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Effect of Spray Angle toward Microstructure Morphology and Hardness of Al-Mg Powder Produced from a Single Orifice Nozzle Water Atomizing

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ABSTRACT

Aluminum alloy is the basic raw material to produce powder metallurgy by implementing a device called as water atomization. Aluminum alloy is melted at a temperature of 1300° C to melt aluminum material. After melt the aluminum alloy is cooled about 15 minutes on the surround air while being cleaned from dirt on the hot liquid material surface thoroughly. Furthermore, the hot liquid material in the kowi is then poured into the atomization tube through a hopper which is then sprayed with water comes out from a twin nozzle with an Ø9 mm diameter nozzle hole. This the granulation process, with a spray pressure about P = 30 psi, a spraying angle variation of: L20°, L30°, and L40° and a constant water rate discharge of (Q) = 15 L/S. The water spraying distance was also varied for the L20°, the spraying distance is taken 2.5 cm; for L30°, the spraying distance was taken 3.5 cm and the spraying distance for the L40 ° is 4.5 cm. From the research, L30 ° with a spraying distance of 3.5 cm may have the best result, with a better metallurgical powder amount and resulted about 295 grams of aluminum powder material. The aluminum weight before melted is about 300 grams. Finally the aluminum powder hardness (HV) was tested; for the L20° process the HV was 55.94 kgm/s^2, for the L30° process the HV was 50.07 kgm/s^2, and for the L40° process the HV was 45.73 kgm/s^2. From the three angle variation observed, the L20° got the highest Vickers Hardness Number.

Keywords: Water Atomization, powder characteristics, macro and micro-structure of Al-Mg powder.

1. Introduction.

The community claim toward the industrial community is to continue to improve their productivity. Besides that, to meet these needs, industry must also improve their product quality. Compete in offering reasonable product prices, good physical quality and a short production time, as well as to meet the demands of the customer design aspects. One of technology that was developed to meet the demands of the society is the powder metallurgy, which is a technology of metal production in which the metal produced from aluminum scrap materials. [1] In producing powder metallurgy, this study is implementing a water atomization system, using two nozzles, with a spraying direction from the left and the right sight under a high water pressure. For smelting the aluminum scrap a special furnace for Non-Ferrous metals is use, with a maximum temperature of 1300°C to 1400°C and a an aluminum melting point of 650°C. [3] Powder metallurgy process was first carried out on cast iron, steel and nickel and carried on in a small amount of copper and refractory metals such as molybdenum and tungsten. Powder metallurgy was used to produce manufacture gears, bearings, power tools and household appliances [5]. Producing equipment by powder metallurgy has an economics beneficial metal because of several things:

(1) Metallurgy powder product could be produced with a shape corresponding to the desired shape, so it does not require a longer advanced work.
(2) Several metals which cannot or difficult to be produced by other processes, can be produced by the powder metallurgy system, for example: Wolfram Filament (tungsten).
(3) Product Controlling dimensions under powder metallurgy can be more precise with a tolerance of 0.13 mm.
(4) Powder metallurgical production can be done automatically so that it can be more economical.

The powder metallurgy technology (PM) has also weaknesses, such as:

(1) Production of PM requires tools and production costs are relatively expensive.
(2) Many constraints in manufacturing mold geometry because metal powders cannot flow by itself in the mold during the compacting process.
(3) PM products strength can vary for complex shapes mold. Metal powders production is one of the main processes to be carried out on the powder metallurgy technology, the metal powder production can be done by several methods such as by machining, atomization, chemical reactions and electrolysis. Powders produced from every method described above will have a different powder characteristic. Powder characteristics include the shape and structure of the powder, the powder surface area, friction coefficient of friction and the flow characteristic.

Micro and macro structures, chemical properties and other properties, will affect the engine component produced such as the component porosity that would affect its strength [2].

Aluminum alloy is a metal which were widely used for automotive components, food and beverage packaging and home appliances. Aluminum utilization is widely use because aluminum has a corrosion resistant characteristic and are very light [6].

