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Effect of new blade of centrifugal separator on particle separation performance

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ABSTRACT

In order to increase particle separation efficiency of the centrifugal separator, a new blade is proposed and particle separation performance was examined by experiment and numerical simulation method.

For the type A blade with inside cylinder and four blades, the 50% cut size decreases with the increase of inside cylinder diameter. The pressure drop of the type A blade increases as the inside diameter increases, especially diameter ratio greater than 0.8. The new blade of type B with inside cylinder, four blades and special rings on the inside cylinder shows higher particle separation efficiency and low pressure drop compared with the type A blade.

The experimental partial separation efficiency qualitatively agreed with the numerical simulation results.

1. Introduction

The wet type centrifugal separators can be used to separate fine particles compared to the hydro-cyclone, because the centrifugal effect of centrifugal separators is greater than that of the hydro-cyclone. Hence, the centrifugal separators are widely used in the study of biology, minerals and colloids for the removal of impurities from products in a short time. Recently, various industries, such as electronics, semiconductors and medicine have developed technologies that require mono-dispersed nano-particles. Therefore, the development of a technique that classifies nano-particles is extremely important. To date, several new particle classification technologies based on strong centrifugal force have been developed for the separation of nano-particles because conventional separation apparatus, such as cyclones and hydro-cyclones are ineffective [1–6]. In a recent study of centrifugal separators, we observed that dead space in the centrifugal separator decreased classification performance [7]. In order to remove the dead space and to decrease the radial particle sedimentation distance, the cylindrical blade was proposed and compared its performance with the conventional blade [8]. However, the necessary energy consumption of the separator increases to separate nano-particles.

This paper presents a new blade type centrifugal separator capable of increasing particle separation efficiency with low energy consumption. The performance of the new blade in the centrifugal separator was examined by experiment and numerical simulations and several new and interesting results are obtained.

2. Experimental apparatus

Fig. 1 shows the centrifugal separator system used in the present study. The centrifugal separator is used to rotate the cylindrical wall at high rotational velocity by the motor attached to the top of the separator. The pump moves the feed slurry from the slurry tank to the bottom of the separator. In order to disperse the particles in water, the ultrasonic prove of 300 W was used with dispersion time of 15 min. The feed slurry concentration was set to 0.25 wt% and the temperature was controlled to 30 °C in the system. The particles in the slurry are subjected to a strong centrifugal force field, resulting in classification of particles in the separator. The fine particles are collected from the top of the separator and the coarse particles are deposited on the rotating wall in the separator.

The apparatus is operated at steady state and time of operation was from 30 to 60 min. The separation performance was nearly constant when the operation time greater than about 10 min. After the experiment, the inlet of rotating cylinder was opened and particles on the paper sheet was collected and mass of the particles was recorded. The partial separation efficiency was determined form the sample slurry of the feed and over-flow side.

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Nomenclature

D_p	particle diameter (μm)
D_{p50}	50% cut size (μm)
D_0	inside diameter of the separator (m)
D_i	diameter of inside cylinder (m)
D_R	ring diameter of blade (m)
f_0 (D_p), f_f (D_p)	particle size distribution of the original and classified fine particles, respectively (–/μm)
g	gravity acceleration (m/s^2)
L	length of the separation zone (m)
m_0, m_f	particle mass flow rate of the original and classified fine particles, respectively (kg/s)
Δp	dimensionless pressure drop (–)
p_1	dynamic pressure (Pa)
Q	inlet flow rate (m^3/s)
r, r'	radial coordinate and radial coordinate of critical particle trajectory in Fig. 4 (m)
r_1, r_2	radial coordinate of separator and inside cylinder shown in Fig. 4 (m)
t	time (s)
u_z, u_r	axial and radial fluid velocity (m/s)
v_z, v_r	axial and radial particle velocity (m/s)
V	hold-up volume of the separator (m^3)
z	axial coordinate (m)
$\Delta\eta$	partial separation efficiency (–)
μ	fluid viscosity (Pa s)
ρ_p, ρ	particle and fluid density (kg/m^3)
ρ_0	reference fluid density (kg/m^3)
ω	angular rotational speed (rad/s)

