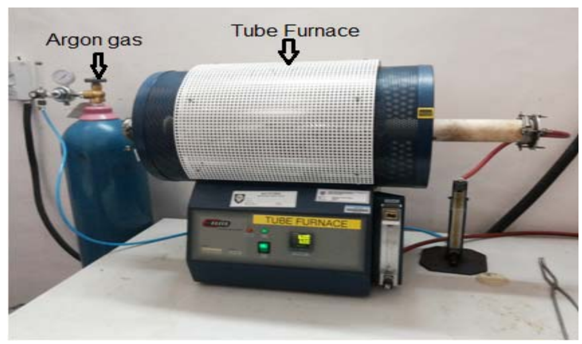

Figure-1. Sintering furnace.

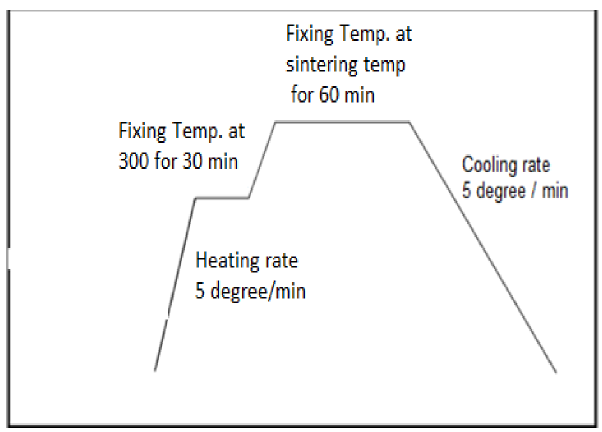

Figure-2. Sintering procedure.

RESULTS AND DISCUSSION

This passage includes the experimental results and their discussion. Aluminium powder type (AA6061) was used in this research. Four types of particle sizes were inspected, which were (25, 63,100, mix) μm. The effect of compacted pressure was experimentally evaluated from compression test. These inspections are very useful to determine the variations in the bonding between the powder particles. The mechanical properties of the four groups depend on the variations in particle size for powder and the pores between particles. Therefore, it is useful first to present and discuss the results of microstructure to understand the strengthening mechanism.

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Effect of compaction pressure on compression strength

The compaction pressure is a significant effect on the sample resistance. Figure-3 describes the relationship between the Compaction pressure and sample strength for all the suggested samples. Four values of compaction pressure were used. The values were 5, 7, 9 and 10 Tons. It is noted that the sample strength increases with increasing of hanging compaction pressure for all the suggested samples (A, B, C, D).

On the other hand, mix type has been gotten for maximum value of compression strength (134 Mpa) while the minimum value was (43 Mpa) for (100 μm) type, whereas the values of (25 μm) and (63 μm) were (109 Mpa) and (59 Mpa) respectively.

It is clear from this, when low compaction pressure was applied lead to be weak bonding between the particles while at a high compaction pressure has high bonding.

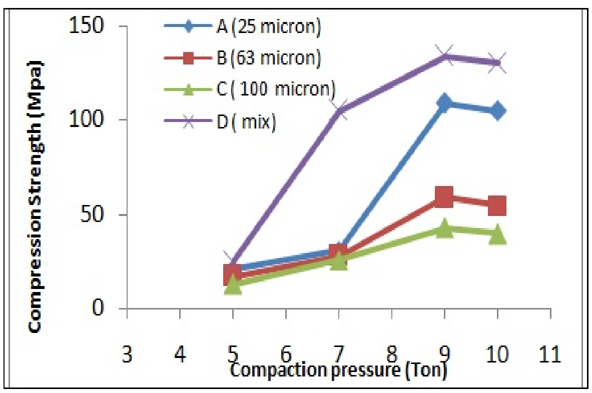


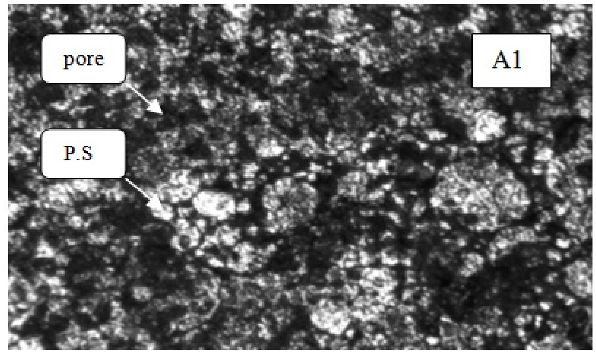
Figure-3. Relation between compaction pressure and compression strength for A, B, C and D.

