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PRODUCTION OF FINE ALUMINUM POWDER FROM METALLIC ALUMINUM

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Abstract: *This paper intends to produce fine aluminum powder from metallic aluminum by using hybrid atomization technique. The hybrid atomization system has three main parts: melting unit, hybrid atomization and powder collector. The characteristic of aluminum metal is analyzed by X-ray Diffraction (XRD) and wet assay. Processing experiments were carried out at gas pressure (0.5, 0.6, 0.7 MPa). The resultant aluminum powder with a mean particle size of under 75 microns were obtained. The size of aluminum particles were calculated by using Scherrer's equation.*
Key Words: ***Melting Unit/ Hybrid Atomization/ Aluminum Powder/ Scanning Electron Microscope***

1. INTRODUCTION

Aluminum is found in many rock minerals, usually combined with silicon and oxygen in compounds called alumino-silicates. Under certain types of tropical soil weathering these alumino-silicate compounds are separated into layers of hydrated iron oxide, hydrated alumina and silica. When such deposits are rich in alumina, they comprise the mineral bauxite.

Aluminum is a lightweight, durable metal. It is silvery in appearance when freshly cut, is a good conductor of heat and electricity and is easily shaped by moulding and extruding. Aluminum has main advantages when compared with other metals. Firstly, it has a low density, about one third that of iron and copper. Secondly, although it reacts rapidly with the oxygen in air, it forms a thin tough and impervious oxide layer which resists further oxidation. [1].

Many uses have been purposed for various application of the aluminium, such as aerospace, architectural construction and marine industries, as well as many domestic uses. Aluminum materials can be produced by a variety of manufacturing routes.

The main production routes, i.e. those for which materials are commercially available are: atomization, melting spinning and subsequently pulverisation of ribbons into flakes, and mechanically alloying [2]. Atomization process is one of the popular processes for making powder metal [3]. The main advantage of gas atomization is due to totally inert processing conditions and the spherical the product homogeneity, the absence of contamination shape of the product powder.

In some conventional atomization method such as centrifugal atomization and confined gas atomization, a liquid film was found to form before the final break up [4]. Furthermore, because the liquid film scatters in the form of droplet, void-free powders with preferable properties, such as fluidity and arrangement, can be obtained. However, with the centrifugal atomization, if the melt not poured onto the centre of the rotating disk, the high-speed disk would become unbalanced, making it difficult to form a stable liquid film, and then the preparation of powders will become impossible.

A new powder- making technique, hybrid atomization was invented and developed recently to produce very fine spherical powders economically. This technology combines low-pressure gas atomization with centrifugal atomization effectively. Its basic idea is to provide a thin but stable liquid film on rotating disk before centrifugal break up by a low-pressure inert gas atomization [5].

As an advantage of this method, the powder with low content oxygen can be easily produced because the powder is produced in an inert gas atmosphere [6]. By this method, is easy to control the powder particle size, particle size distribution, powder shape and other characteristics by detail investigation of the relation between the metal physical properties and the rotational speed of the rotary disk [7]. Powder characterisation is a rather complex procedure since not only the properties of individual particles (size, shape, etc) must be determined, but also the characteristics of the powder mass (particle size distribution, apparent density, etc.) and of the porosity in the powder mass (average pore size, pore volume, etc.).

The suitable metals that can be melted and it used commercially for powder production are iron, copper, alloys steels, brass, bronze, low melting point metals such as tin, lead, zinc and aluminum [8]. In this paper, the primary aim of this paper was to apply for the production of solid rocket propellant. To fulfil this aim the following objectives is carried out; to examine the characteristics of raw aluminum sample, to fabricate the hybrid atomization structure and to explore aluminum powder by using hybrid atomization technique.

