Influence of Atomizing Condition on Particle Size Distributions for High Pressure Water Atomized Powder

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Abstract

To improve the properties of fine metal powder, such as particle size distribution and geometric standard deviation, this work was done at various atomizing conditions. The new atomization mechanism and the correlation equation were proposed to estimate the mean particle diameter.

Keywords : High pressure water atomization, Particle size distribution, Fine metal powder

1. Introduction

The demand for fine metallic powders by high pressure water atomization has been increasing rapidly. The improvement of properties of these fine powders has continued. The fine powders with average particle size of less than ten micron, low oxygen concentration and narrow size distribution has been developed in house for twenty years.

This work identified useful equations to express the relationship between average particle size and process conditions.

2. Experimental and Results

A) Experimental Procedure

Fig.1 shows a schematic cross section for the atomizing nozzle that has an annular slit to form an inverse cone with a high velocity water wall. The molten metal in the tundish falls into the atomizer through the nozzle located at the bottom of the tundish. The molten metal stream is disintegrated into fine particles by high pressure water.

The water pressures from 50 Mpa to 100Mpa were used. The pressure distributions along the central axis of this nozzle were measured with the pressure probe.

Stainless steel, such as 410, 440C, 316L and 17-4PH, low alloy steel, Cupper, Cobalt and Kovar were atomized.

B) Results

Fig.2 shows one of the typical particles of fine stainless steel 316L powder. This powder has the spherical shape. The average particle size is 7.6 m. Fig.3 shows the particle size distribution. The geometric standard deviation is 1.97.

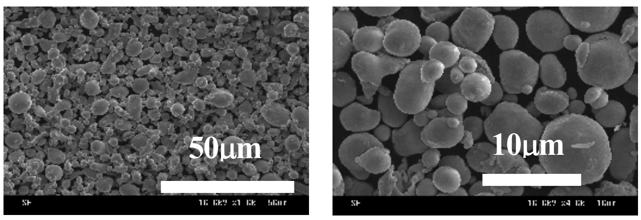

Fig. 2. SEM micrographs of 316L powder

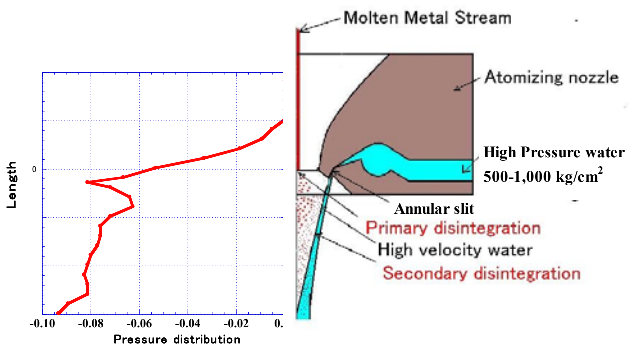

Fig. 1. Schematic View of Disintegration and Pressure Distribution on the central axis.

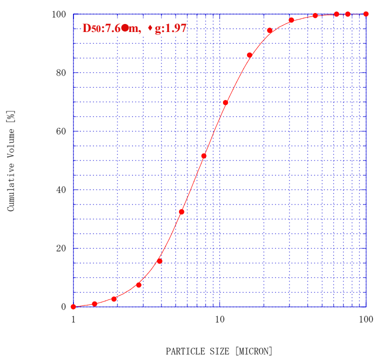

Fig. 3. Particle size distribution of 316L powder

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Lubanska[1] obtained Eq. (1) for the mean particle size using multi-lance gas atomizing method. Nakamura[2] derived that Lubanska's equation is available to the full cone type water atomizing nozzle. Satoh[3] reported that their test results using Ar gas atomization were in agreement with Lubanska's equation. Hiraga[4] adopted Lubanska's equation for estimation of the experimental results by water atomization using multi-holes nozzle and modified it from estimation of water flow rate and the inner diameter of the poring nozzle.

The results to apply Eq. (1) to this work did not show good relation.

$$d_m = K \cdot D \cdot \left[\frac{\nu_m}{\nu_g \cdot We} \cdot \left(1 + \frac{Q_m}{Q_g} \right) \right]^{1/2} \quad (1)$$

d_m ; Median particle size , D ; Nozzle diameter
K ; constant , ν_m ; Kinetic viscosity of molten metal
ν_g ; Kinetic viscosity of atomizing gas
We ; Weber number ($\rho_m \cdot V_g^2 \cdot D/\gamma_m$)
Q_m ; Mass flow rate of molten metal
Q_g ; Mass flow rate of atomizing gas

The new atomization mechanism was proposed.