Effect of compaction pressure on microstructure

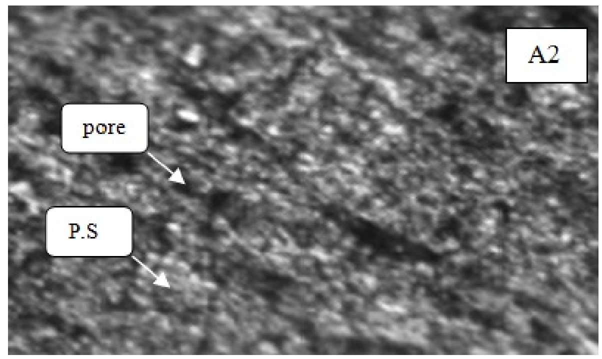
Various types of technologies are used to observe and characterize the microstructure of aluminium alloy on different scales. Microstructure observation is conducted by using Optical Microscope. This apparatus is widely used to observed polish sample to obtain qualitative information about the size, shape and orientation of grains. The solid cylinder shape was fabricated for this test, (13) mm diameter (10) mm height

Figures-4, 5, 6 and 7 show effect compaction pressure on Microstructure.

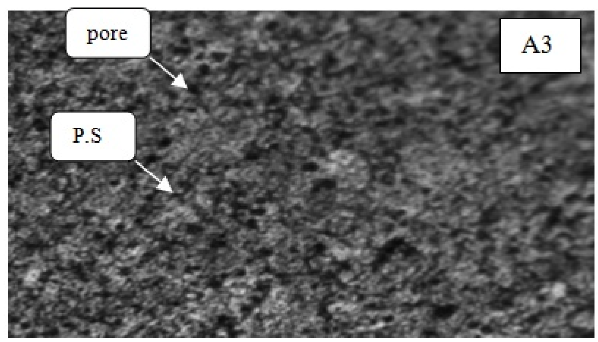
The figure below shows the specimen (A1) has compaction pressure (5) tons. Therefore, it has a large amount of pores. While the specimen (A2) has the smallest amount of pores due to the compaction pressure was bigger. Hence, the specimen (A3) has a few amounts of pores.



(a)Applied (5) tons

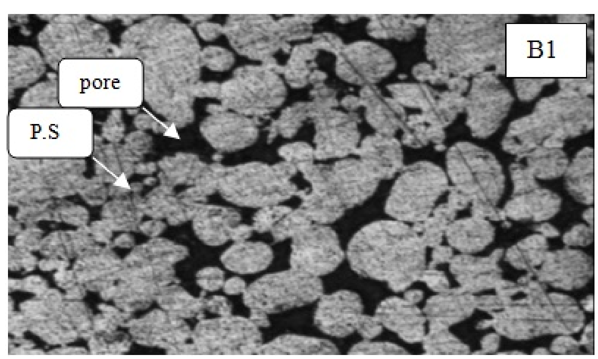


(b)Applied (7) tons



(c) Applied (9) tons

Figure-4. Effect compaction pressure on microstructure of A (25 μm powder).



