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Effect of Spraying Discharge Towards the Microstructure Morphology of the AL Mg Powder Hardness as a Result of Water Atomization Process Using a Twenty-Hole Nozzle

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ABSTRACT

Aluminum alloy is the base material to produce aluminum metal powders by using a water atomization system with a spraying method under a high pressure condition of about 30 to 40 psi. The water spraying discharge was set as Q = 20 l/s with a spraying angle variation of 20°, 30° and 40° and by implementing a 20 holed nozzle. Each nozzle hole has a diameter of $Ø_{hole}$ = 1mm. The aim of setting these parameters is to get a fine and bulky aluminum alloy powder. The other objective is that a fine grain powder could have a better structure and hopefully can avoid porosity as well as improve the aluminum alloy mechanical properties, such as the metal hardness, metal tensile strength, metal ductility and of course a normal micro and macro structure. Furthermore, to determine the metal powder granules form and size it is depend on the spraying distance parameters variation. The spraying parameter variations are the nozzle spraying distance to the hot liquid metal and the nozzle angle toward the hot liquid metal stream (θ). In this research the parameter variations are 2.5 cm spraying distance for the 20° spraying angle, a 3.5 cm spraying distance for the 30° spraying angle and a 4.5 cm spraying distance for the 40° spraying angle. The spray angle variation would give a special powder shape characteristic. Moreover, the spray distance could give a specific powder number produced. From the three kind of spray angle variation the highest metal powder number produced occurs at a spray angle of 30°, with a 3.5 cm spray distance a 297 grams of metal powder was produced. With a 20 holes nozzle and a nozzle hole diameter of ∅ = 1 mm and a pressure of = 15 psi, and water flow rate of 15 l/s.

Keywords: Water Atomization, Granule shape, Micro-vickers, Macro and Micro Structure

INTRODUCTION

Public demand for the industry to continue to improve their productivity was the main concern that could not be denied. In addition to meet these needs, the industry should also increase their product quality, competing by offering reasonable product prices, a good product physical quality and a short production time, as well as to meet the customer design aspects demands . One of the technologies that developed nowadays to meet the community demands is powder metallurgy. Aluminum powder metallurgy is a technology of metal production in which the metal is produced from aluminum metal material. In producing this powder metallurgy, researchers used a system of water atomization by implementing two nozzles with a spraying direction from the left and right and a high pressure water jet. For the aluminum metal alloy smelting a special non-ferrous metals furnace is used with a maximum temperature 1300°C up to 1400°C and an Aluminum melting point of 650°C. The powder metallurgy process was first performed for cast iron, steel, nickel and a small number done on copper and some refractory metals such as molybdenum and tungsten. Some products made by implementing this powder metallurgy process are for example producing gears, bearings, electrical tools and household appliances. [1] Economically, powder metallurgy process for metal production is very profitable because of several things, such as:

- Powder metallurgy could produce the form that corresponds to the desired shape, a minimum or no finishing process is needed.
- Some of metal products that could not or difficult to produce by other means, can be produced by powder metallurgy system, for example: Wolfram Filament (tungsten)
- The product size could be easily controlled and be more precise with a tolerance of 0.13 mm.
- The powder metallurgy production process could be done automatically.

The powder metallurgy technology also has some weakness:

- PM production requires tools and production costs are relatively high.
- Metal powders could not flow by itself in the mold during the compacting process.
- The product strength could be varied for complex product shapes. [2] Aluminum alloy metals are widely used for automotive components, food packaging, home appliances and others. Aluminum alloy is widely used because it is corrosion-resistant and it is very light [3].

Hisashi [4] conducting a research using the Spinning Water Atomization Process (SWAP). This system process is one of the sophisticated powder metallurgy processing and a high performance is required, to get a fine powder [5].

Ileana [6] examined the process of making metal powders using water atomization with iron (Fe) as the raw material in order to obtain high quality powder. The iron powder product was then tested their mechanical properties and physical properties.