Hisashi (2007) conducted a study how to produce aluminum alloy powder by implementing the Spinning Water Atomization Process (SWAP). Spinning Water Atomization Process (SWAP) is one of the sophisticated powder processing technologies. [7] Ileana (2010) examined the process of making iron metal powders using water atomization, in order to obtain superior powder performance [19].

Suchart, Y. (2011) examined the metal powders production with Al-Si 304 stainless steel as the raw material, by using a water atomization system is the appropriate method to produce various types of metal powder. Water atomization machine is designed for spraying liquid metal.

With two-way spraying going horizontal direction and going vertical direction depend on the nozzle design. The variables that affect the powder product are the particle size, particle shape and the metal particles powder distribution; which is connecting with the water pressure, high speed water flow, a higher temperature than the metal melting point and the molten metal flow rate [21].

The fundamental difference in producing metal power using water atomization, which was observed on the previous research has been carried out, lies on the angle spraying variation, spraying pressure variations, temperature and time. The angular variation spraying was L20°, L30° and L40° and the spray distance variation for L20° is 2.5 cm, a spray distance of 3.5 cm for L30° and a spray distance of 4.5 cm for L40°. The pressures variation are between 10 to 20 Psi, with constant water flow rate Q = 15 l / s, for a furnace temperature of 1300°C. Thus this study will fulfill the previous research result information related to the two-way spraying angle.

Experimental Procedures

Aluminum scrap as raw material will be prepared before the metal smelting. The raw material will then be weighing about 300 grams until about 500 grams. The raw material would then be smelted in the furnace until melted on temperature about 800°C. Furthermore the liquid material is then filled in the water atomization tube through a funnel and finally the melted material was then sprayed with water from two nozzles from two opposite sides with a 10 to 15 Psi high air pressure spray. From this granulation process an aluminum powder is produced. The powder product would then be weighed and the result is an average of 285 grams of aluminum powder. This powder product would then be meshed on a mesh level of 8, 26, 30, 50, 100 and 200. The greater the mesh value, the finer the powder grain.

Table 1: Heavy metal powders result of a three spray angle direction variation for a 300 gr material melted (Single nozzle hole Ø9 mm)

No.	Angle Direction	Spray Distance	Pressure (P)	Powder Result (G)
1	L20 °	2.5 cm	15.Psi	246
2	L30 °	3.5 cm	15.Psi	295
3	L40 °	4.5. Cm	15.Psi	258

After the aluminum powder screening process, the screened aluminum powder microstructure would be than tested. The aim of this test is to find out the aluminum powder phase content. All of the L20°, L30° and L40° powder produced should pass this microstructure test. Picture below is the result of Mickrovickers photo:

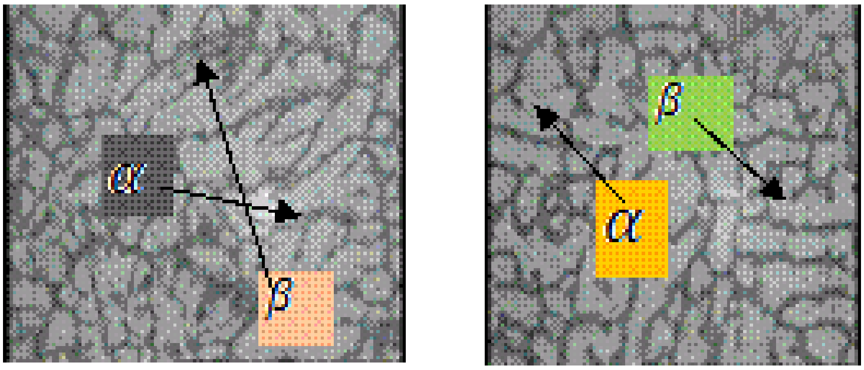


Fig.1: 400X microstructure phase

L20° spraying angle water atomization process
From the microstructure photo result, it could be seen that for the L20° the α phase is denser than the β phase.

This material has a ductile mechanical property.