2. MATERIALS AND METHOD

2.1. Analysis of raw material

In this paper, the raw material aluminum metal wires are collected from a local market. The composition of raw sample is analyzed by wet assay and the composition of raw sample is analyzed by X-ray diffraction (XRD).The compositions data are shown in Fig. 1 and Table 1. On viewing the XRD pattern of aluminum, the detailed peaks were clearly identify for the amount of aluminum in the aluminum metal wire.

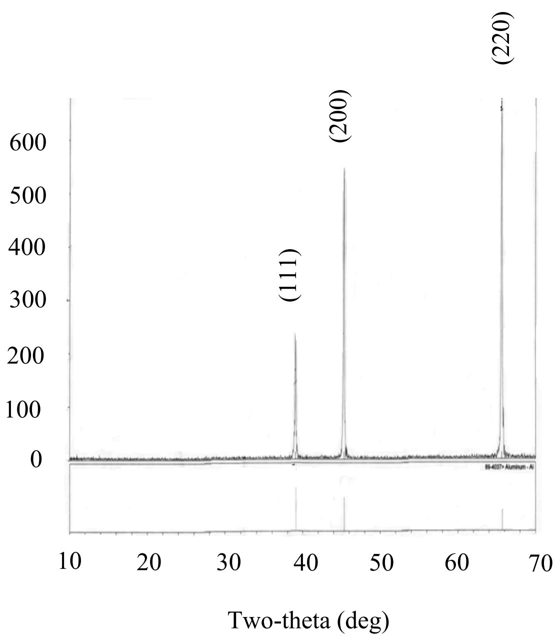

Fig.1. X-ray diffraction pattern of raw aluminum

Table 1. *Composition of aluminum metal*

Composition	Percentage
Aluminum	95.97
Copper	0.26
Iron	2.77
Zinc	0.04
Silicon dioxide	-
Insoluble matter	-

2.2. Specification of meltig unit

The dimensions of melting unit used in this study are described in Table 2.

Table 2. *Specification of melting unit*

Specification	Dimension
Height of furnace, mm	135
Outside diameter of furnace, mm	255
Inside diameter of furnace, mm	80
Height of crucible, mm	38
Inside diameter of crucible, mm	27
Outside diameter of crucible, mm	30
Total heat, Watt	2000

2.3. Specification of atomizer design

The dimensions of atomizer used in this study was described in Table 3. In this paper, confined-type nozzle was chosen to produce aluminum metal powder.

Table 3. *Specification of atomizer design*

Specification	Dimension
Tip angle of delivery tube	23°
Apex angle	23°
Atomization gas	Nitrogen
Inside diameter of nozzle, mm	3

2.4. Fabrication of hybrid atomization

The required units for hybrid atomization structure are constructed in the local workshop and fabricated at laboratory of Mandalay Technological University. The design of this structure has three parts of units as shown in Fig. 2. The first process of this structure is preparation of the material and then fabricated based on drawing design.

The melting unit is the upper part of this system and atomizer, disk and gas supply system are the middle parts also. The lower parts of this system are a high speed motor, an air cleaner and powder collector. The dimensions of the laboratory scale hybrid atomizer are 45.7cm (width) × 65cm (length) × 118.1cm (height).

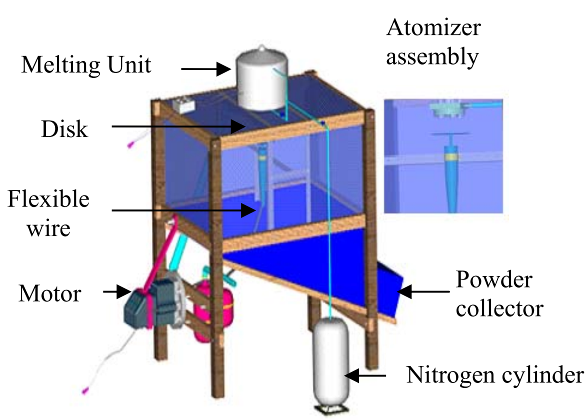

Fig.2. Schematic diagram of hybrid atomization

In the upper part of the system, the melting unit is made of fire brick, fire clay, and asbestos. The crucible is placed into the furnace. Moreover, there is a temperature controller (0-1300ºC) inside the crucible to indicate the temperature of liquid metal.

