Impact of Gas Pressure on Atomization Process and Particle Size of the Fe-Based Powder

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Abstract: Gas atomization is a commonly employed method for producing metal powder in additive manufacturing. This paper utilizes computational fluid dynamics to simulate the flow field and analyze the gas-melt two-phase mechanism in two-stage atomization, based on experimental data. The study explores the influence of gas pressure on the gas flow field, the gas-liquid field, and particle size distribution. The findings suggest that the powder required for Laser Melting Deposition can be produced at an atomization pressure of 4 MPa, yielding the highest powder output. Additionally, an increase in gas pressure results in a decrease in the particle size of the powder. The Volume of Fluid model and Discrete Phase Model effectively simulate the gas atomization process, with the simulated particle size distribution closely matching the experimental results. The experimental Fe-based alloy powder exhibits good sphericity with minimal satellites, rendering it suitable for laser additive manufacturing with metallic materials.

Keywords: gas atomization, metal powder, numerical simulation, gas pressure, atomization process

1 Introduction

High-quality, low-cost metal powder is the fundamental material for rapidly producing parts. Gas atomization is the predominant method for producing metal powders in industrial settings [1]. The entire atomization process encompasses the supersonic flow of inert gas and the breakup of high-temperature melt, and the atomization mechanism is not yet fully understood [2]. Therefore, this study aims to examine the impact of gas pressure on the atomization process and the particle size distribution of the powder through a combination of simulation and experimental methods.

2 Experimental procedure

Fig. 1 shows the computational domain and boundary conditions. Argon was used as the atomizing gas and was defined as an isentropic, compressible, ideal gas. Fe-based alloy was chosen as the atomizing material. The VOF (Volume of Fluid) multiphase flow model was used to simulate the primary atomization, and the DPM (Discrete Phase Model) was used to simulate the secondary atomization. The experiments were conducted using a close-coupled discrete-jet atomizer within a Vacuum Induction Melting Inert Gas Atomization (VIGA) system.

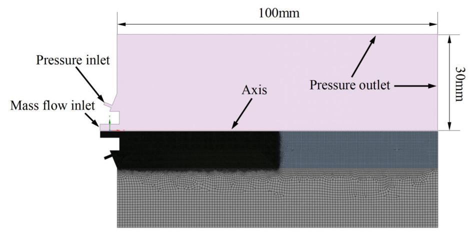

Fig. 1 The model size, boundary conditions, and grid for simulating the atomization process.

3 Result and discussion

Impact of gas pressure on the gas flow field

Fig. 2 illustrates the velocity field, directional vector, axial velocity, and static pressure at different gas pressures. The position of the Mach disk in the flow field gradually shifts to the right with increasing atomization pressure, leading to an increase in the length and width of the supersonic expanding gas flow.

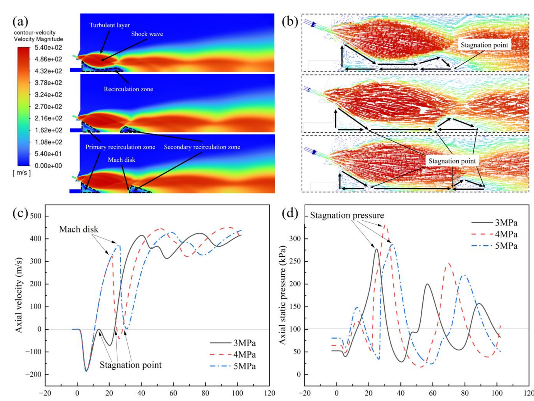

Fig. 2 The velocity field contour (a) and directional vector (b) at different gas pressures, while figures (c) and (d) illustrate the effects of gas pressure on axial velocity and static pressure.

Primary atomization and secondary atomization

Fig. 3 illustrates the primary atomization process under varying gas pressures. Notably, at 4 MPa, the melt requires less time to break under the influence of high-speed airflow compared to 3 MPa, thus contributing to the primary breaking process. At 5 MPa, the melt moves upward due to reverse airflow, leading to radial flow and subsequent breakage into smaller droplets, albeit with a risk of backflow.