(a) Applied (5) tons

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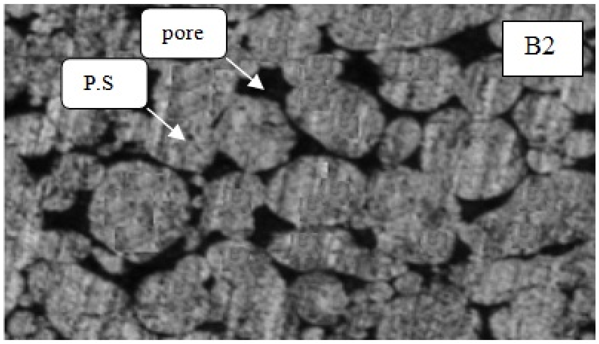
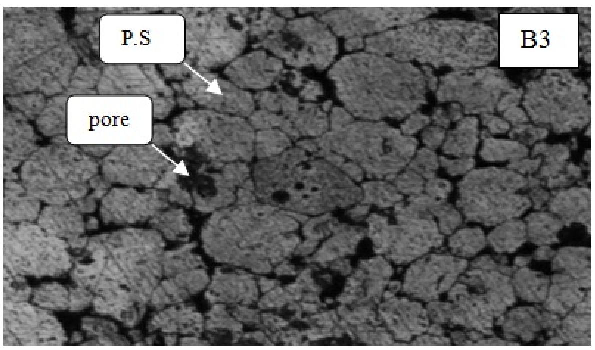
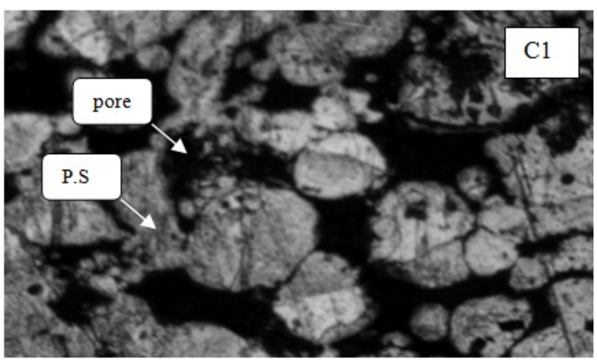


(b) Applied (7) tons

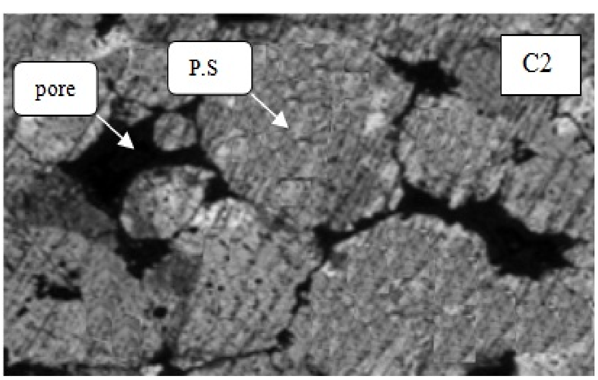


(c) Applied (9) tons

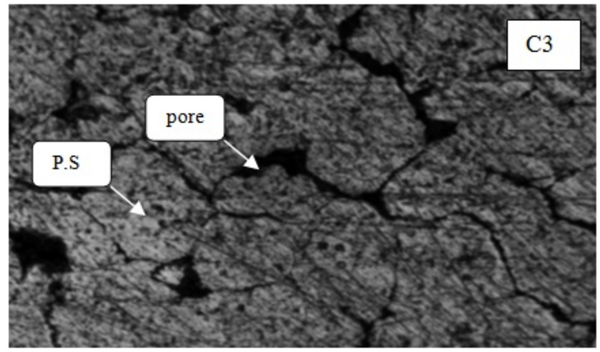
Figure-5. Effect compaction pressure on microstructure of B (63 μm powder).



(a)Applied (5) tons



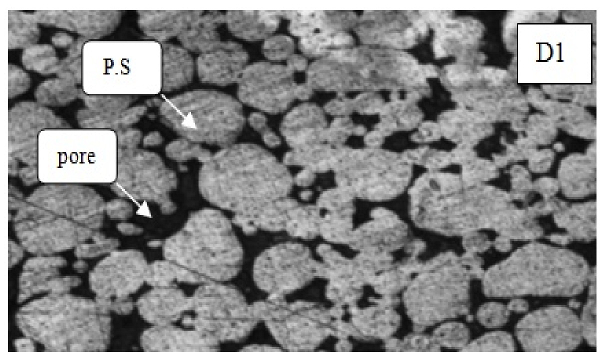
(b) Applied (7) tons



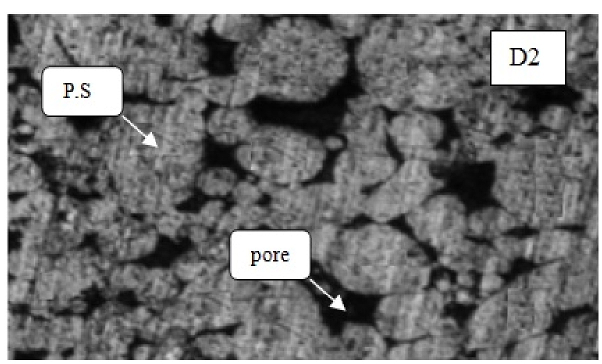
(c) Applied (9) tons

Figure-6. Effect compaction pressure on microstructure of C (100 μm powder).