At the bottom of the crucible, feed tube is attached. The end of the tube is extended into an atomizing nozzle. The diameter of nozzle is 3mm. In this system, confined type nozzle is used. In the middle part of the system, disk actually is a basic element in the centrifugal atomization process. The disk is made of stainless steel. Disk is attached with flexible wire from the high speed motor.

The motor rotating speed is up to 23000 rpm. The spray distance has 100mm and the atomizing gas (nitrogen) enters the furnace and atomizer. Nitrogen gas is used as an atomizing medium. This gas can be adjusted by using a pressure regulator. The function of this gas is to prevent the oxidation on the particle. The atomizing chamber is divided by two sides, a glass chamber at the upper side and zinc chamber at the bottom side.

The lower part of the atomizer involves an air cleaner and powder collector.

3. EXPERIMENTAL DESIGN PROCEDURE

3.1. Experimental procedure

Experimental procedure of aluminum powder is shown in Fig. 3. Twenty grams of aluminum metal wire was weighed and placed in a crucible. Then, the crucible was placed into the furnace and heated for 30 min at 710ºC.

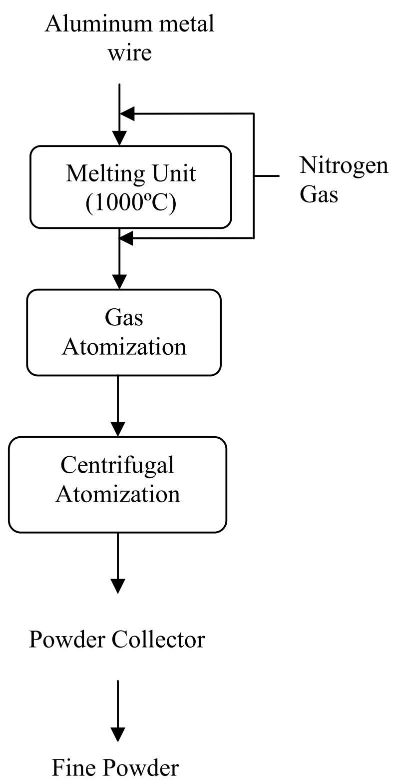

Fig.3. Schematic diagram of hybrid atomization

The melt is atomized by a gas atomizer into coarse liquid droplets. After that, the thin liquid film was centrifuged at 23000 rpm. The solidified powders are collected by a powder collector. The sample was weighed for particle size distribution analysis. A sample of weight is passed through a set of known mesh sizes (Retsch- AS 200 basic). The powder was weight and analyzed by scanning electron microscope (SEM).

3.2. Experimental parameter

Hybrid atomization was carried out for aluminum metal with variable ranges of main parameters as gas pressure: 0.5, 0.6, and 0.7 MPa. Other parameters are disk diameter: 100mm, spray distance: 100mm, rotational speed: 23000rpm and melting temperature: 710ºC which are kept constant in this study. Operational parameters of experiments are shown in Table 4.

Table 4. *Experimental parameters*

	Experiment 1	Experiment 2	Experiment 3
Weight of sample	20 g	20g	20g
Disk diameter	100mm	100mm	100mm
Spray distance	100mm	100mm	100mm
Rotational speed	23000rpm	23000rpm	23000rpm
Temperature	710ºC	710ºC	710ºC
Gas pressure	0.5 MPa	0.6 MPa	0.7 MPa

4. EXPERIMENTAL DESIGN PROCEDURE

4.1. Particle size distribution of aluminum powder

According to the experimental parameters, the data of particle size distribution, established by mechanical sieving, is given in Tables 5, 6 and 7. The result of particle size distribution is shown in Fig 4. The size distribution is also described by the cumulative fraction as shown in Fig. 5.

