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The Effect of Microstructures and Hardness Characteristics of Recycling Aluminium Chip AA6061/Al Powder on Various Sintering Temperatures

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Abstract: Aluminium is a metal that has been widely used for commercial applications in the transportation, construction and aerospace industries. Previous studies on recycling aluminium have shown that a lot of energy was used to recycle the aluminium by using conventional method. Therefore, this study was carried out to discover the effect of sintering temperature on physical and mechanical properties of the recycled aluminium chip (AA6061) and aluminium powder with the particle size of 25µm by using a direct conversion method which is the powder metallurgy has been used. The samples were fabricated by using hydraulic press machine at 9 tonnes for 20 minutes. Since this study was focused on the sintering temperature, the samples were sintered at four different temperatures which were 520°C, 552°C, 585°C and 617°C. This study involved two types of tests which were the physical and mechanical test. The physical test involved microstructure observation, density test, porosity test, whereas, the mechanical test involved hardness test. Based on the results obtained, it can be concluded that the sintered temperature at 552°C was the best result of sintered sample to obtain better physical and mechanical for the recycled aluminium chip (AA6061).

Keywords: AA6061, recycling aluminium, powder metallurgy, sintering, microstructures, hardness

1. Introduction

Aluminium actually can be defined as global metal because it can be found everywhere, especially in manufacturing industry. Recycling is a process to alter of waste material to become a new product. It is used to overcome the waste of potentially useful material, reduce consumption of raw material, reduce energy usage, reduces water pollution and air pollution [1].

Even recycling is very common to us but most people do not realise is that aluminium is the perfectly ideal recyclable material. Apart from usual recyclable material clutter up our landfill; paper, plastics, metals, glass, electronic part and textiles, aluminium is one of the materials that endlessly repeats recyclable [2].

Metal always become the most recycled material in industry. The recycling of waste metallic material and use of scrap is important for the economic production of steelworks [3], in fact, the making of steel requires recycled steel in the production of raw material [4]. Furthermore, some of the ways for a steel production to save energy and reduce the consumption of natural resources is recycling metals. This is indicated everything that containing metals is hugely valuable and also depict in future demand on metals especially aluminium in transportation and construction sector really give a high impact of growth and well develop [5].

Recycling aluminium uses about 5% to 15% of the energy required to create aluminium from bauxite; the amount of energy required to convert aluminium oxide into an aluminium can be vividly seen the process is reversed during the combustion of termite [6-7].

Direct conversion for recycling aluminium contributes high efficiency and about 80% green density (before sintering), plus this newest technology release very little air pollution and high metal reduction as compared to conventional methods. Moreover, conventional method discharges losses at each stage of the recycling process and needs many further operations in order to lower. The energy consumption, the cost of labour and environmental protection is also high [8].

In fact, powder metallurgy and direct recycling technique offer better recycling process, relatively simple, decrease energy using up as well as minimise the overall cost of the process. Even though, there are still many restrictions in the powder metallurgy technique that more volume of the metal powder produced, more material oxidised and lead to lower physical properties. But, due to its low cost and multipurpose processing, powder metallurgy become the one most widely used method for recycling aluminium [7].

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Powder compaction is mainly the process of compacting metal powder in die through the application of desired suitable high pressures. Uniaxial hydraulic pressing is classified as an old technology, but it is the shaping technology that provides for high production capability at low prices mostly when compared to highly sophisticated like other ways, such isostatic pressing. Hence, it is always valuable to take account of this technology when a product becomes marketable and a suitable production process needs to develop [9].

2. Materials and Experimental Procedures

Aluminium AA6061 block with a theoretical density of 2.7 g/cm^3 was used as the metal matrix material in this study. Whereas, the aluminium powder used came with an average particle size of 25 µm. Both of this aluminium block and powder were supplied the Newspark Technology and Chengdu Best New Materials Co., Ltd., China. Aluminium chips were produced by using CNC milling machine type High-Speed Milling (SODICK – MC4301), feed rate (1100mm/min), depth of cut (1.0 mm), cutting velocity (345.4 m/min).

