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AN INVESTIGATION OF THE NOZZLE GEOMETRY AND GAS VELOCITY INFLUENCE ON ALUMINIUM POWDER SIZE DISTRIBUTION

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ABSTRACT

There are many ways in producing metal powders. However metal (or alloy) chemical and physical properties as well as expected powder shape and distribution usually determine the powder production route. In most cases the optimal process is melt atomization, either by using high pressure gaseous or liquid media. In present work we designed confined anular nozzle to atomize aluminium melt by high pressure nitrogen gas. The nozzle was made in such a way that the atomizing gas cone angle, surrounding the sucked melt stream, was possible to vary between 0 and 60°. Gas exit velocities were varied between 0.5 and 2.5 Mach. The influence of those two varying parameters on particle size distribution was investigated in this work. The results were compared with other relevant work showing good agreement.

INTRODUCTION

Liquid metal atomizing is a well known phenomenon, although atomizing mechanizma are not exactly known. However, experimental results did gave some empirical correlations of atomizing parameters (like atomizing and atomized media, their relative velocities and mass ratios) and mean particle diameters [1,2,3,4]. Unfortunately the empirical results (equations) are only valid in a very narow range of experimental conditions being very sensitive to the particular design as well. Comparing with liquid (room temperature) spraying, proper metal atomization is a quite complicated task. Namely, having much higher melting points than ambient (or gas) temperature, metal stream is very easily blocked by cold gas or even by some other effects especially in close coupled nozzle configuration [5] which was employed here. All problems regarding proper nozzle function were carefully studied before final construction of confined nozzle for continous atomization of metallic melts. High quality refractory lining for metal stream path ruled out need for additional nozzle heating prior to start of atomization.

This work was done on a designed nozzle with some changing parameters (gas cone angle and gas velocity) in order to study and consequently control particle distribution as well as cooling rate and microstructure of obtained powders.

EXPERIMENTAL

It is well known that proper metal spraying need good prefilming of metal stream before atomization. Prefilming was provided by sucking a sheat of molten metal into the atomizing gas cone. Atomizing upwards, which was employed here, gave better prefilming even for higher metal to gas ratios.

Gas pressures in the range of 4-16 bars were used (note that conventional gas atomizers use usually gas pressures below 8 bars) consequently designing nozzle for outlet gas velocites from 0.5 to 2.5 mach numbers. Supersonic nozzle design was employed in order to maximize kinetic energy transfer from gas to metal. As can be seen gas was tangentially introduced making atomization more uniform as well as effective (Figure 1).

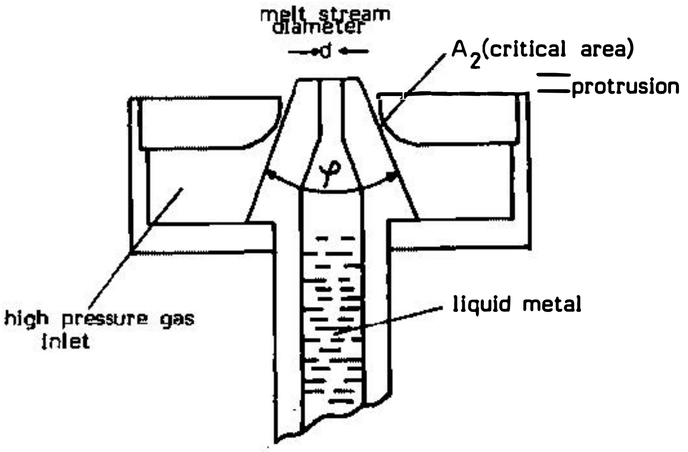

Figure 1.

Exit gas cone (φ) was varied from 0 to 60°. In all cases precautions were taken to avoid shock wave formation inside the nozzle troat (A_2).

RESULTS

Powder size distributions of obtained aluminium powder using 4-16 bars nitrogen pressure and cone of 15°, are shown in Figure 2. As can be seen produced powder was between medium and fine (US standard) [7], being the finest for the pressure of 12 bars. This limit for maximum fine particles at 12 bars was probably due to increased resistance to gas flow through the narrow annular troat (A_2 in Figure 1.) at higher pressure. Optimization of A_2 gas pressure was not made here.

In Figure 3. aluminium powder size distributions for 12 bars gas pressure and different cone angles (0-60°) are shown. It was observed that by increasing cone angle there was decrease in the mean particle size diameter being in the range of fine powder at 60° cone angle [7].