The previous figures show the optical microstructure of aluminium alloy AA6061 particle size (25, 63, 100, mix) μm. As observed, the fine particle size (25) μm produced a little amount of pores, while the bigger size (63 , 100) μm was more pores, whereas the mix was smaller amount of pores, therefore, it can be concluded, the compaction pressure treated as inverse proportional to amount of pores. Consequently, the production the little amount of pores was the required goal, therefore, the best compaction pressure was the bigger one. On the other hand, it can be seen in the amount of pores at mix microstructure was the smaller one, therefore, the best powder was the mix type.



(a)Applied (5) tons



(b) Applied (7) tons

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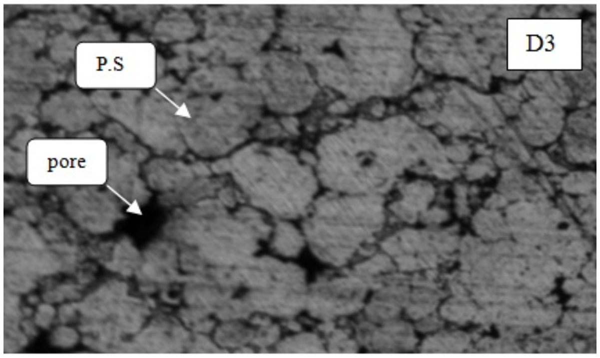

(c) Applied (9) tons

Figure-7. Effect compaction pressure on microstructure of D (mix powder).

Effect of compaction pressure on microhardness

Hardness gives good idea about 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. Usually the material suffering from elastic deformation then the plastic deformation.

In this test, eight values for each sample was taken to calculate the average. Figure (8) shows the relationship between compaction pressure and Microhardness for the groups (A , B , C , D).

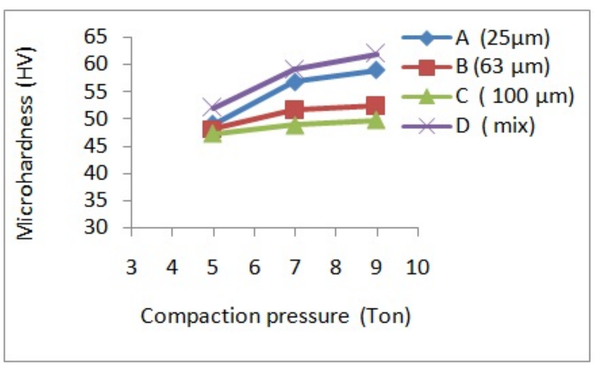

Figure-8. The relationship between compaction pressure and micro-hardness for the groups (AI, BI, CI, DI).

Four groups for micro-hardness was noted. The biggest one was (D) because it has a large amount of grain boundaries, therefore it has big value of hardness which was (61HV) . While (C) has the lower one, which was (49HV) due to it has big particle size and pores. Whereas (A) and (B) have values between them which were (59HV) and (52HV) respectively.

On the other hand, we can be seen from the chart, it is noted the value of micro-hardness increase with increasing compaction pressure for all suggestion samples. Therefore, it was noted the maximum value of micro-hardness of the specimen which contain on the less value of pores. While the minimum value of micro-hardness contains large amount of pores.

Generally, the relationship between compaction pressure and hardness is Direct proportional.

CONCLUSIONS

Based on investigations, it is revealed that the powder metallurgy designed experiments were successfully conducted. So, we can be concluded the relationship between compaction pressure and mechanical properties (compression strength and micro-hardness). When compaction pressure was increased, the compression strength and micro-hardness increased.

On the other hand, high compression strength and micro-hardness were given by the mix particle size specimen. Whereas, the others by single particle size have been given higher compression strength and micro-hardness by using smaller particle size. In addition, the increasing of compacted pressure has led to decreasing of the pores and increasing of contact points. So, Direct proportion was detected between the compaction pressure and the hardness.

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