2.1 Compaction process

Metallic powder was performed by a cold process at room temperature. The die surface and tools (upper and lower punch) were cleaned and sprayed with a lubricant saturated solution. The manual handling pressing of the powder will begin with the mixed recycled aluminium (AA6061) with aluminium powder is placed in the die, the upper punch slowly compressed to the power according to desired pressure and holding time. This experiment uses pressure at 9 tonnes with 20 minutes holding time each of samples. The compaction machine that was used in this process is Carver unheated manual hydraulic press series 3851.

2.2 Sintering process

Sintering is a part of heat treatment process to bond the metallic particles, thereby improving strength and hardness. After done with the compacting process, the samples undergo sintering process. The pressed sample was sintered at four different temperatures, 520˚C, 552°C, 585°C and 617°C with pressure 1 atm for eight hours with heating rate 5˚C/min. The sample was sintered in a tube furnace (Elite Thermal System Ltd/30A power Supply/75mm Ø alumina Tube/Horizontal operation) and argon gas was inserted into the furnace to address the metal oxidation occurs. Fig. 1 show the sintering profile.

The sintering profile has 5 stages which were the label from i-v in the Fig. 1. The 5 stages represented the processes as following:

i. Heating up to the temperature of 300°.
ii. Binder burnout for 30 minutes.
iii. Heating up to the desired sintering temperature (520°, 552°C, 585°C and 617°C).
iv. The samples were sintered for 60 minutes.
v. The process of cooling down.

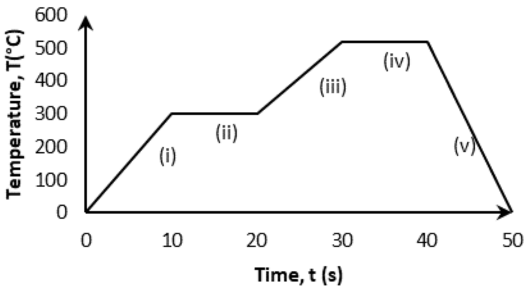

Fig. 1 Sintering profile.

3. Results and Discussion

3.1 Microstructural analysis

The image captured using optical microscopic at low and high magnification shows the existence of pores and grain boundaries of a sample body.

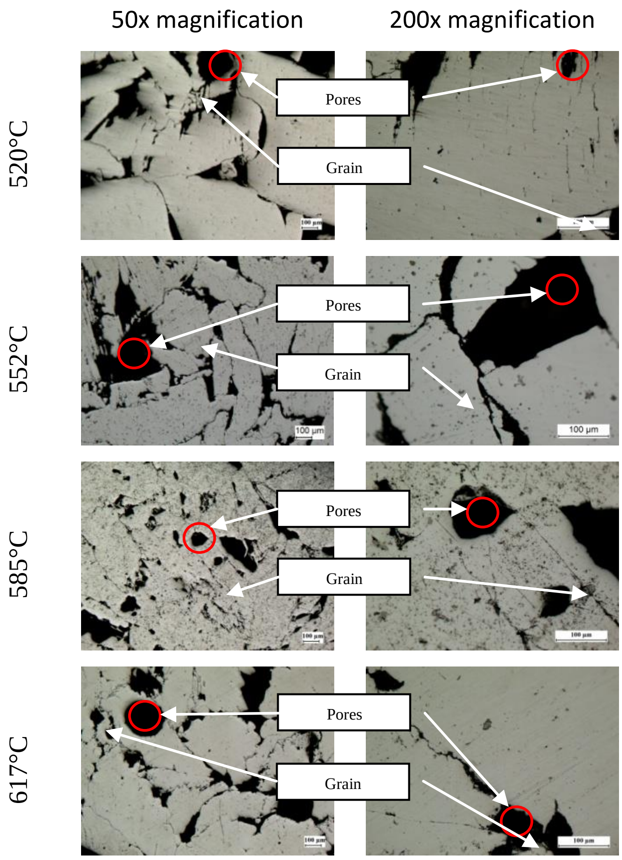

Fig. 2 The microstructure analysis of recycled aluminium (AA6061) at four different sintering temperature.