ANALYSIS AND DISCUSSION

Our results showed that powder size distribution can be controlled to a quite large extent just by changing some "pasive" external parameters apparently more effectively then by spending additional atomizing gas. Hence resultant particle distribution for the same gas flow was very sensitive to the nozzle design. It should be mentioned that just by increasing cone angle from 15° to 45° with the same gas flow melt flow increased by 12% (increased sucking) and fine fraction percentage was almost doubled [8]. Optimum cone angle was between 45 and 60°, while further increase of cone angle resulted in much lower atomizing rates (not shown here). Normally, gas pressure plays an important role showing best results at around 12 bars. As we pointed out

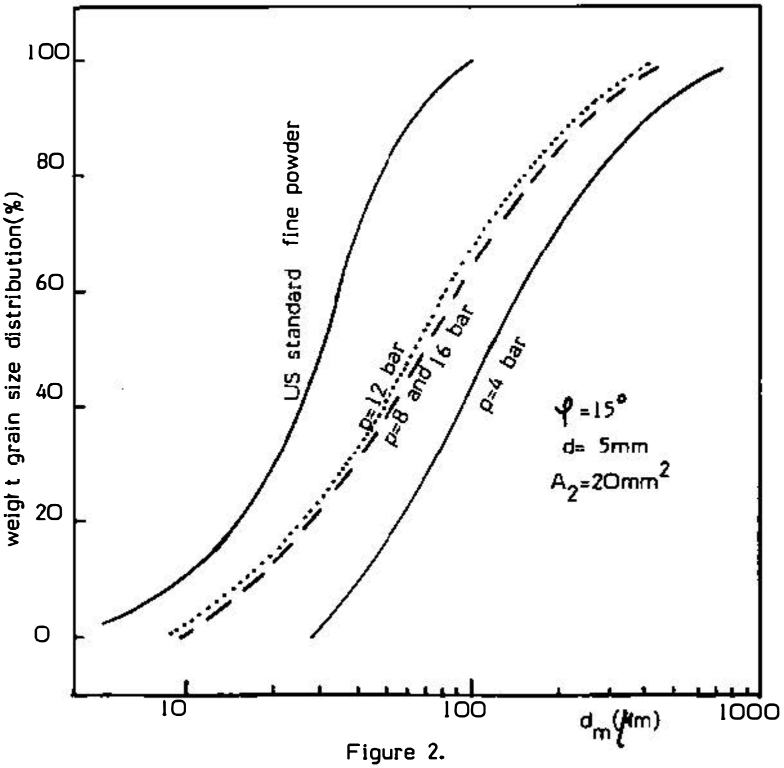

Figure 2.

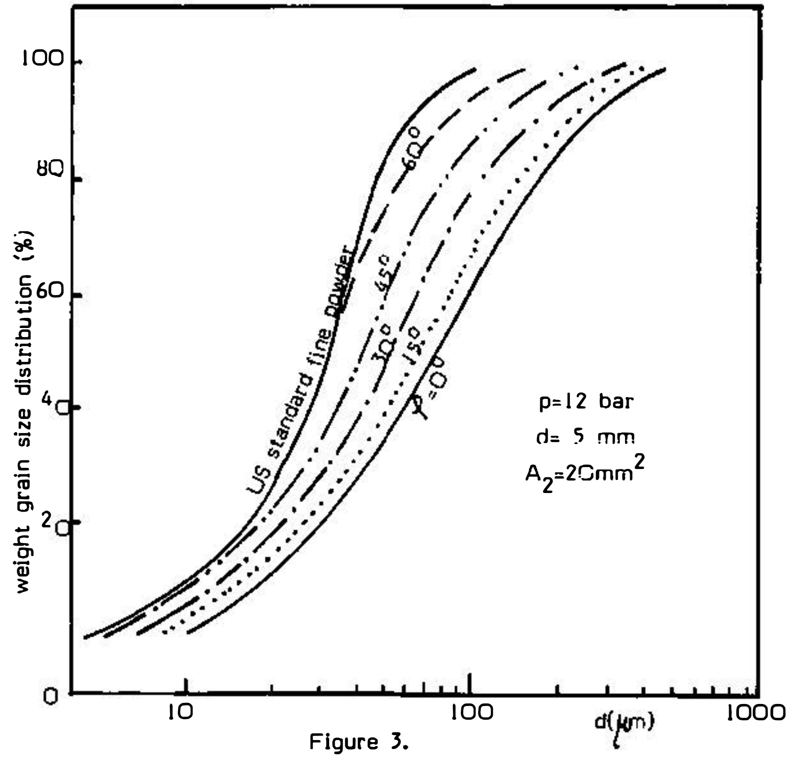

Figure 3.

earlier for higher pressures there was no improvement probably due to increased resistance to gas flow in this tangential gas inlet and hence to the rotating gas movement in the troat area and outside nozzle, which was more pronounced at lower cone angles. Using Lubanska's [1] empirical equation, for aluminium case, the mean particle diameter (D) in milimeters is:

$$D = 50\, d \left\{ \frac{\eta_{melt}}{\eta_{gas} N_{we}} \left(1 + \frac{J_{melt}}{J_{gas}} \right) \right\}^{1/2}$$

and

$$N_{we} = \frac{v^2 \rho_{melt}\, d}{\sigma_{melt}}.$$

η melt - viscosity of melt (SI), η_{gas} - viscosity of gas (SI), v - gas velocity, ρ melt - melt density, σ_{melt} - kinematic viscosity of the melt, Jmelt/Jgas - ratio liquid to gass mass flow.

Using this calculations, it was found that our D results were somewhat below expected for theoretical no-friction prediction of gas velocities. If we consider gas friction inside the nozzle this calculation is in good agreement with our results.

For this range of powder granulations our design showed to be comparable (not worse) than recently published ones [9, 10, 11] for very fine rapidly solidified aluminium and some other powders.

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