Suchart [7]examines the metal powders producing of stainless steel material AlSi 304, by using water atomization and by combining the vertical and horizontal spray direction. Variables affecting this system are the product size; product shape and metal powder particles distribution. Other variables are the water pressure, water flow rate, temperature that is higher than the metal melting point and liquid metal flow rate.

Research done by Omar [8], is producing metal powders by water atomization for stainless steel. The purpose of this research is to increase the stainless steel physical properties and mechanical properties. This system is using the Metal Injection Molding (MIM).

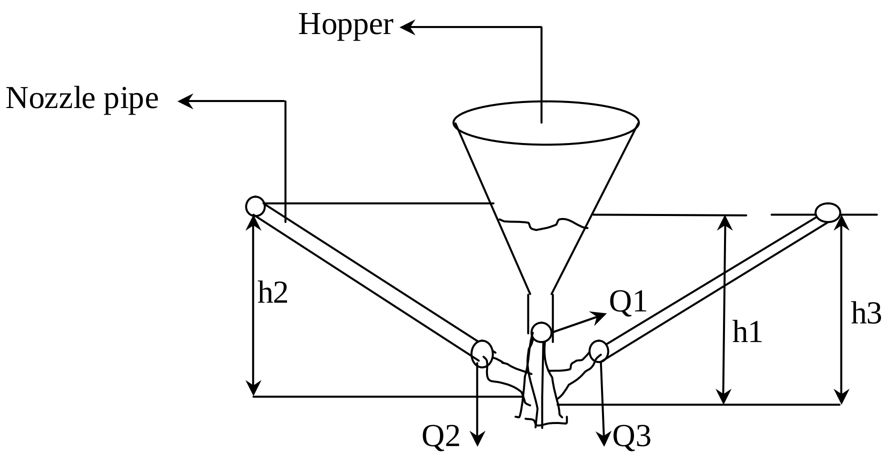
In this research, three kind of spray angle was chosen which are the spray angle of $\theta = 20°$, $\theta = 30°$ and $\theta = 40°$. The spray distance for $\theta = 20°$ is 2.5 cm, while the spray distance for $\theta = 30°$ is 3.5 cm and lastly for the spray angle of $\theta = 20°$ the spray distance is 4.5 cm.

EXPERIMENTAL PROCEDURES

Before the metal smelting, weight as much as 300 grams aluminum alloy as the base metals and then melt it in the furnace with a melting temperature of 800 and then leave the melted aluminum about 30 minutes until the aluminum alloy melt completely. Furthermore, pour the melted metal into the water atomization barrel through a funnel and then spray the melted aluminum with a high pressure water spray about 15 to 20 psi with a 30° spray angle and a spray distance of 3.5 cm. Finally, a powder granulation process occurs. The granule product is then screened on a mesh of 8, 16, 30, 50, 100 and 200. The granule produced could be seen in table 1 below.

Table 1: The metal powder result amount for 3 spray angle variation with a 300 gram raw material and sprayed with a 20 hole nozzle with a nozzle diameter of 1mm.

No	Spray angle(θ)	Spray Distance	Pressure (P)	Powder amount (gr)
1	20°	2,5 cm	15psi	292
2	30°	3,5 cm	15psi	297
3	40°	4,5cm	15psi	279



The chemical reaction that occurs at the time of the collision between the liquid hot metal with the speed of water spray:

Room temperature - 280 : $2\ Al + 6\ H_2O$ ---- $2\ Al\ (Oh)_3 + 3H_2$
280 - 480 : $2\ Al + 4\ H_2O$ ----- $2\ Al0\ (OH) + 3\ H_2$
>80 : $2\ Al + 3H_2O$ ---- $Al2O3 + 3\ H_2$