Fig. 2 shows the feed particle size frequency distribution measured by dynamic light scattering method (DLS, LB-550, Horiba Co., Ltd.). The test particles used was spherical acril with its density of 1190 kg/m^3. The size range of particles is from 0.15 to 2 μm. The pure water was used as a dispersing fluid for the test particles. In order to determine the particle separation performance, the partial separation efficiency defined by Eq. (1) was used to evaluate particle separation process.

$$\Delta\eta = \frac{m_0 f_0(D_p)\Delta D_p - m_f f_f(D_p)\Delta D_p}{m_0 f_0(D_p)\Delta D_p} \quad (1)$$

where m_0 and m_f are particle mass flow rate of feed and fine side. The f_0 (D_p) and f_f (D_p) are size frequency distribution of feed and fine side, respectively. After the separation experiment, the four variables, m_0, m_f, f_0 (D_p) and f_f (D_p) are measured and then the partial separation efficiency $\Delta\eta$ is calculated by Eq. (1).

Fig. 3 shows the various blades used in the centrifugal separator. In order to increase the particle separation performance, the entering particles should be passed near the rotating wall region with high rotational fluid velocity. The type S is the conventional type with four blades.

A disadvantage of the conventional type S blade is that the particles moving near the center region cannot be subjected to large centrifugal force. On the other hand, a cylindrical blades shown in type A-1 and A-2, the cylinder part prevents particles from passing through the central region of the separator. In order to increase

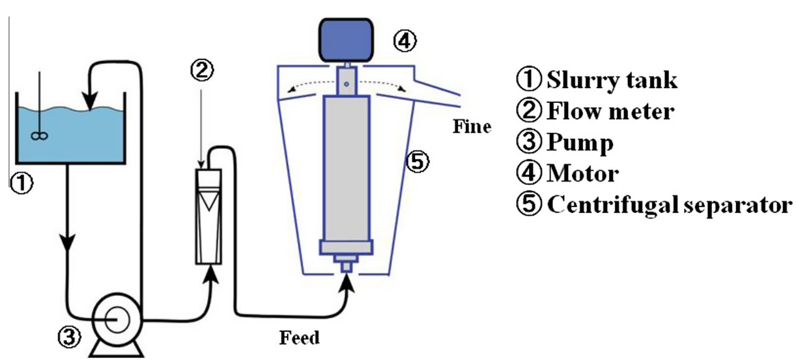

Fig. 1. Experimental apparatus.

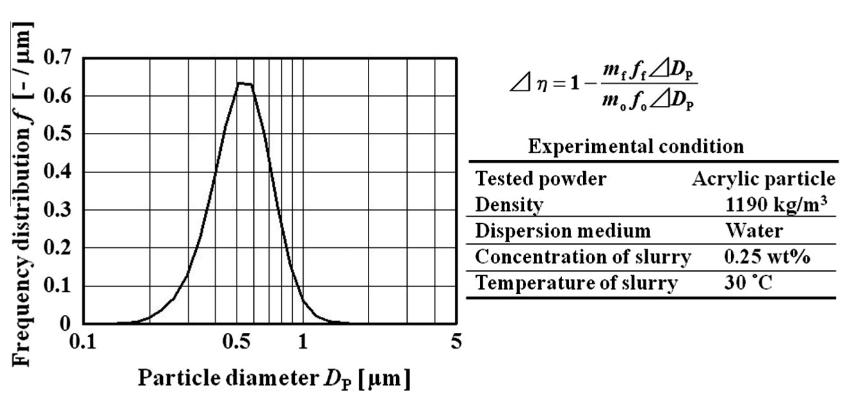

Fig. 2. Particle size distribution of original particle and experimental condition.