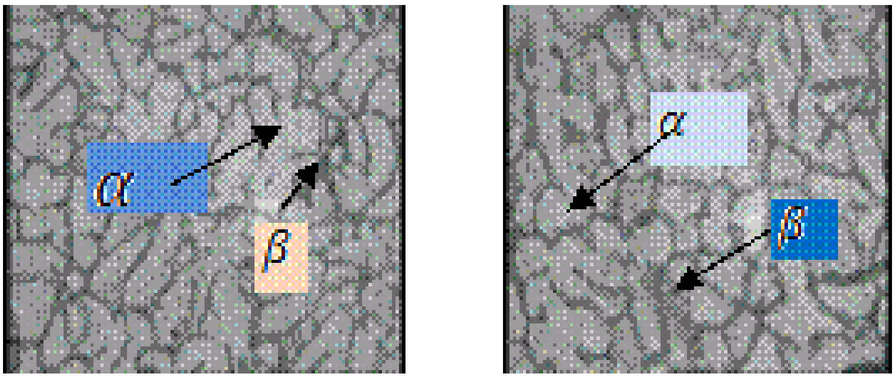


Fig. 2: L30° spraying water atomization process 400x microstructure results.

From the microstructure photo result, it could be seen that for the L30° the α phase is more dominant than the β phase. This material has a ductile mechanical property. It is because of the spraying distance is 3.5 cm. According to the research results for the L30° spraying distance, a 3.5 cm spraying distance end up with a best metal powder, compared with a spraying distance more than 3.5 cm or less than 3.5 cm.

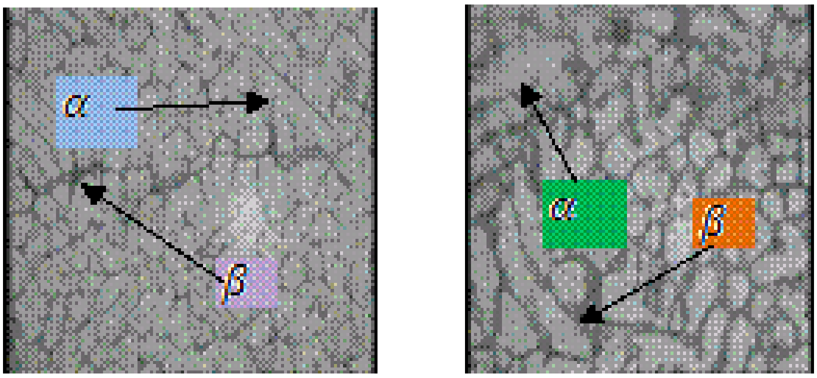


Fig. 3: L40° spraying water atomization process 400x microstructure results.

By looking at the microstructure photo result for the L40°, it is seen the α phase is more than the β phase. It is because of the cooling spraying distance is a little bit farther and a slower spraying speed. So, that a recrystallization process occurs. The α phase growth is higher than the β phase, which would give a ductile result for the metal material property [7].

The hardness test result: The Microvickers Hardness test was implementing a load of 0.98 N.

The Vickers Hardness test formula is as below:

HV = P/A (1)

Where

A = —. Cos 22°

HV = Vickers Hardness Number

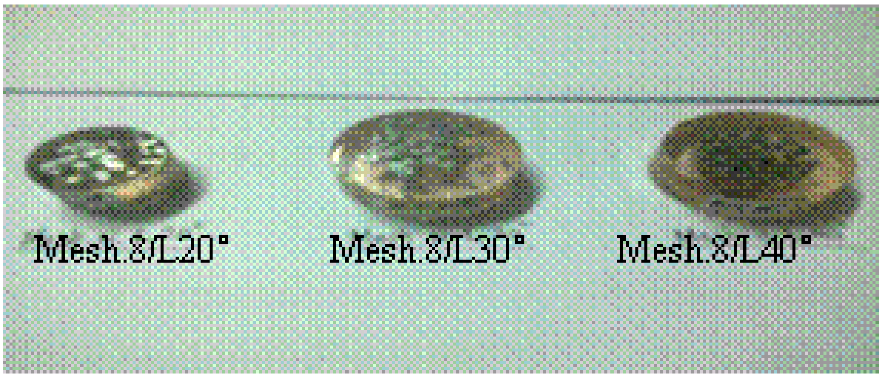
P = Indentation load (kg)

D = Average Diagonal Indentation

The pyramid indentation angle is: 136°

Table 2: Microvickers Hardness for AL-Mg Water Atomization.