Powder/kristal Gas

Reaction: $Mg + H_2O$ ----- $MgO + H_2$

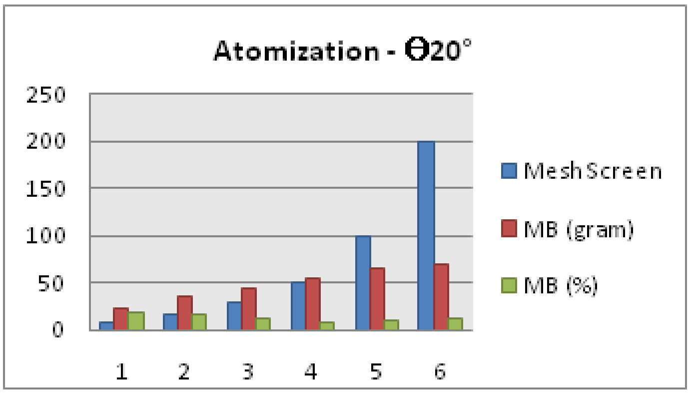


Fig 1: Atomization process graph results under a 20° spray angle

From figure 1 it is seen the powder product after a screen mesh result. The first aluminum raw material is about 300 grams and become 292 grams after the powdering process with a 20° spray angle, the MB percentage = 97.64%.The distance between the hopper and the atomization process is about 2.5 cm, this is a very close distance so that a rapid cooling occurs. The powder product percentage would be very high and the grain powder size would be very fine and has a high strength.

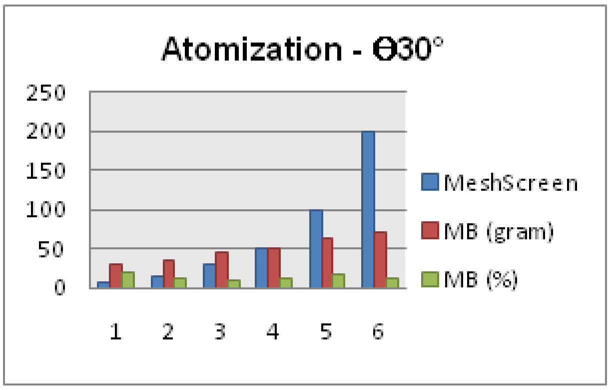


Fig 2:Atomization process graph results under a 30° spray angle

The distance between the hopper and the atomization process is about3.5 cm, this distance is a very ideal distance, because the spray distance is not too far and not too close to the hopper outlet where liquid hot metal falls. The approximately powder mass weight (MB) = 297 grams. The powder product got a heat treatment process under a low cooling rate process. It would a result of a ductile and high strength product.

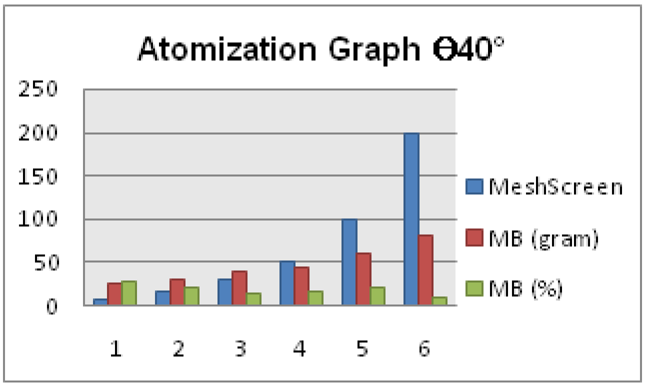


Fig 3: Atomization process graph results under a 40° spray angle

From figure 3 it is seen the powder product after a screen mesh result. The first aluminum raw material is about 300 grams and become 279 grams after the powdering process with a 40° spray angle, the MB percentage = 92.98%.The distance between the hopper and the atomization process is about 4.5 cm, this distance is a bit too far so that the cooling rate become a little bit too slow and would resulted a large aluminum granule size.

Hardness Test

All powder produced from the research would be test by a Micro Vickers Hardness.

