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Production and Characterization of Commercial Aluminum Powders by a New Nozzle Design and Atomization Unit

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***Abstract:** A large area cross section of the production of spherical metal powders by gas atomization in the manufacturing method. Powder metal characteristic improves with small powder size. This aim was realized by vertical gas atomization unit, a new a closely-matched nozzle system and manufacture. In the experimental studies, pure aluminium powders which has an important place in the automotive, air and defence industries were produced. In the studies carried out with the Vertical Gas Atomization unit, aluminium was superheated up to 900°C and atomized at different gas pressures (20-30 bar). Scanning electron microscope (SEM) and particle size measuring device were used for the characterization and size measurements of the produced powders, respectively. The average particle size of the finest powder produced with increasing atomization pressure was determined as d50=19.50µm. Aluminium powder shape and morphology was used as spherical and very little satellization was seen.*
***Keywords:** Powder Metallurgy, Atomisation, Nozzle, Al powder, Characterisation*

I. INTRODUCTION

Powder metallurgy (P/M) is the production of metal or ceramic powders and the process of turning these powders into parts by combining them with mechanical and thermal effects. The production of parts by the powder metallurgy method is very widely used today, and this is increasingly becoming an alternative to the well-known classical production methods [1, 2].
The method is based on the principle of giving shape to metal or alloy particulates under pressure and keeping them at a temperature below melting temperatures [3].
The use of the powder metallurgy manufacturing technique is increasing in the production of engineering materials day by day. Advances in powder technology allow the production of complex-shaped machine parts at a high production speed, high quality, low dimensional tolerance, and economically by using different pressing techniques [4].
There are four basic mechanisms in the production of metal powders. These are mechanical methods, chemical methods, electrolysis method, and atomization methods. The fact that one method of powder production can be chosen over others depends on the economy of the method, whether it is understood, the characteristics of the powders obtained, and to what extent these characteristics can meet the needs of the place of use.
Depending on the production method, the geometric shape of a powder can be in many different shapes, from spherical to dendritic forms. Moreover, the surface condition of the powder (i.e. being smooth or porous) also varies based on the production method. Among these production methods, the gas atomization method is most commonly used to obtain fine and spherical powders [5].
Atomization is defined as the breaking down of molten metal into very small droplets by water, air, and gas pressure or mechanically and then the solidification of it.
Therefore, the atomization process is divided into four different parts: water atomization, gas atomization, centrifugal atomization, and vacuum atomization [6, 7]. Among them, gas atomization is the most common, and it is a low-cost method that allows the production of a variety of particle sizes from 1 µm to several millimeters.Molten liquid metal is atomized with various gases such as air, argon and/or nitrogen [8]. In this system, it is possible to produce fine spherical powder particles by a closely-matched nozzle system or designs [9].
In this study, a pure aluminum material, which is widely used in automotive, aerospace, and defense industries, was produced in spherical powder shape morphology by using the vertical gas atomization method.

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II. MATERIAL AND METHOD

The aluminum raw material used in pure aluminum (Al) powder metal productions was commercially supplied with a purity of 99.70% (Table 1). In the Al material, the remaining composition consists of trace amounts of other chemicals.

TABLE I
Chemical composition of commercial Al material (%)

Al	Si	Fe	Cu	Mg	Zn	Cr	Ni
99.7	0.0508	0.147	0.0013	0.005	0.0046	0.0054	<0.0030

In the experimental studies, the vertical gas atomization method was used for the production of pure Al powders (Figure 1). The vertical gas atomization method used in the experimental studies includes stages such as the Melting system, Nozzle, Atomization tower and Cyclones, Powder collection sections, and Pressurized gas system. It can be said that one of the most important parameters in the production of metal powder is the design and manufacture of nozzles. In this study, a closely-matched nozzle system, which had been designed and manufactured, was used (Figure 2).

Fig 1. Vertical gas atomization unit designed and manufactured

In experimental studies focused on the production of metal powder, the liquid metal temperature was selected as 900°C and argon gas was used as a high-pressure fluid jet. In aluminum powder production experiments, gas pressures of 20-25-30 bar were studied. An optimum gas pressure providing a fine and spherical powder shape morphology in terms of these pressure values was investigated. Powder size analysis was performed with the Mastersizer 3000 model device. The XRD analyses of the powder material were also performed using the Mastersizer model device. In order to determine the effects of different gas pressure and temperature values on the shape and morphology of pure Al powder, microstructure imaging studies were carried out with an optical microscope and Scanning Electron Microscope (SEM).

