



Preparation of Al_2O_3 magnetic abrasives by gas-solid two-phase double-stage atomization and rapid solidification

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ABSTRACT

This paper describes the production of Al_2O_3 magnetic abrasives via a double-stage atomization method. The matched pressures of atomization were simulated via Ansys-Fluent commercial software. The structure, phase composition and properties of the abrasives were examined. The analysis indicates that the magnetic abrasives have ideal spherical shape, and the Al_2O_3 hard particles are uniformly embedded into the surface of the iron matrix. The Al_2O_3 magnetic abrasives have good soft magnetic properties, with a saturation magnetization of 119 emu/g and a coercivity of 2.287 Oe. In addition, a series of plane magnetic abrasive finishing experiments were conducted using magnetic abrasives. The result of the Inconel718 plate shows that the developed abrasives have excellent processing performance, high grinding efficiency and long service life. Moreover, the atomization method described here could be promising for large-scale industrial preparation technologies.

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1. Introduction

Non-traditional magnetic finishing of surfaces involves polishing the plane, surface, tube surface, or other hard and brittle complex surface [1]. The processing capacity has an important impact on the surface integrity and performance [2]. Magnetic abrasives are processing tools, and their performance and service life directly affect the quality and efficiency of processing. The traditional preparation methods for magnetic abrasives currently include sintering [3], plasma spraying [4], and electroless composite plating [5] etc.

This paper presents a new gas-solid two-phase double-stage atomization with rapid solidification. This technique produces magnetic abrasives via ferromagnetic Fe-Si-Ni-Cu raw materials and Al_2O_3 hard particles. A molten metal film is first atomized by the first-stage atomizer with low velocity gas-solid two-phase flow consisting of atomized gas and Al_2O_3 particles. This was then atomized a second time by the next stage atomizer with only high purity atomization gas. We noted smaller erosion effects with the atomizer and more bonding strength of Al_2O_3 particles. This method offers better Al_2O_3 magnetic abrasives than conventional single stage atomization [6].

2. Materials and methods

The facility used to prepare Al_2O_3 composite magnetic abrasives is illustrated in Fig. 1. In the atomization system, a special double-stage atomizer was designed in our lab to convey atomization gas and Al_2O_3 particles (Fig. 1 (A)). The ferromagnetic alloy matrix had the following composition (in wt%): 3.7 ± 0.3 Si, 1 ± 0.2 Ni, 1 ± 0.2 Cu with the balance Fe. White Al_2O_3 particles ($d_{50} = 14 \mu\text{m}$) can be fed quantitatively to the discharge port and mixed with the side N_2 gas to form a uniform gas-solid two-phase atomization medium in the first-stage atomizer (Fig. 1(B)).

The step of preparation magnetic abrasive was as follows: The molten iron matrix with appropriate superheat flow from the guide tube encountered low-pressure two-phase flow. This was then atomized into the big metal droplets. With balanced and matched pressure, these droplets entered the next atomization area. In the atomization cone, the pre-atomized droplets were blown, crushed, and refined into small droplets by high-pressure inert gas from the second-atomizer. The atomized droplets were rapidly cooled (10^5 – 10^6 K/s) via heat transfer between droplets and high-speed air flow. During solidification at high undercooling, the Al_2O_3 particles were captured by the matrix.

3. Results and discussion

Fig. 2(a) shows the collision and atomization process of the Al_2O_3 particles and gas with the molten metal. In the first stage