Spray Angle	HARDNESS (HV)					
	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6
8/L 20^o	51.41	55.37	56.83	56.46	57.71	57.84
8/L 30^o	49.23	49.33	50.98	49.23	50.35	51.30
8/L 40^o	42.90	46.91	47.57	46.26	45.63	45.10



From Table 2 it is seen that on L20° condition the hardness result is higher than that of L30° and L40°, this is because of the high cooling rate speed.

Materials and Methods
Scanning Electron Microscope (SEM)
The results of SEM with L20°, metal powders can be seen below:

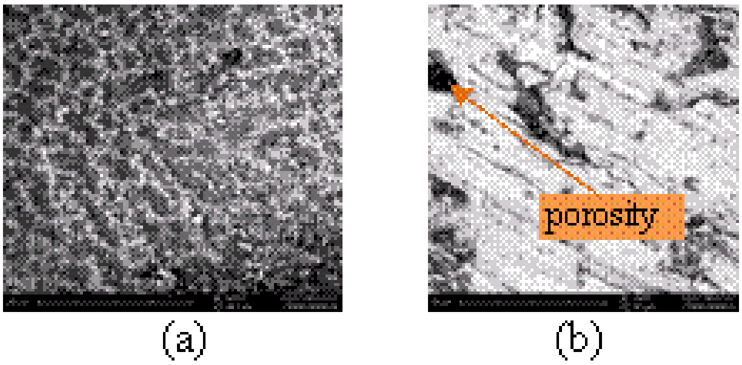


Fig. 3: SEM photo for L20° water atomization process results for Al-Mg.

The water atomization process with L20° SEM photo result description could be seen in figure 3 a. From this photo result, it is seen that there are no porosity and the α phase content is higher than the β phase. On figure 3 (b) a few porosity occurs, while the α phase content is about 90% and the β phase is about 10%. This is the effect of a high pressure water spray which is about 15 to 20 psi. The other cause is the small distance between the hopper and the nozzle orifice which is about 2.5 cm compare with the L30° and L40°.

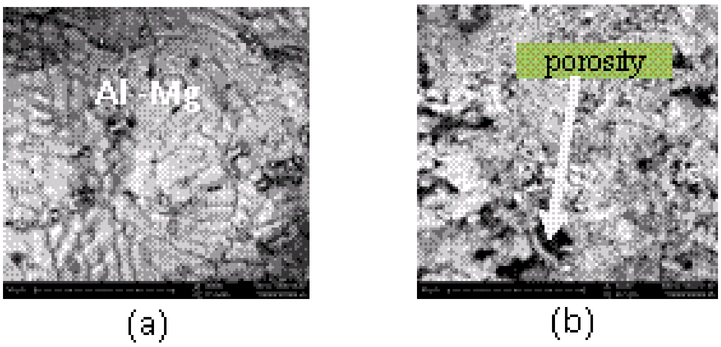


Fig. 4: SEM photo for L30° water atomization process results on Al-Mg.

The water atomization process with L30° SEM photo result description could be seen in figure 4 a. From this photo result, it is seen that there are nearly no porosity, while the α phase content is about 80% and the β phase content is about 20%. On figure 4 b a few porosity occurs which is about 20%, while the α phase content is about 70% and the β phase is about 30%. This is because of the 3.5 cm water spray distance. From the observation it is found that 3.5 cm water spray distance would give the best and the highest metal powder produced.