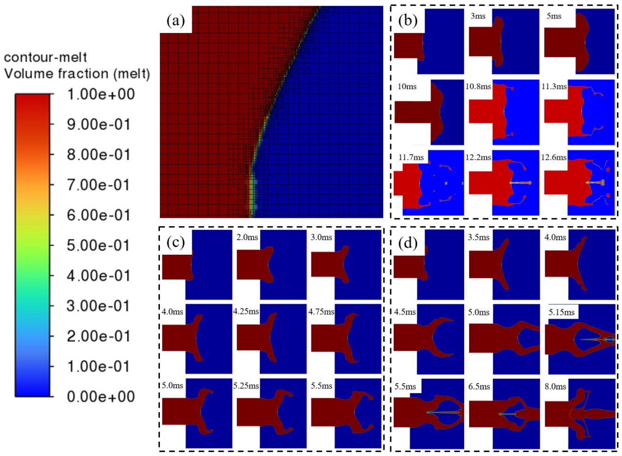

Fig. 3 Adaptive grid schematic at the gas-liquid interface (a) and the impact of gas pressure on primary atomization. (b) 3 MPa (c) 4 MPa (d) 5 MPa

Fig. 4(a) illustrates the process of secondary atomization, while Fig. 4(b) to (d) depicts the particle size distribution at varying gas pressures. With an increase in atomization gas pressure from 3 MPa to 4 MPa and 5 MPa, the median particle size decreases to 76.79 μm, 71.12 μm, and 57.88 μm, respectively.

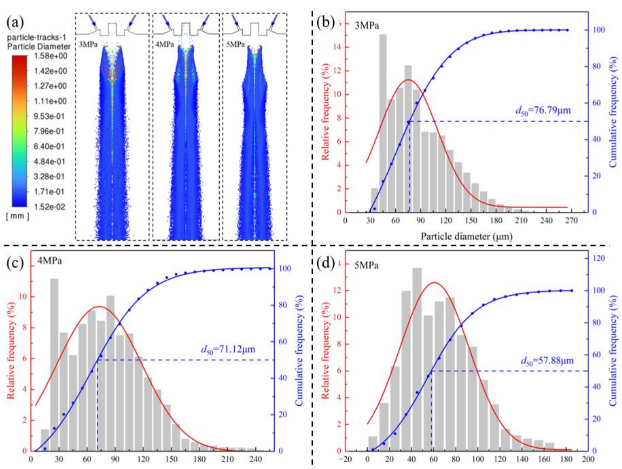

Fig. 4 Particle fragmentation (a) and particle size distribution during the secondary atomization process. (b) 3 MPa (c) 4 MPa (d) 5 MPa

Powder characteristics

The particle size distribution of the Fe-based powder obtained at various atomizing gas pressures is depicted in Fig. 5(a) to (c). As the gas pressure increases, the median particle size of the powder gradually decreases to 87.6 μm, 70.1 μm, and 53.9 μm, respectively. In comparison with the simulation results, the errors are 12.3%, 1.5%, and 7.4% respectively, indicating that the simulated particle size distribution aligns with the experimental results. The surface morphology of the powder is illustrated in Fig. 5(d). Overall, the powder exhibits good sphericity, with a small number of irregular and defective particles, such as coated particles and satellites.

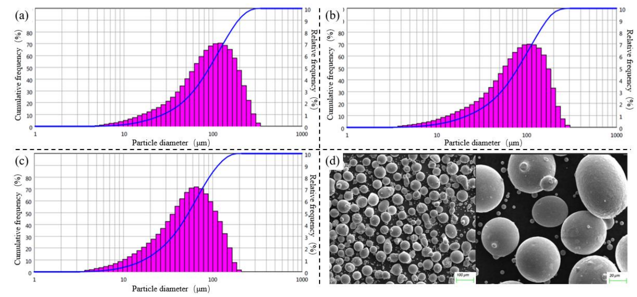

Fig. 5 The particle size distribution and SEM image of the Fe-based powder (d) produced by gas atomization. (a) 3 MPa (b) 4 MPa (c) 5 MPa

4 Conclusion

The simulation and experimental findings suggest that the powder necessary for Laser Melting Deposition can be generated at a pressure of 4 MPa, resulting in the highest yield. Furthermore, elevating the gas pressure leads to a decrease in the size of powder particles. The VOF and DPM models proficiently replicate the gas atomization process, and the simulated particle size distribution closely corresponds to the experimental results. The Fe-based powder produced by gas atomization demonstrates favorable sphericity with minimal satellite particles, rendering it suitable for laser additive manufacturing.

Acknowledgments

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