From Fig. 2 and 3 shows the microstructure surface of the recycled aluminium chip (AA6061) and aluminium powder with four different sintering temperature (520°C, 520°C, 585°C and 617°C) through image at 50x and 200x magnification with 100 µm scale written on the image.

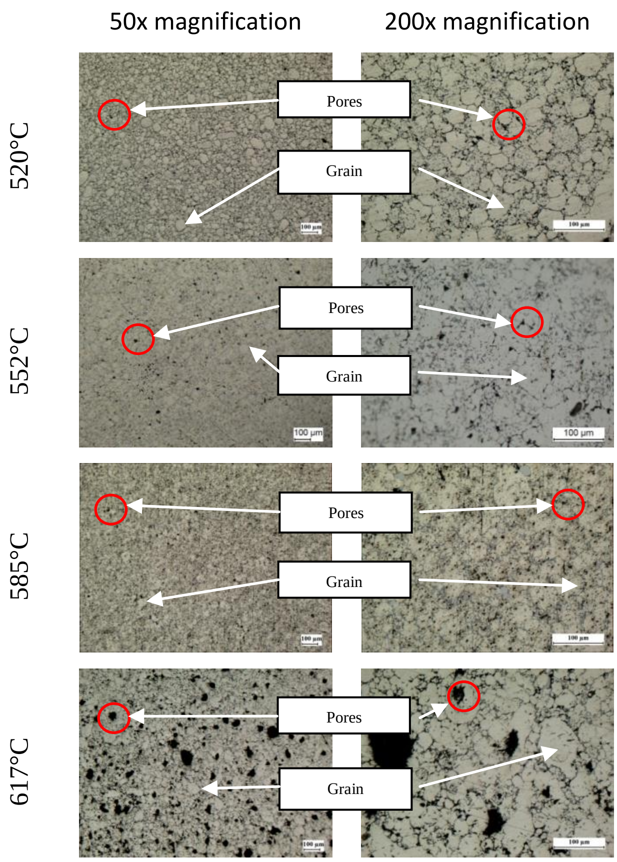

Fig. 3 The microstructure analysis of aluminium powder at four different sintering temperature

It can be observed that at 552°C of sintering temperature, the distribution and orientation of the particle are tightly and the presences of pores are fewer in numbers compared to the other 520°C, 585°C and 617°C of sintered temperature samples. From the result obtained, the grain boundaries between particles of 552°C are not closely compacted to each other. In other words, the presence of grain boundary at 552°C sintered temperature results is higher compared to the other sintered temperature as well as written by Mustapa et al., 2016 [10]. Besides that, at 552°C of sintered temperature, less of pores spotted in the sample can be seen compared to the other sintered temperature results. From the particular test result, it is hard to the specific relation between sintered temperature and the microstructure observation accurately, but it will be proven more specifically in the next tests conducted.

3.2 Density and Porosity

Fig. 4 shows, the graph of density (g/cm^3) versus sintering temperature of samples (°C) for recycling aluminium chip (AA6061) which was categorised under sintered temperature 520°C, 552°C, 585°C and 617°C. From the Fig. 4, it can observe that the highest density was 2.5203 g/cm^3 and the lowest was 1.9793 g/cm^3. The density at temperature 552°C of sintering has the higher density for every sample compared to other sintered temperature. Therefore, the result which is partial to the theoretical density value is 2.5203g/cm^3 for the sample 100% aluminium powder at 552°C sintered temperature has the closest value to the existing theoretical density with the percentage difference of 6.7%. As observed, it can be seen that 552°C of sintered temperature for every sample was the optimum sintering temperature for the aluminium as the density obtained was closest to the existing theoretical density.

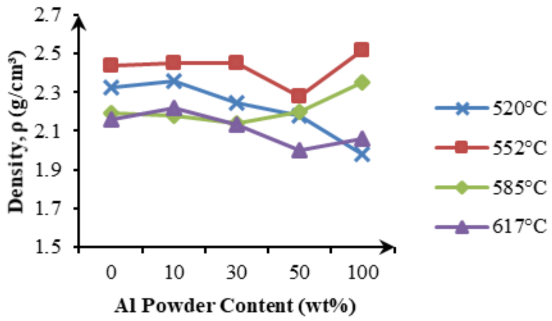

Fig. 4 Changes of density (*g/cm³*) against sintering temperature of samples.

