Separation and Purification Technology 158 (2016) 223–229

Contents lists available at ScienceDirect

Separation and Purification Technology

journal homepage: www.elsevier.com/locate/seppur

Improvement of particle separation performance by new type hydro cyclone

Tetsuya Yamamoto [b], Takuma Oshikawa [a], Hideto Yoshida [a,*], Kunihiro Fukui [a]

[a] Department of Chemical Engineering, Hiroshima University, 1-4-1, Kagamiyama, Higashi-hiroshima 739-8527, Japan
[b] Formulation Process Group, Production Technology Department, Mitsui Chemicals Agro, Inc., 1358, Ichimiyake, Yasu-shi, Shiga 520-2362, Japan

ARTICLE INFO

Article history:
Received 15 July 2015
Received in revised form 9 November 2015
Accepted 11 December 2015
Available online 14 December 2015

Keywords:
Hydro cyclone
Particle separation
Cut size
Particle size
CFD simulation

ABSTRACT

In order to improve the particle separation performance of a hydro cyclone, experimental and simulation studies have been conducted on the modification of the under flow section. The average particle downward velocity in the upper part of the under flow section increases by use of the inclined ring in the Type A cyclone. Particle separation performance of the Type A cyclone is better than that of the conventional Type S cyclone. The number of re-entrainment particles from the center region to the outlet pipe section in the under flow region decreases by use of the center rod in the Type B cyclone. Below the apex cone region of the Type C cyclone, the magnitude of fluid velocity decreases and an increase of particle separation efficiency is obtained. The highest particle separation efficiency is obtained by the Type D cyclone with the inclined ring, center rod and apex cone in the under flow section. The results of CFD simulation qualitatively agree with the particle trajectory observation experiments.

The Type D cyclone, which is newly developed in this research, is expected to exhibit better particle separation performance compared to the conventional cyclone, and is expected to have a wide range of potential uses in various wet particle separation processes.

1. Introduction

Hydro cyclones are widely used as a separation or size classification apparatus for solid–liquid flow due to their simple structure and low cost. Recently, with improvements to the movable guide plate and spiral inlet, and increased feed slurry temperature, high precision classification of particles of diameter 5–30 μm has become possible [1,2]. Using the hydro cyclone, Yoshida et al. [2] reported that the classification performance by use of the spiral inlet is better than that of the tangential inlet. In our previous paper, the cut size of the hydro cyclone decreases with the increase of feed slurry temperature, because the liquid viscosity decreases as the feed liquid temperature increases.

Using both the blow-up and under flow methods, Yoshida et al. [3] found that the amount of fine particles in the under flow side can be controlled to less than the under flow ratio. In order to classify the slurry particles by use of the hydro cyclone, it is necessary to classify the particles to a high level of classification performance, and recent interest for the industrial hydro cyclone has been focused on cut size control and high classification performance under operating conditions. By use of the dry-cyclone, Yoshida et al. reported that particle collection efficiency increases with the apex cone used in the upper part of the dust box [4], because the number of particles escaping from the dust box to the outlet pipe side can be decreased. In order to increase particle separation performance in the hydro cyclone, use of the apex cone in the under flow section might be one effective method, but this point has not yet been thoroughly investigated.

This paper describes the effect the apex cone and upper inclined ring in the under flow section on particle separation performance.

A new method to improve the particle collection efficiency of the hydro cyclone is investigated by experiment and CFD simulation. Several new methods based on local fluid flow control are discovered in the under flow section of the hydro cyclone.

2. Experimental apparatus

Fig. 1 shows a schematic diagram of the hydro cyclone used in this study. The cyclone diameter was 20 mm [5].

In order to generate strong rotational fluid flow, two inlet flows were introduced tangentially into the cyclone. The average inlet flow velocity in the two inlets was controlled to the same value. The inlet fluid temperature was kept constant using a temperature controller.

