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Improvement of gas-cyclone performance by use of local fluid flow control method

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ABSTRACT

The purpose of this paper is to study the effects of a secondary flow injection method on sub-micron particle separation in a new type of gas-cyclone. It was found that particle collection efficiency and classification accuracy of the improved type cyclone was higher than that of the original type cyclone. Three-dimensional simulation results of the improved type cyclone indicated increased fluid rotational velocity in the cylindrical part and increased downward velocity in the conical part compared to the original type cyclone. Experimental results qualitatively agree with the numerical simulation. In order to improve high particle separation performance of gas-cyclones, it is recommended to use both the secondary flow injection and inlet guide plate methods.

1. Introduction

Gas-cyclones are widely used in the separation or size classification apparatus for gas–solid flows, because of their simple structure and low cost. Recently, with improvements in the dimensions of various parts of cyclones, a fairly high level of precision in the classification of sub-micron order particles has become possible [1–3]. Recent industrial requirements of ceramics or metal powders require particle size distributions with a narrow standard deviation, because the physical properties of such classified particles are related to the performance of electrical, magnetic and chemical reactions. In particular, particles with a diameter of 0.1 to 1 μm are required for various powder handling processes. In order to classify a particle cut size in the size range of 0.1 to 1 μm, forced centrifugal classifiers are not always effective because of particle erosion problems and the increased maintenance costs of such classifiers due to high revolutions.

While Iinoya et al. [4] found that it is possible to classify powders even in the 0.4 μm size range using special cyclones, it is generally difficult to change the cut size in a conventional cyclone separator. To solve this problem, Yoshida et al. [1,5] found that it is possible to change the cut size by the use of a moving circular guide plate at the cyclone inlet or by the use of an additional secondary flow injection method in the upper cylindrical part of cyclone.

The concept of tornado dust collectors was presented by Ogawa [6,7], but optimum operational conditions are not clear and detailed studies have not been reported.

The purpose of this paper is to find new optimum operational conditions of the secondary flow injection method. In order to realize sub-micron particle classification by the secondary flow injection method, the optimum secondary flow injection place should be determined. This paper presents a new secondary flow injection place and compares the particle classification performance between conventional and new methods. Three-dimensional computer simulation was also carried out and proved the effectiveness of the new type of cyclone. Particle classification performance by use of both the inlet guide plate and secondary injection flow methods are newly examined. Interesting conclusions that can be used in practical applications are obtained.

2. Experimental apparatus

Fig. 1 shows a schematic diagram of the gas-cyclone used in this study. The cyclone diameter was set at 72 mm and each of the dimensions was determined from experimental data that proved superior in classification performance [4]. In order to change the 50% cut size in the sub-micron range, a secondary flow injection method in the upper cylindrical part of the cyclone as shown in Fig. 1-a was proposed and its performance was examined [5]. Only one inlet flow is used in conventional cyclones, but in this case, the tangential fluid flow velocity component decreases in the lower conical part. The tangential fluid flow velocity near the upper plate of the cyclone decreases, because of an increase in fluid viscosity effect near the upper plate boundary layer region. To increase the tangential velocity component, and to achieve high particle collection efficiency, a new secondary flow injection method is examined.

In our previous paper, particle collection efficiency of the secondary flow injection method was higher than that of the conventional one inlet cyclone [5]. But in order to carry out particle classification in the sub-micron range, additional better methods

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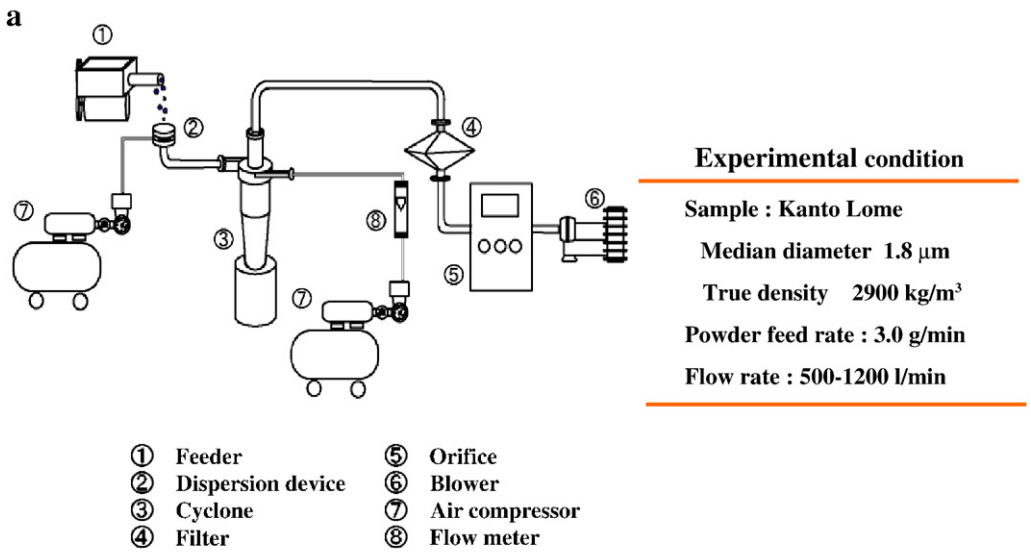