Porosity is the quality of being porous or full of tiny holes. It is a measure of the percentage of the size of the tiny holes (pores) in the powder for the total volume of powder bulk.

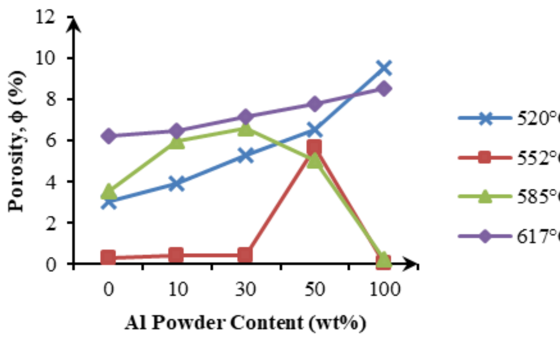

Fig. 5 The apparent porosity (%) against sintering temperatures with increasing Al powder content.

Fig. 5 illustrated the relationship of apparent porosity and sintering temperature of samples. It can observe that the minimum porosity is at 552°C sintered temperature for 100% of aluminium powder sample with value is 0.03%. The maximum percentage of porosity is at 520°C sintered temperature for AA6061 recycled aluminium chip with value 9.54% which is not quite good for aluminium, as it can affect the hardness of the sample.

Based on this analysis, it can be concluded that sintering temperature has an effect on the percentage of porosity of the samples. Therefore, the best sintering temperature for recycled aluminium with less porosity was 552°C because most the samples show less porosity compared to others

3.3 Microhardness analysis

The Vickers microhardness test is the most method used to provide a hardness of small part of the thin cross section. The micro indentation testing was set automatic mode with 0.1HV (9.807mN) of test load force for 10s. Five points of the test (indentations) were made at random on the surface of each samples.

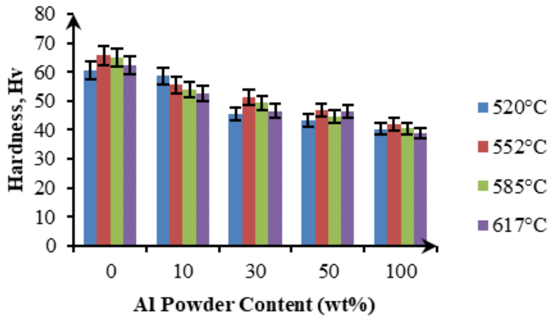

Fig. 6 The graph of hardness (H_V) against different sintering temperatures with increasing Al powder content.

Fig. 6 shows the graph of mean hardness (H_V) against sintering temperature of samples. The highest value of hardness is 65.6 H_v at 552°C sintered temperature for AA6061 recycled aluminium chip sample, while the lowest value is 38.89 H_v at 617°C for 100% of the aluminium powder sample. Grain boundaries delayed dislocation movement and a number of dislocations within a grain have an impact on, thus causing the high hardness result on the surface of sample. Indirectly, the simply dislocations will traverse grain boundaries and travel from grain to grain [11]. However, to make sure that the data of hardness of the sample can be obtained accurately, the indention point on the sample must be pointed to the particle of the sample.

4. Conclusion

This study was achieved as the effect of sintering temperature on the properties of the recycled aluminium chip (AA6061) and aluminium powder were identified. In this study, every sample showed clear differentiation between chip and powder grains and porosity. In addition, the density of sintered sample 552°C gave the closest value of existing theoretical density of Aluminium. Meanwhile, porosity of the recycled aluminium decreased when the sintering temperature decreased. The porosity resulted in how much water were contain in the sintered sample during the test. The density of the sample increased at sintering temperature 520°C to 552°C and decreased at 552°C to 617°C. The closest density obtained with the theoretical density was 2.52 g/cm³ with sintering temperature at 552°C for sample 100% of aluminium powder. The hardness number decreased gradually with the increment of sintering temperature. Significantly at temperature 552°C, all sample have the highest hardness value compared to others thus concluding that it was the best sintering temperature for this research study.

5. Acknowledgement

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