* Corresponding author.
E-mail address: r736619@hiroshima-u.ac.jp (H. Yoshida).

http://dx.doi.org/10.1016/j.seppur.2015.12.020
1383-5866/

Nomenclature

A	bottom diameter of apex cone (m)
B_d	under flow ratio (–)
D_p	particle diameter (μm)
D_{p50}	50% cut size of cyclone (μm)
D_i	center rod diameter in the under flow section (m)
$f_c(D_p)$, $f_s(D_p)$	particle size distributions of coarse and fine sides, respectively (–/μm)
m_c, m_s	particle mass flow rate for coarse and fine sides, respectively (kg/s)
ΔP	pressure drop of cyclone (MPa)
Q, Q_d	feed and under flow flow rate (l/h)
T	feed slurry temperature (°C)
$\Delta\eta$	partial separation efficiency (–)
α	slope angle of inclined ring shown in the Type A cyclone (°)

Fig. 2 shows the various types of cyclones used in this study. In order to decrease re-entrainment of particles from the under flow section to the upper part, increase of the average downward fluid velocity is recommended. Type S is the standard type. Type A is the revised cyclone with the upper inclined ring on the upper plate. The two types of apex cones are used for Type B and C. Type D is the combined version of Type A and C. The average downward velocity in the under flow section will be at maximum for the Type D cyclone, therefore, particle collection efficiency is also expected to be at maximum value for the Type D cyclone.

Fig. 3 shows the dimensions of each cyclone. For the Type A cyclone, the inclined angle α of the inclined ring was changed from 0° to 70°. For the Type B cyclone, the center rod diameter was set to 10 mm. For the Type C cyclone, the bottom diameter of the apex cone A was changed from 10 to 35 mm.

The partial separation performance was evaluated by use of the partial separation efficiency, $\Delta\eta$, calculated by the following equation.

$$\Delta\eta = \frac{m_c f_c \Delta D_p}{m_c f_c \Delta D_p + m_s f_s \Delta D_p} \tag{1}$$

In the above equation, m_c and m_s are the mass of the collected particles in the under flow and over-flow sides, respectively. f_c and f_s are particle size frequency distributions for each size range. The particle size distributions were measured by the Laser-light scattering method (Horiba, Co., Ltd. LA-950). Particle size distribution of the test particles is shown in Fig. 4. Pure silica particles of spherical shape were used with a particle size range of 0.6–6 μm.

3. Experimental results

3.1. Effect of the inclined ring wall on particle separation performance

In order to improve particle separation performance, the number of re-entrainment particles from the under flow section to the outlet pipe side should be decreased. For the standard Type S cyclone, the particles collected in the upper wall side of the under flow section will be affected by rotational and random fluid flow. Particles moving near the upper wall side may then have a chance to move from the upper part of the under flow side to the outlet pipe side. In order to reduce these re-entrainment particles, increase of average downward velocity is considered to improve particle separation efficiency. The new Type A cyclone shown in Fig. 2 is therefore proposed in this report.

Fig. 5 shows particle separation performance using the Type A cyclone with various inclined angles of the inclined ring wall. The 50% cut size shows a minimum value for the inclined angle of approximately 30°. The 50% cut size shows a nearly constant value for the inclined angle greater than approximately 30°. The under flow ratio defined by the following equation was changed from 0% to 20%.

$$B_d = \frac{Q_d}{Q} \tag{2}$$

In order to increase particle separation efficiency, the inclined angle of the ring should be greater than approximately 30°. and a high under flow ratio condition is recommended. Because the average downward velocity in the upper under flow section increases

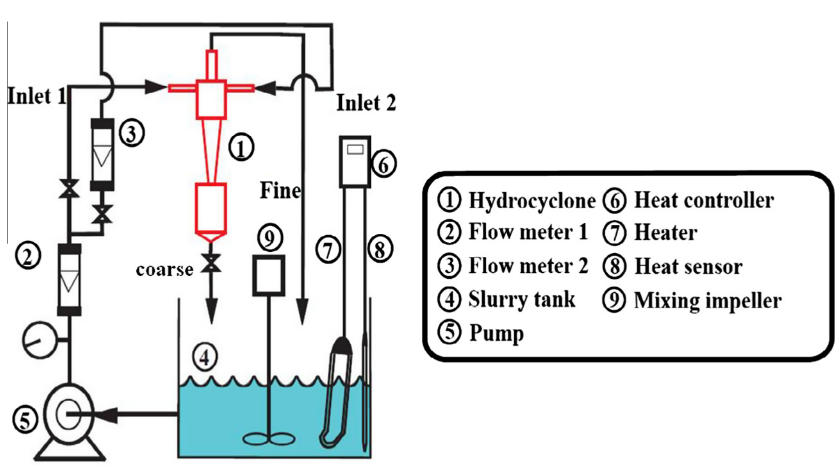

Fig. 1. Experimental setup of the hydro cyclone.