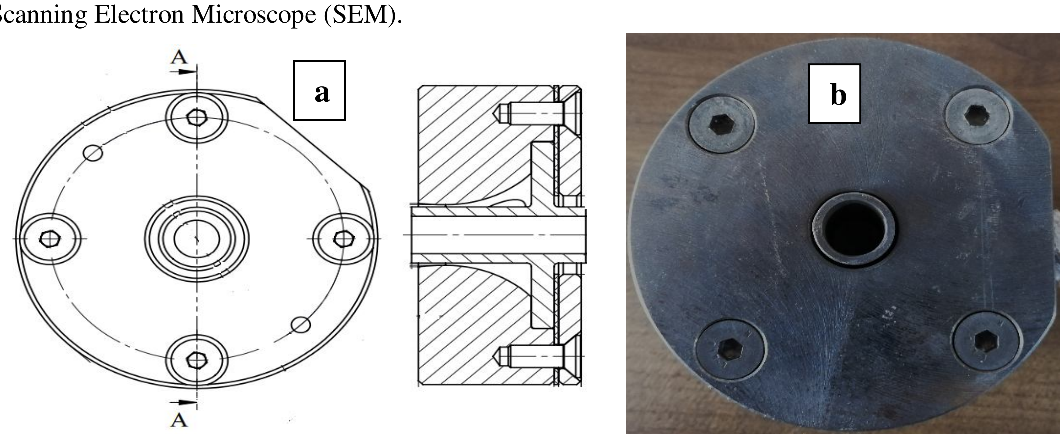


Fig 2. Close-coupled nozzle design (a) and manufacture (b)

III. RESULTS AND DISCUSSION

XRD analysis was applied to the commercial pure aluminum material supplied as the starting material for the production of aluminum powder by using the vertical gas atomization technique, which is one of the methods of powder metallurgy production (Figure 3). When the result of the obtained XRD analysis was examined, it was seen that all of the resulting peaks represented the pure aluminum material.

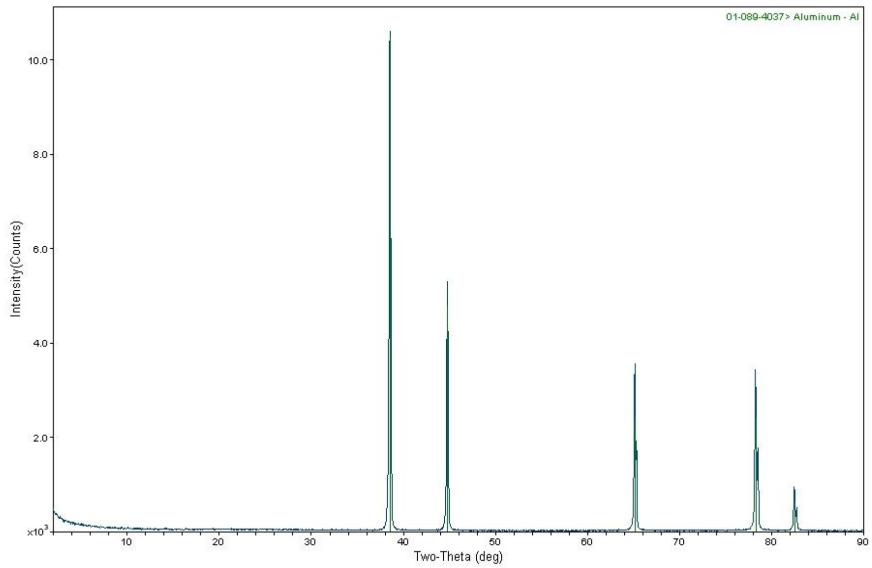
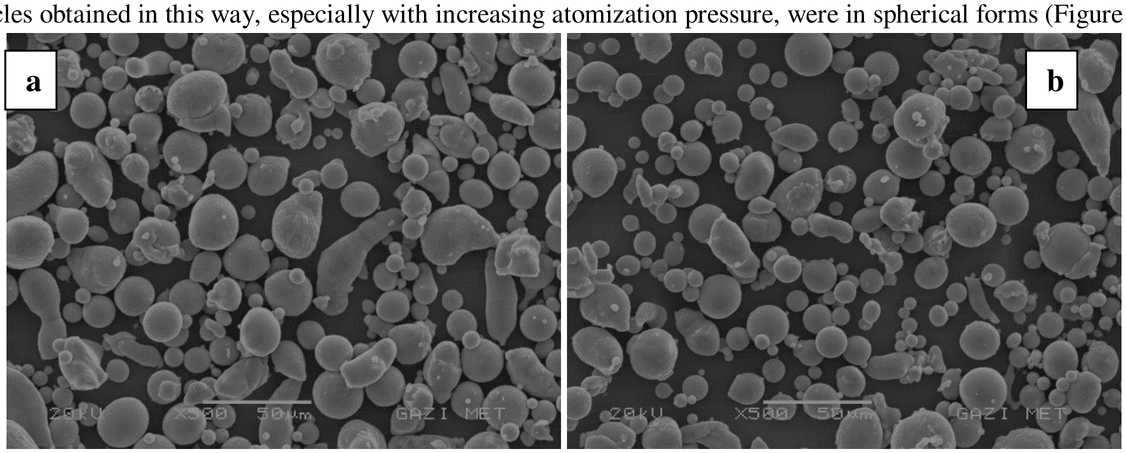