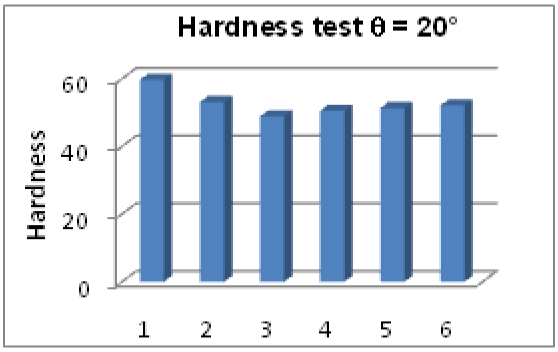


Fig 4: Hardness test results for a 20°spray angle

From the micro-vickers hardness test results above it is seen that the hardness could reach a number of 52.65 Hv. It is caused by the high spray pressure, a spray angle of 75° and the spray distance 2.5 cm so that the liquid hot metal cools very quickly and the Alpowder properties could change their properties, such as lowered the porosity.

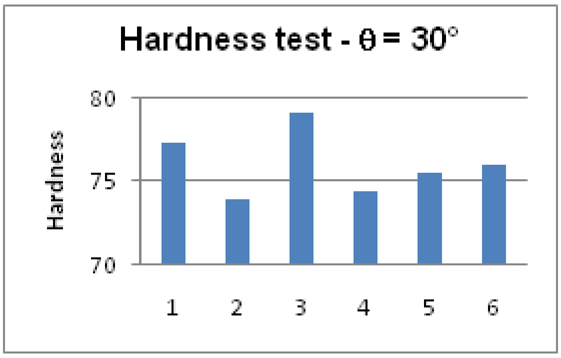


Fig 5:Hardness test results for a 30°spray angle

From the hardness test results (Figure 5) above it is seen that the hardness increase significantly and could reach an average number of 75.97 Hv. It is caused by the low granulation process time, a perfect spray distance of 3.5 cm and a water spray pressure of 15 psi. If the microstructure or phase changes, it will change the mechanical properties too, such as the hardness number, ductility and toughness.

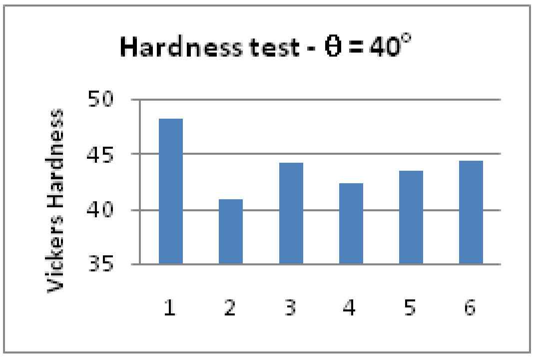


Fig 6:Hardness test results for a 40°spray angle

From the hardness test results for a spray angle of 40° (Figure 6) above it is seen that the hardness is a little bit lower than that the experiment for a spray angle of 20° and 30°. This is because of the spraying distance is too large (4.5 cm), so that cooling process would be longer than that in the 20° and 30° spray angle, and resulted a bigger powder grain size.

Micro Structure Test Result:
After getting thealuminum metal powderresults a further powder microstructure was conducted using a Photo Optical Microscope with a magnification of 4000 times. This test done is to find out the microstructure content.

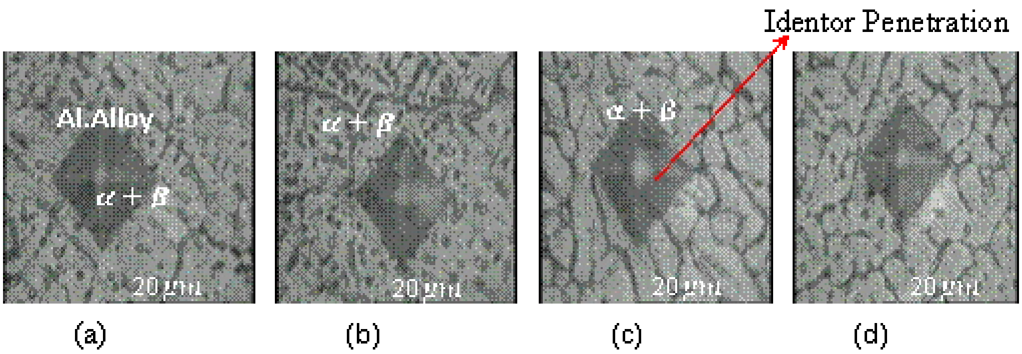


Fig 7:A Microstructure test result, 4000X magnification (θ = 20°)

