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Original Research Paper

Development of a spiral-flow jet mill with improved classification performance

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ABSTRACT

Our group has proposed a jet mill equipped with a particle-trap ring at the exit of the comminution zone to prevent the escape of large particles entrained by shortcut flow. The visualized swirl flow compares favorably with simulation results obtained by CFD. Experimental results reveal that a trap ring with a height of 4 mm is the most effective for attaining high classification performance. Yet the classification efficiencies measured at various ring heights are much lower than the classification efficiencies calculated by the CFD. This discrepancy may be attributable to the particle-flow interaction and the change in particle size during the particle movement.

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1. Introduction

The pulverization or comminution of coarse particles is an increasingly important process for obtaining uniform particles with closed-circuit grinding systems [1–6]. The spiral flow jet mill, a machine that pulverizes coarse particles using a circular gas flow, is highly effective for comminution. The mill breaks down large particles via particle–particle collisions, particle–wall collisions, and the shear force in the high-velocity jet stream. Some types of jet mills are equipped with an internal classifying mechanism to control the particle size distribution of a product. The mills use circular flow to classify particles by balancing the centrifugal force and the drag force acting on a particle. Manufacturers in the food, pharmaceutical, electronic, and ceramics industries widely adopt jet mills of various types to take advantage of their simple structures and high comminution performance. A number of studies have been conducted to analyze the comminution process and classification mechanisms of jet mills [7–9]. Based on estimations of the external force acting on a particle from the radial and tangential air velocities calculated by two-dimensional numerical analysis, Tanaka [10] proposed a method for predicting cut-off diameters and a strategy for scaling-up of the process. Yet two-dimensional models fail to sufficiently describe the complex three-dimensional flow profiles in a jet mill. When Levy and Kalman [11] numerically calculated the air mass flow in a jet mill by three-dimensional simulation, their results agreed well with results obtained experimentally. The three-dimensional circular flow, however, is much too complicated to permit a clear understanding of the flow pattern in a jet mill, that is, the three-dimensional velocity distribution.

Our objectives in this study are to improve the classification performance of a jet mill by applying a new design for the classification zone and to clarify the classification mechanisms with this modification applied. The jet mill we propose in this work is equipped with a particle-trap ring at the exit of the classifier to prevent the escape of large particles entrained by shortcut flow. We visualize the flow in the jet mill and compare the visualized results with simulation results obtained with a computational fluid dynamic package (Fluent, ver. 6.3, Ansys Japan). Lastly, we measure the classification efficiency at various ring heights and compare them with the efficiencies calculated by the CFD.

2. Design of developed jet mill

Fig. 1 shows a schematic diagram of the jet mill developed in the present work [12]. Compressed air is introduced in a tangential direction through six nozzles. Coarse powder (raw material) is supplied into the comminution zone from a hopper by a suction flow generated by the tangential compressed air jet. The coarse particles are broken down via collisions and air shear force as they move towards the outlet tube at the center of the jet mill. Centrifugal force pulls the particles outwards as they travel, which prevents the particles with centrifugal terminal velocities larger than the radial air flow velocity from reaching the outlet tube. As a result, a fine

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