Table 5. *Particle size distribution of experimental conditions gas pressure of 0.5MPa*

Size (μm)	Mass (g)	Fraction	Cumulative fraction
300	2.29	0.123	0.123
212	2.608	0.1406	0.2636
150	2.574	0.1388	0.4024
106	1.994	0.107	0.5094
75	4.944	0.266	0.7754
<75	4.133	0.222	0.9974

Table 6. *Particle size distribution of experimental conditions gas pressure of 0.6MPa*

Size (μm)	Mass (g)	Fraction	Cumulative fraction
300	2.466	0.1329	0.1329
212	1.4141	0.0762	0.2091
150	1.439	0.0775	0.2866
106	1.3778	0.0742	0.3608
75	6.441	0.3473	0.7081
<75	5.406	0.2915	0.9996

Table 7. *Particle size distribution of experimental conditions gas pressure of 0.7MPa*

Size (μm)	Mass (g)	Fraction	Cumulative fraction
300	2.3821	0.1284	0.1284
212	2.2051	0.1189	0.2473
150	1.8085	0.0975	0.3448
106	1.1169	0.0602	0.405
75	2.1339	0.1139	0.5189
<75	8.9186	0.4809	0.9998

The experiments were conducted under three gas pressure (0.5, 0.6, 0.7 MPa). For the particle size less than 75 microns, the weight of aluminum powder at gas pressure 0.7 MPa is greater than the other two pressures.

According to the experiment 1, yield of aluminum powder under 75µm was found to be 17%. As for experiment 3, although it gave 48% of yield, it had greater particle size than experiment 2. In experiment 2, yield of product was lower than that of experiment 3. The yield percent of aluminum powder is given in Table 8.

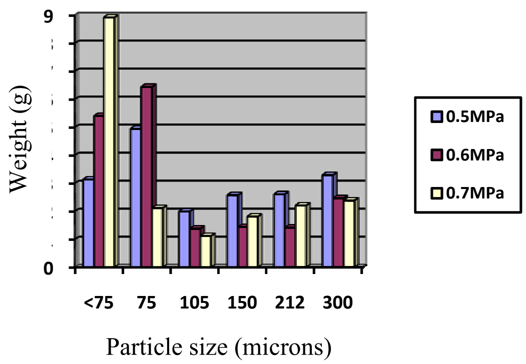

Fig.4. Particle size distribution of powders under different gas pressure (experimental conditions: 0.5MPa, 0.6MPa, 0.7MPa)

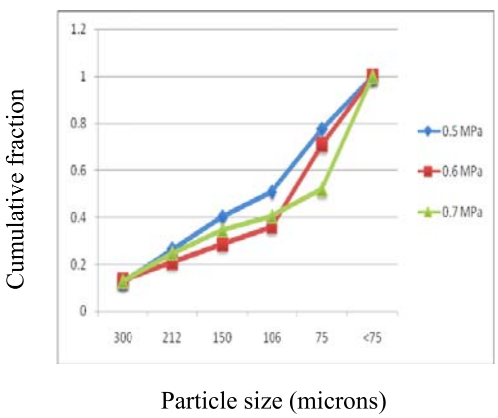

Fig.5. Particle size distribution and cumulative fraction (experimental conditions: 0.5MPa, 0.6MPa, 0.7MPa)

Table 8. *Yield percent of aluminum powder*

Experiment No.	Gas pressure (MPa)	Yield percent	Total yield percent
1	0.5	17	92.69
2	0.6	29	92.71
3	0.7	48	92.72

The result shows that pressure variable has a strong influence on weight of grams. By viewing from this experiments, it was found that yield of aluminum powder (48%) at gas pressure (0.7MPa) is higher than other two conditions.

4.2. Particle size distribution of aluminum powder

The shape and microstructures of the powders were observed by a scanning electron microscope (SEM)(SEM JEOL JSL-5610). Scanning electron microscope images of the produced powders are shown in Figs 6, 7 and 8. Most of the powder particles are dumbelled shape or granular. According to the Figs, the powder particles are more granular at gas pressure 0.6 MPa than at other gas conditions.