From the microscope optic picture result, a α + β phase substance was identified with a 75% α content and 25% of β phase. The β phase has a harder characteristic compared with the α phase it could be seen from figure 7 (a), (b) and (c), this means that the material is more ductile.

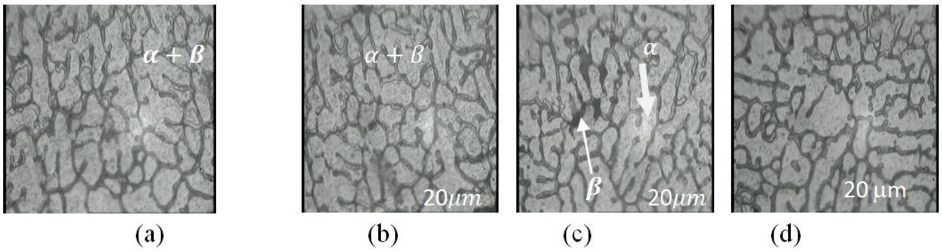


Fig 8:A Microstructure test result, 4000X magnification (θ = 30°)

From the microscope optic picture result, it is detected a α + β phase substance, the α phase is more dominant than the β phase. This is because of the spraying distance is little bit too far, which would affect the slow cooling process and resulted a recrystallization or a new grain growth process. This kind of powder has a strong and has a high ductility.

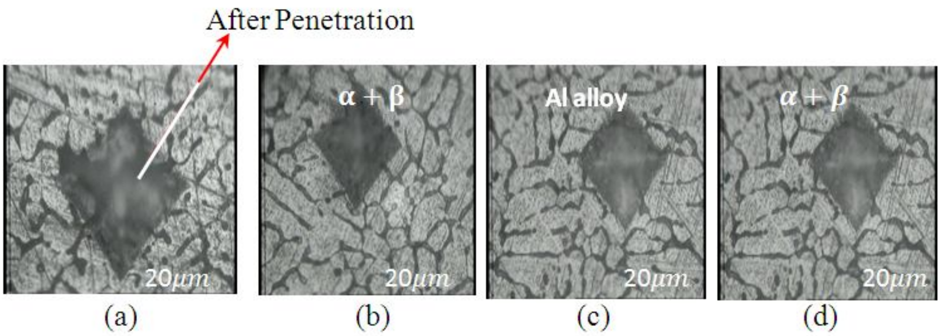


Fig 9: A Microstructure test result, 4000X magnification (θ = 40°)

From the microscope optic picture result, it is detected a α + β phase. On figure 9 part (a), (c) and (d) it could be seen that the grains are large. This kind of material has a strong and ductile characteristic. Furthermore, from figure 9 part (b) it is seen that the α + β phase has a more small structure. This kind of material is more ductile and hard compared with the materials shown in figure (a), (c) and (d).

The aim of Scanning Electron Microscope process is to identify and analyzed the material surface defect such as porosity, point defect and line defect.

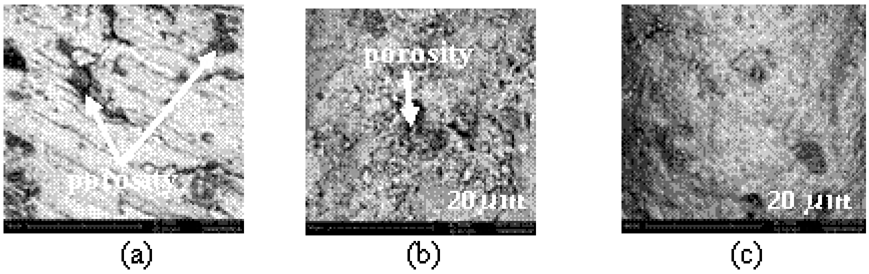


Fig 10: SEM photograph, water atomization process with a 20° spray angle. (5000 X)

On the 20° spray angle SEM photo result, it is seen on figure 10, part (a) and part (b) there has been some porosity while on part (c) there is almost no porosity. The porosity occurrence take place because there is no oxygen or hydrogen trapped during the granulation process. This is because of the rapid cooling process, so that very often a defect could take place such as a hole defect, crack defect, although some of the granules did not suffering from porosity.