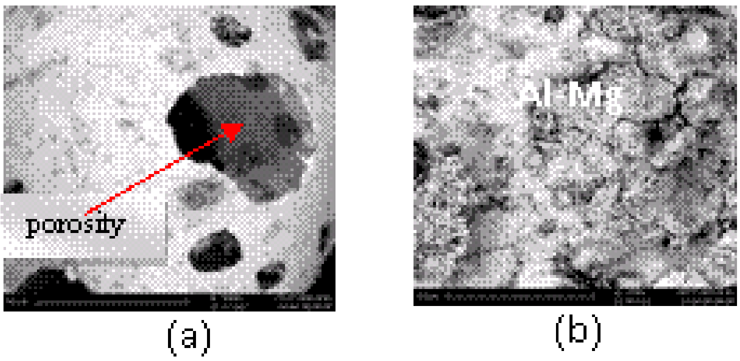


Fig. 5: SEM photo for L40° water atomization process results on Al-Mg

The explanation of Figure 5 a is that a porosity occurs about 30%, the α phase content is about 70% while the β phase content is about 30% On figure 5 b it is seen that there is a porosity of 20%. Whereas, the α phase content is about 80% and the β phase is about 20%. This phenomenon occurs because the water spray distance is a bit far from the metal hopper. The cooling process is a little bit too slow so that the metal powder amount produced was lower and the powder granule shapes were not equal. There are even big shapes.

Results and Discussions

The formula used in this study is as follows:

The metal fluid flow rate is as follows:

$$Q1 = A.\ V \quad (2)$$

Where:

$$V = \sqrt{2.g.h} \quad (3)$$

$$A = \pi/4.d^2 \quad (4)$$

To calculate the spraying water discharge:

$$Q2 = \frac{v}{t} \quad (5)$$

where

$$V2 = \frac{Q2}{A}\ ;\ V3 = \frac{Q3}{A}\ ;\ Q2 = Q3$$

To determine the liquid metal flow capacity:

$$Q_{LGM} = A.\ VL\ (\square\ m / s) \quad (6)$$

Where:

A = Output cross section area (m^2)

$A = d^2$

d = Output diameter (m)

VL = Average Velocity

h = Average head (from the hopper to the spraying nozzle position) (m)

To determine the water cooling flow capacity (Randall M. German)

$$Q_{water} = 15.\ Q_{Metal}\ (m^2 / s) \quad (7)$$

To determine the nozzle cooling water speed

$$Va = \frac{Qair}{2.AT}\ (m / s) \quad (8)$$

Where:

AT = nozzle hole area (m^2) = $\frac{\pi}{4}.dn^2$

dn = diameter of the nozzle orifice (m)

Nozzle spray force

$$F = m.\ Va\ (N) \quad (9)$$

Where:

m = cooling water mass flow rate = $\frac{\rho air.Qair}{2}$ (kg/s)

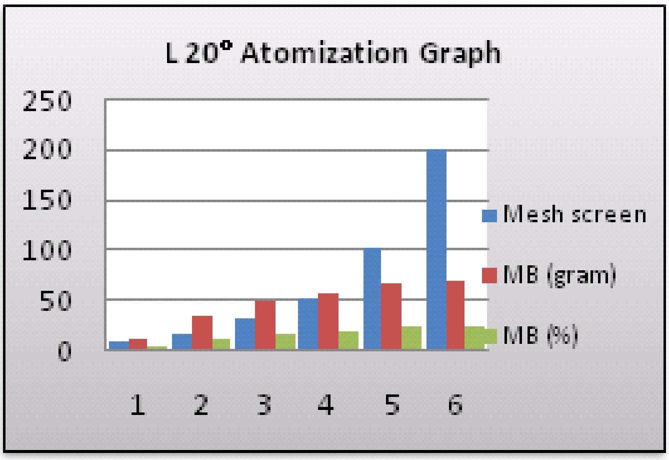
ρ_{water} = Water Density based on temperature (kg/m□).

Va = Nozzle spray speed (m/s)

F = spray force (N)

Table 3: The mesh screen results L20° spray angle and pressure (P) = 15 Psi. Metal raw material initial weight of 300 grams.