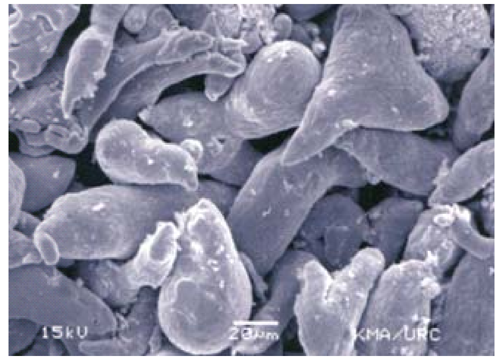

Fig.6. SEM micrograph of aluminum powder at gas pressure 0.5 MPa

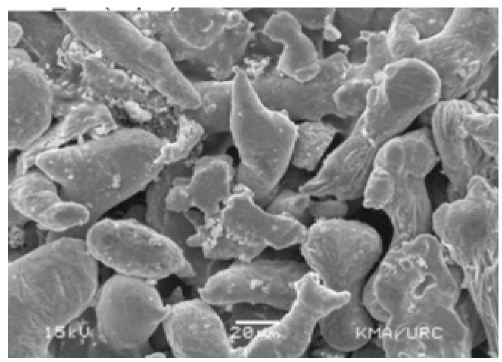

Fig.7. SEM micrograph of aluminum powder at gas pressure 0.6 MPa

Fig.8. SEM micrograph of aluminum powder at gas pressure 0.7 MPa

As can be seen that powder particle size of hybrid atomization was obtained under 75 microns. Therefore, the optimum atomization results depend on the gas pressure and other processing parameters.

4.3. Analysis of obtained aluminum powder

The crystal structure of the aluminum powder is characterized by XRD (RIGAKU model RINT 2000) diffractometer using Cu/K α radiation (λ=1.54056 Aº with 40kV, 40mA), scan speed of 4º/min, in the 2θ range of 10º to 70º. The XRD patterns of aluminum powder are observed at 2θ angles of 39.11º (111), 45.32º (200), 65.67º (220). The typical XRD pattern of product aluminum powder is shown in Fig. 9. The sizes of the particles were estimated by calculation using Scherrer's equation. The result shows that the distribution size is narrowest at 710ºC with the minimum size of 71nm and maximum of 86nm.

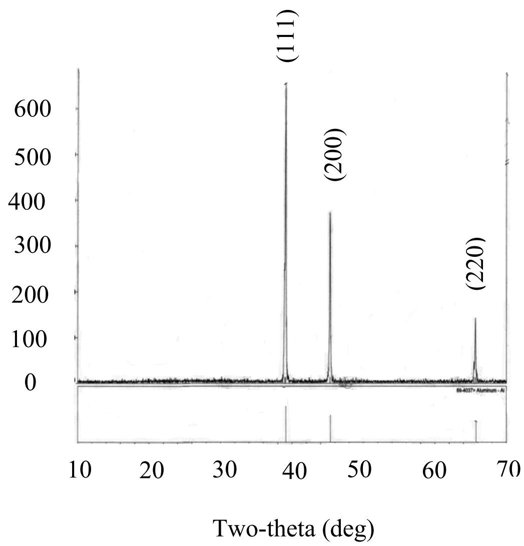

Fig.9. X-ray Diffraction pattern of product aluminum powder

5. CONCLUSIONS

In this paper, aluminum powders were obtained under 75 microns by using hybrid atomization method. The smallest sizes of 71-86nm were obtained from powder synthesize at 710ºC. The result of product yield (48%) can be obtained at gas pressure 0.7 MPa. It has been shown that increasing the pressure leads to decrease the powder particle size. From the result, aluminum powder can be apply as an energetic material for the production of solid propellant.

6. REFERENCES

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