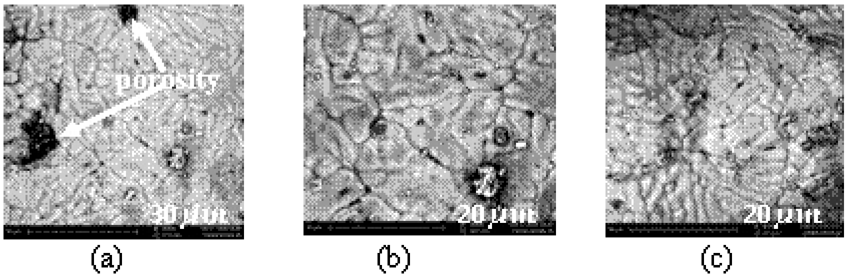
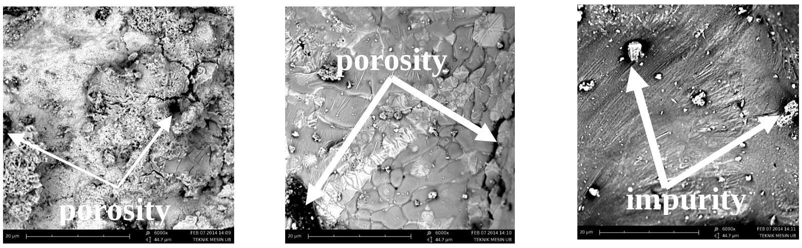


Fig 11: SEM photograph, water atomization process with a 30° spray angle. (4000 X)

On the 30° spray angle SEM photo result, it is seen on figure 11, part (a) porosity occurred while on part (b) and part (c) there is almost no porosity. The porosity did not appear because during the atomization process no oxygen or hydrogen was trapped during the granulation process. This is because of the rapid cooling process. From the whole research result the 30° spray angle gives the best metal powder quality.



(a) (b) (c)

Fig 12: SEM photograph, water atomization process with a 40° spray angle. (5000 X)

On the 40° spray angle SEM photo result, it is seen on figure 12, part (a) and part (b) about the product structure has undergone porosity and part (c) there is no porosity, but there is a little bit impurity. With a spray distance rather far from the hopper mouth, about 4.5 cm, the cooling process would rather slow and ended with a grain surface porosity and cracks.

CONCLUSIONS

- The water atomization method implementing a 20 holes nozzle with a 1 mm diameter hole. The spraying angle variation is 20°, 30° and 40°. The liquid metal aluminum alloy temperature is around 850°C. According to the research result the 30° has the best result in producing the powder. With a mass of 297 grams, compared with the 20° spray angle with a result of 292 grams and 279 grams for the 40° spray angle. This is because of accurate the spray distance.
- The aluminum metal powder alloy hardness test results reported a Hv = 75.96 N for the 30° spray angle, which is the highest number compared with Hv = 52.65 N for the 20° spray angle and Hv = 52.65 N for the 40° spray angle. On the 30° spray angle the cooling process was continuously so that a process recrystallization process occurs, obviously the α and β phase forms small phases and resulted a hard and strong material.
- From the water atomization process microstructure test under the three spray angle variations the 30° spray angle gives the best product result. The α phase content has a higher amount compared with the β phase it would resulted a ductile and strong material.
- From the SEM, the 30° spray angle gives the best result too, no porosity and impurities occurs in this spray angle variation.

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