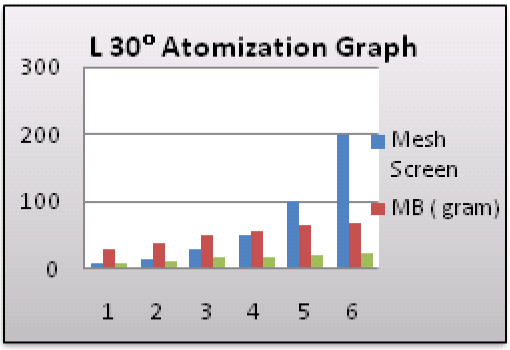
Mesh screen	MB (grams)	MB (%)
8	10	3:33
16	34	11:33
30	48	16
50	55	18:33
100	60	20
200	67	22:33
number	274	91.32



The mesh screen result of the metal powder produced from an initial weight of 300 gram under the L 20° spray angle is 274 grams, or a percentage MB = 91.32%. The whole final result could be seen in Table 3.

Table 4: The mesh screen results L30° spray angle and pressure (P) = 15 Psi. Metal raw material initial weight of 300 grams.

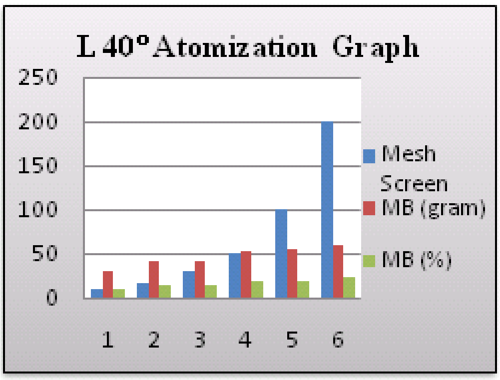
Mesh screen	MB (grams)	MB (%)
8	30	10
16	35	11.66
30	50	16.66
50	56	18.66
100	66	22
200	60	20
number	297	98.96



The mesh screen result of the metal powder produced from an initial weight of 300 gram under the L 20° spray angle is 297 grams, or a percentage MB = 98.96%. From the whole research it is seen that the L30° spray angle could produce the largest powder compared with to L20° and L40°. The whole L30° final result could be seen in Table 4.

Table: 5: The mesh screen results L40° spray angle and pressure (P) = 15 Psi. Metal raw material initial weight of 300 grams.

Mesh Screen	MB (grams)	MB (%)
8	30	10
16	40	13:33
30	41	13.66
50	52	17:33
100	55	18:33
200	60	20
Number	278	92.65



The mesh screen result of the metal powder produced from an initial weight of 300 gram under the L 40° spray angle is 278 grams, or a percentage MB = 92.65%.

The powder production result from the L40° has a little bit larger granule diameter compared with the L30° spray angle powder product. The whole L40° final result could be seen in Table 5.