Fig 3. XRD analysis of commercial pure aluminum

The production of the material supplied as commercial pure aluminum was carried out at 900°C temperature and variable gas pressures (20-25-30 bar) by using the vertical gas atomization method. The powder shape and morphology of the pure aluminum material from which powder production was done are given in Figure 4. When the SEM images in Figure 4 were examined, it was determined that rod-like, teardrop, and spherical powder shapes and morphologies were formed. In particular, it was determined that the powders produced at an atomization pressure as low as 20 bar were mostly in the rod-like and teardrop powder shapes as well as the targeted spherical shape morphology (Figure 4a). On the other hand, it was observed that the powders were formed in the spherical powder shape and morphology in experiments performed with increased atomization pressures (25-30) (Figure 4b). In particular, when SEM images of aluminum powders obtained using an atomization pressure as high as 30 bar were examined (Figure 4c), it was determined that almost all of the powders were formed in spherical shapes. The powder shape that is likely to form in powder particles produced by the atomization method is known as spherical/near-spherical [10]. It was observed that the powder particles obtained in this way, especially with increasing atomization pressure, were in spherical forms (Figure 5).



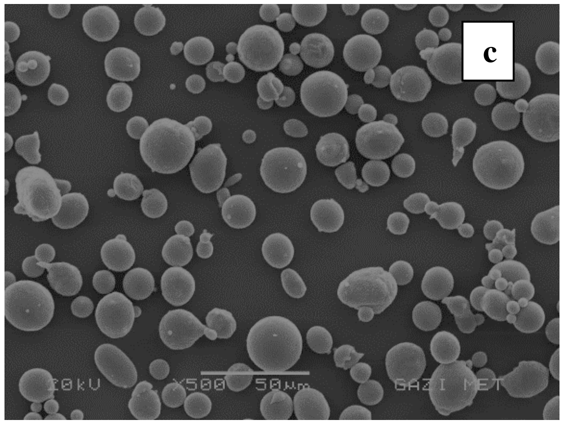


Fig 4 SEM images of pure Al powders; a) 20 bar, b) 25 bar, c) 30 bar

In particle size measurement processes performed after the production of metal powders, sieve analysis process is mostly applied conventionally. In addition, considering the imaging and microstructure studies that have been developing in recent years, size measurements are also performed during the imaging process by using electron microscopes. In this regard, particle size measurements were performed using SEM images of aluminum powders (Figure 5a). After particle size measurement procedures based on spherical powder shape and morphology, it was determined that the majority of powders were below 20µm. In addition, when the SEM image was examined (Figure 5b), it was observed that there were powders in sizes of 3µm, 8.11µm, and 2.54 µm, respectively. In the literature, the holding/adhesion of fine powders that have just completed solidification to coarse powders that had completed solidification is defined as "satellization" [11]. This condition was detected in powders with a particle size of 3 or 5 µm in the form of adhesion to large powder particles (satellization).