According to the pressure distribution of Fig.1, the pressure decreases dramatically from atmospheric pressure to less than –80kPa. This pressure drop inside the atomizer forms an expansion wave. This wave is reflected on the high-velocity water wall to produce a compression wave. By repeated this reflection, the expansion-compression waves induce disintegration action of the molten metal stream. This phenomenon is "Primary disintegration".

After primary disintegration, molten metal particles hit on the high-velocity water wall. The molten particles are further disintegrated in the jet due to the high-velocity water. This phenomenon is "Secondary disintegration".

In order to obtain the relation between the mean particle size and atomizing condition, we modified Lubanska's equation as double atomization instead of single atomization.

Eq. (1) was converted to Eq. (2) to put $\rho_m \cdot V_g^2 \cdot D/\gamma_m$ in the place of We number.

$$d_m = K_1 \cdot D^{1/2} \cdot \frac{(\gamma_m \cdot \eta_m)^{1/2}}{V_g \cdot \rho_m \cdot \nu_g^{1/2}} \cdot \left(1 + \frac{Q_m}{Q_g} \right)^{1/2} \quad (2)$$

ρ_m ; Density of molten melt , V_g ; gas velocity
γ_m ; Surface tension of molten metal
η_m ; Viscosity of molten metal ($\nu_m \cdot \rho_m = \eta_m$)

We applied Eq. (2) to both the primary disintegration and the secondary disintegration. Eq. (3) was derived from putting the mean particle size d_m of the primary disintegration to the atomizing nozzle diameter D of the secondary disintegration. The mean particle size d_m of Eq. (3) corresponds to D_{50} of this work.

$$d_m = K_2 \cdot D^{1/4} \frac{(\gamma_m \cdot \eta_m)^{3/4}}{V_w \cdot V_g^{1/2} \cdot \rho_m^{3/2} \cdot \nu_g^{1/4} \cdot \nu_w^{1/2}} \cdot \left(1 + \frac{Q_m}{Q_w} \right)^{1/2} \cdot \left(1 + \frac{Q_m}{Q_g} \right)^{1/4} \quad (3)$$

V_w ; Water velocity、
Q_w ; Mass flow rate of atomizing water、
ν_w ; Kinetic viscosity of atomizing water

Eq. (4) was obtained to divide Eq. (3) by the atomizing nozzle diameter D.

$$d_m/D = K_2 \cdot \frac{(\gamma_m \cdot \eta_m)^{3/4}}{D^{3/4} \cdot / V_w \cdot V_g^{1/2} \cdot \rho_m^{3/2} \cdot \nu_g^{1/4} \cdot \nu_w^{1/2}} \cdot \left(1 + \frac{Q_m}{Q_w} \right)^{1/2} \cdot \left(1 + \frac{Q_m}{Q_g} \right)^{1/4} \quad (4)$$

Fig.4 shows the relation between d_m/D and

$$\frac{(\gamma m \cdot \eta m)^{3/4}}{D^{3/4} \cdot / V_w \cdot V_g^{1/2} \cdot \rho_m^{3/2} \cdot \nu_g^{1/4} \cdot \nu_w^{1/2}} \cdot \left(1 + \frac{Q_m}{Q_w} \right)^{1/2} \cdot \left(1 + \frac{Q_m}{Q_g} \right)^{1/4}$$

, which we call Atomizing Parameter Ap.

Although this work was done under wide range of atomizing conditions, Fig.4 indicates that d_m/D is almost proportional to Atomizing Parameter Ap.

The experimental equation was obtained as indicated below Eq. (5).

$$d_m/D = 452 \cdot A_p \quad (5)$$

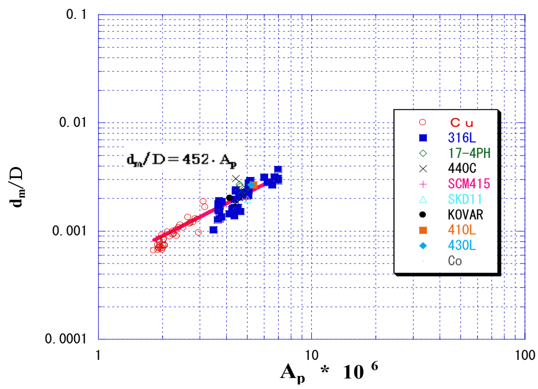

Fig. 4. Correlation between dm/D and Atomizing Parameter

3. Summary

Lubanska's equation was modified to adopt for estimation of the experimental results on the base of new atomization mechanism which consists of two atomization steps or the primary/secondary disintegration.

Atomizing Parameter does not include the factors, such as geometric design of atomizing nozzle, supper heat and so on. The further examination was continued to obtain more sophisticated relation.

4. References

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