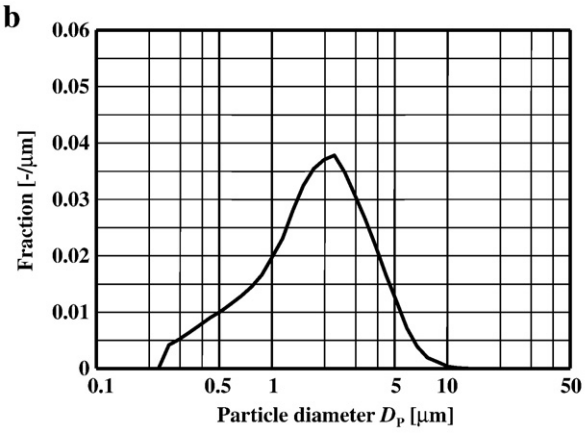

Fig. 1. a Experimental apparatus. b Particle size distribution of raw material.

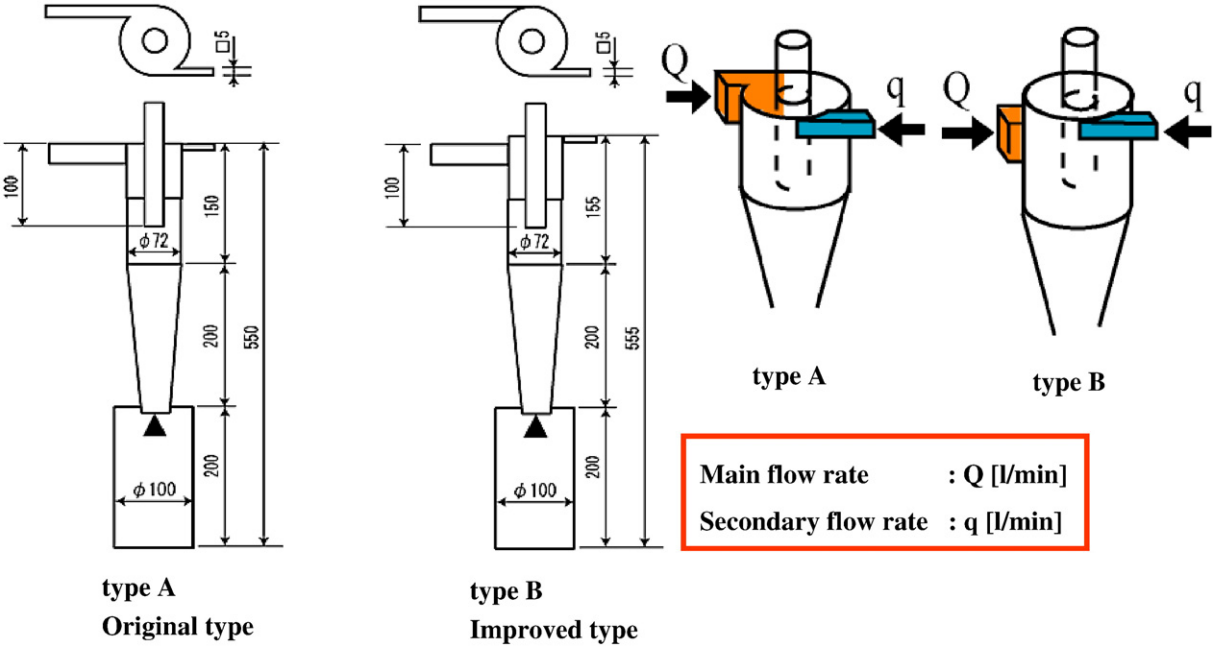

Fig. 2. Two types of cyclones (Type A and B).