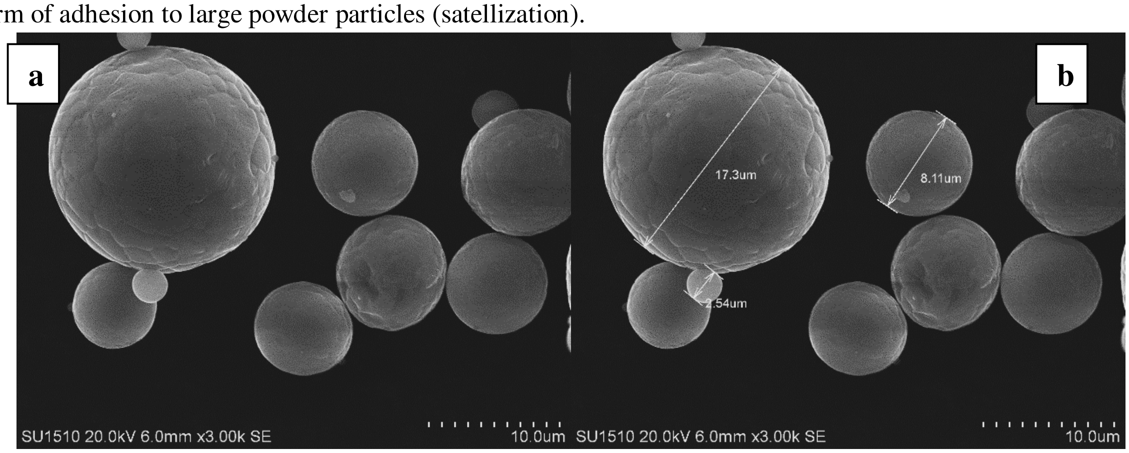


Fig 5 SEM images of pure Al powders produced at 30 bar

In commercial pure aluminum powder metal production processes, the atomization was tested by performing different experiments that had different gas pressures. The effect of this condition on the powder size was evaluated. It was found that as gas pressure increased, the size of the powder decreased.

The reason for this is the energy transferred to the molten liquid metal. Therefore, the more energy that can be transferred to liquid metal during the gas atomization, the smaller the produced powder particles can be [12]. In this context, it was found in experimental studies that the powder size decreased with increasing atomization gas pressure (Figure 6). As can be seen in Figure 6, the finest powder particle size was obtained at an atomization pressure of 30 bar as d_{50}=19.50µm. At low atomization pressures, that is, in experiments where 25 and 20 bars were applied, the particle sizes were measured as d_{50}=20.846µm and d_{50}=26.436µm, respectively.

Thus, it is believed that in addition to the increased atomization pressure, the designed and manufactured closely-matched nozzle system was also effective on the size of the powder examined.

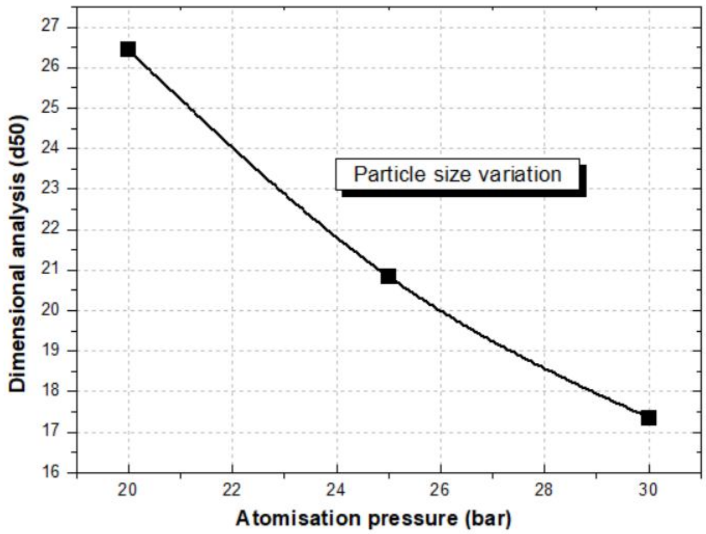


Fig 6 Particle size variation at different atomization pressures

IV. CONCLUSIONS

In this study, the production and characterization of commercial pure aluminum powders were carried out by using the designed and manufactured vertical gas atomization unit and nozzle together. The obtained results are summarized below;

In the context of the production of commercial pure aluminum powders, the finest powder size was obtained under a molten metal temperature of 900°C and pressure of 30 bar. It was determined that especially at low pressures, the powders were in shapes and morphologies called rod-like and teardrop as well as the spherical powder form. With an atomization pressure of 30 bar, a completely spherical powder shape and morphology was produced. It was determined with SEM images that small-sized gas-atomized aluminum powders form a satellization over larger-sized powders. As a result of the particle size measurements, the smallest powder size was determined as d_{50}=19.50µm with an atomization pressure of 30 bar.