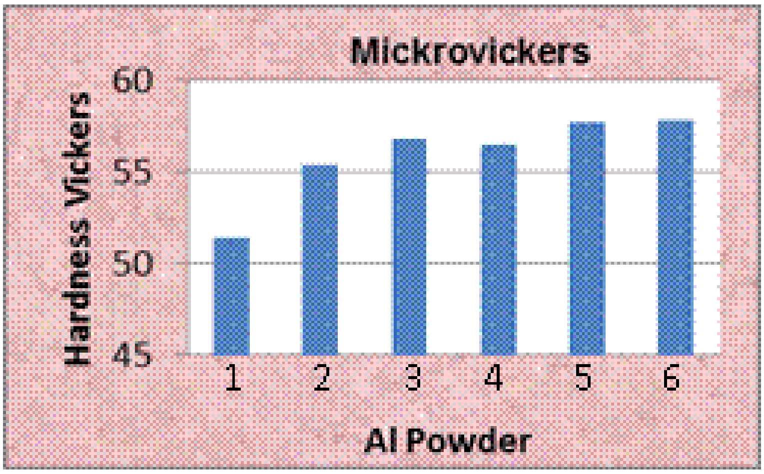


Fig. 6: L20° 8 mesh screen Hardness Test Results

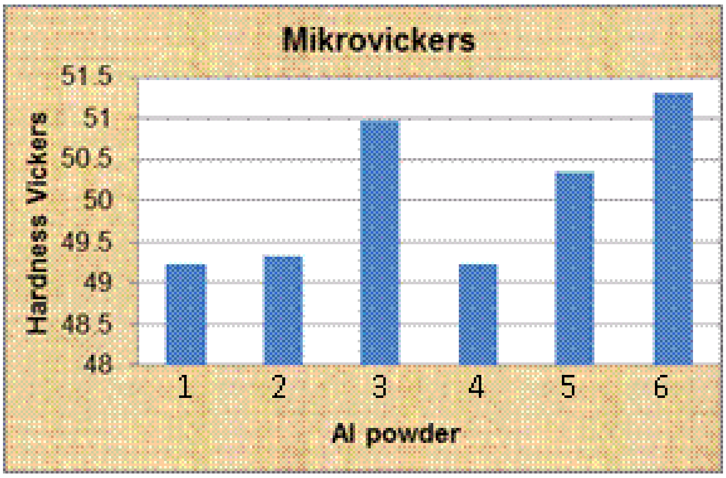


Fig. 7: Hardness Number Test result for L30° spray angle.

From the research observation it is seen that cooling process occurs perfectly under the water atomization with an L 30° spray angle and a spray distance of 3.5 cm. The product hardness number has a good result, reaching a maximum point of 51.3 N from an average value of 50.07 N.

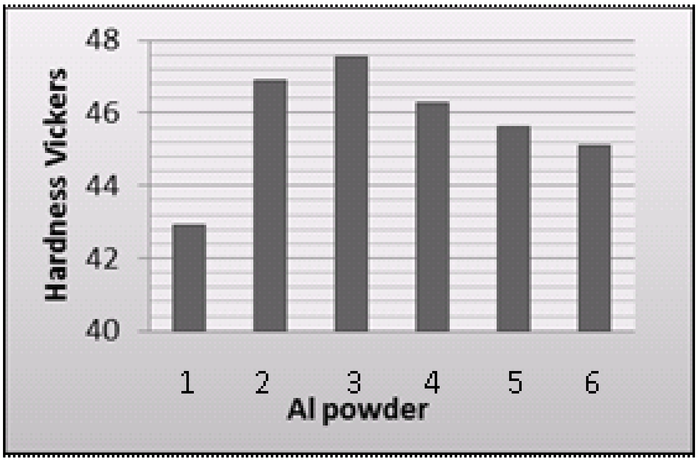


Fig. 8: Hardness Number Test result for L40° spray angle.

For the L40° spray angle process it is seen that cooling process occurs very slowly so that the powder number is very high and the powder size is very big. After a hardness test it is found that the product average hardness number is about 45.36 N. From the research observation it is indicated that the product hardness number is gone lower compare with the product from the L20° and L30° process.

Conclusions

The water atomization method in this research is using a spraying angle variation of L20°, L30° and L40°, and a liquefied aluminum metal temperature around 850°C. From the research result the L30° spraying angle has the best aluminum powder product, compare with the L20° and L40°, with a production amount MB about 297 grams and a percentage of 98.96%. It can be concluded that a lower spray angle of L20° could not produce any metal powder, while the spray angle above L40° could not produce a good metal powder, because the powder granular is too large. This is because of very slow cooling time.

From the metal powder hardness test for the three spray angle variation, the L20° spray angle has the hardest result with 56 N. This is because of the very close spraying distance about 2.5 cm, compared with L30° and L40°. The rapid cooling would push the recrystallization process so that the metal becomes harder and stronger.

From the three spray angle variation microstructure test L40° spray angle has the highest ductility compared with L20° and L30°. Furthermore L20° has the highest strength and highest hardness.

From the SEM test for the L30° spray angle has the best result, because it has a very low porosity as well as a less crack. It is because of the not too far and not too close spraying gap so that the cooling process goes perfectly.

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