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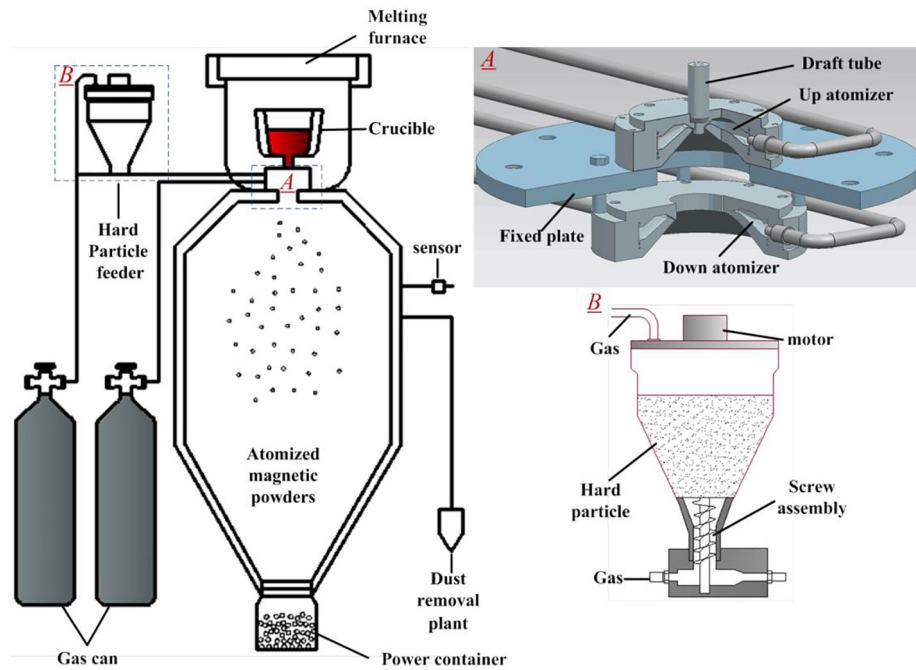


Fig. 1. Schematic diagram of double-stage atomization and rapid solidification.

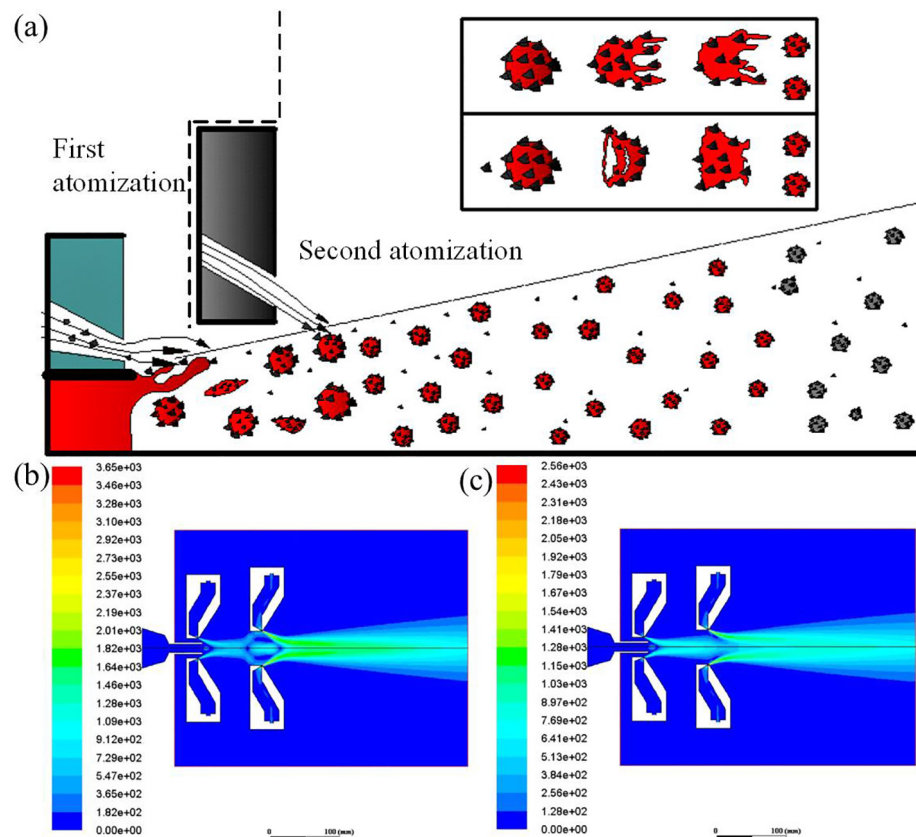


Fig. 2. (a) Double-stage atomization process; (b) and (c) Simulated failure and success diagram of atomization flow field, respectively.

of atomization, the surface of the molten metal is disturbed by sinusoidal oscillation and collision of hard particles. It is then broken into large initial droplets or unstable ligaments containing Al_2O_3 particles. The small particles without captured droplets have a very high kinetic energy due to the high-pressure gas from the

second-stage atomizer. By combining particles and high-pressure gas, the large initial droplets or unstable ligaments can be atomized into smaller droplets. During atomization, the geometry and operating parameters of the double-stage atomizer directly affects the success or failure of the process. The atomization flow

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