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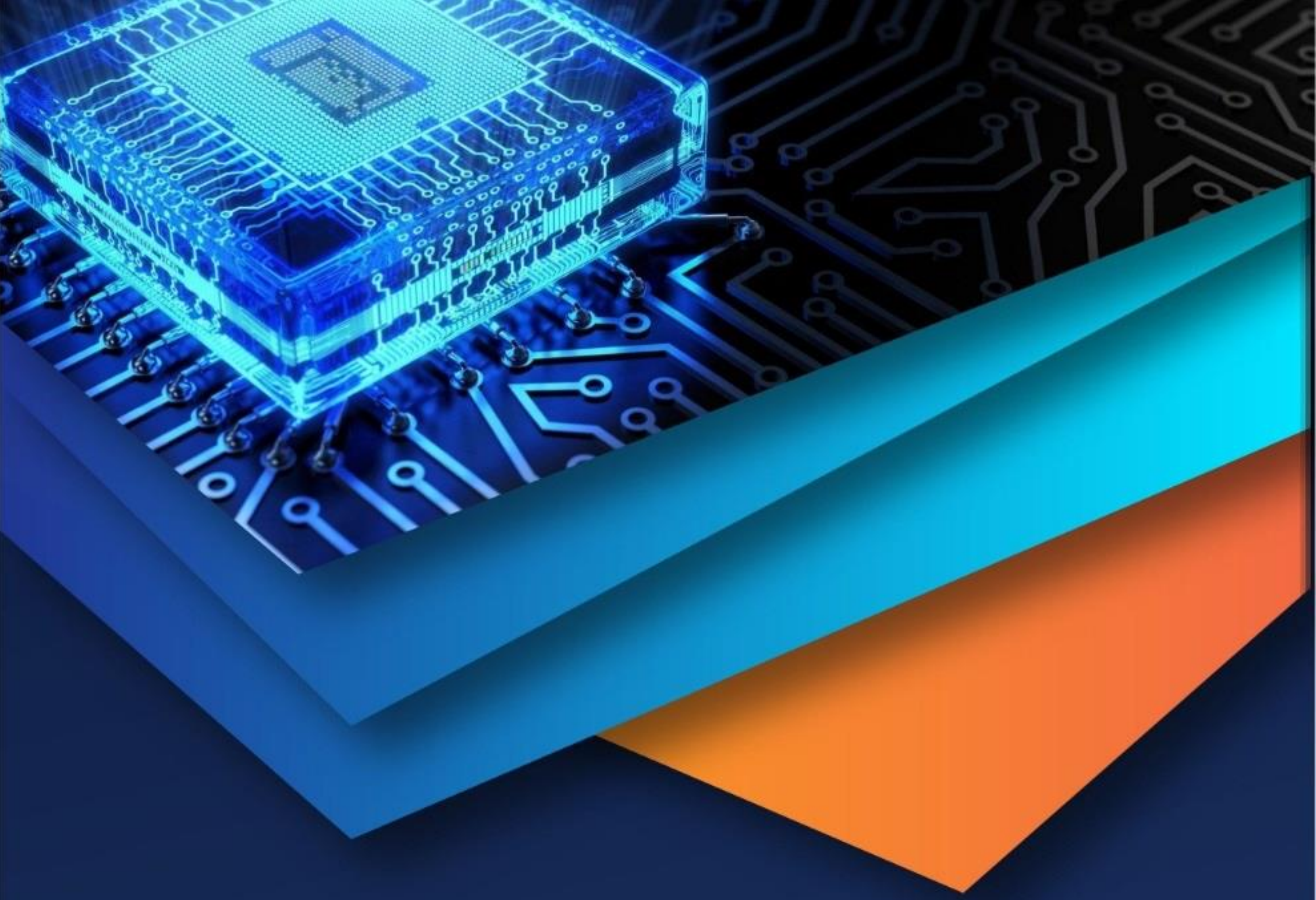

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