



## KKU Engineering Journal

<https://www.tci-thaijo.org/index.php/easr/index>

Published by the Faculty of Engineering, Khon Kaen University, Thailand

### The effect of vortex finder heights on separation efficiency of a dust cyclone

Suthin Pholboorn\*

Department of Mechanical Technology, Faculty of Technology, Udon Thani Rajabhat University, Udon Thani 41000, Thailand

Received October 2015  
Accepted December 2015

#### Abstract

The effect of vortex finder heights on the separation efficiency of a dust cyclone was experimentally investigated in the present study. The separation efficiency of three cyclones with different vortex finder heights was measured as a function of the particle size of dust and velocity of air. Husk ash was used as dust particles in the air. Three values of vortex finder heights of cyclone were investigated, 30, 50 and 70 mm. The inlet velocities of air were varied from 6.61, 7.35, 8.06 to 8.81 m/s. The diameters of husk ash particles were classified into four ranges, 0-150, 150-250, 250-500 and 500-850  $\mu\text{m}$ . The experimental results revealed that the separation efficiency of the dust cyclones increased when the particle size of husk ash and the air velocity were increased for all of vortex finder heights. A vortex finder height of 50 mm was observed to have better separation efficiency than the others for all air velocities and particle sizes. The maximum separation efficiencies with a vortex finder height of 50 mm and an air velocity of 8.81 m/s for the aforementioned particle size ranges were found 98.85, 99.51, 99.69 and 99.91%, respectively.

**Keywords:** Vortex finder height, Dust cyclone, Dust particles, Husk ash

#### 1. Introduction

Cyclone separators are the most widely devices to separate the dust particles from industries. The mechanism of cyclone separators was induced by centrifugal force to separate the dust from gas stream, the dust particles were rotated to the wall of the cyclone and down to the conical section of the dust outlet and the gas exited through the vortex finder [1]. The advantages of cyclone were included of simple design, lower construction, lower costs maintenance, high resistance to both temperature and pressure [2-3]. Several researchers have been investigated about separation efficiency and pressure drop of cyclone by experimental and numerical study [4-8].

The effects of flow parameters and inlet geometry on cyclone by using converging symmetrical spiral inlet (CSSI) and conventional tangential single inlet (CTSI) cyclone were presented. The experimental result found that the CSSI cyclone provide higher separation efficiency more than that of the CTSI cyclone [9]. The study of particle collection efficiency of cylindrical inlet type cyclone separator and operated under high solid loading conditions was experimented. The investigating showed that for increasing of solid loading rate and inlet velocity, the particle separation efficiency of cyclone was increased [10]. The effect of the inlet section angle on the separation performance of a cyclone was studied. The results showed that the inlet section angle was improved the separation efficiency of cyclone and

the optimal angle should be  $45^\circ$  for the range of the inlet section angle in this experiment [11].

The new design of vortex finder shape of cyclone by using discrete adjoint method was carried out by the numerical method. The results found that the gas cyclone with new vortex finder shape decreased the pressure drop and improved the collection efficiency [12]. The gas flow characteristics of a guide-vane-inlet cyclone with a novel vortex finder were conducted. The new design was based on the idea of increasing cyclone efficiency and reducing pressure drop by improving vortex finder structure. From the experiment, the particle collection efficiency was increased and pressure drop was decreased [13]. The numerical analysis of hydrocyclones with different vortex finder configurations was computed. The result showed that the separation efficiency of diameter and shape of vortex finder was more significant than that of vortex finder length [14].

The numerical simulation and optimization of fluid flow in cyclone vortex finder by using four different cyclone-shape and six cone-shaped vortex finders were studied. The result obtained that decreasing of vortex finder divergence angle, the collection efficiency was decreased [15]. The characteristics of the collection efficiency for a cyclone with different vortex finder shapes by using four cylinder-shaped and six cone-shaped vortex finders were experimented. The result found that the cone shapes or lengths of cone-shaped vortex finder were not important factor in affecting the particle collection efficiency [16].

\*Corresponding author. Tel.: +6695 789 1183  
Email address: suthin\_27@hotmail.com  
doi: 10.14456/kkuenj.2016.13

From the above literature can't clear to the separation efficiency of cyclone with the difference of vortex finder heights. The present work is to study the separation efficiency of cyclone with three values of vortex finder heights of 30, 50 and 70 mm by experimental investigated. The husk ash was used to the particle of dust in the air. The dust particle size was separated by sieving machine. The dust particles for this experiment were included four ranges; 0-150, 150-250, 250-500 and 500-850 micrometres. The volume flow rates of air were experimented from 0.0015 to 0.002 m<sup>3</sup>/s or were converted to the velocity from 6.61 to 8.81 m/s.

## 2. Determination of the separation efficiency

The separation efficiency of cyclone [8] was determined as equation (1),

$$\eta = \frac{m_c}{m_t} \times 100 \quad (1)$$

Here,  $\eta$  is the separation efficiency of cyclone,  $m_c$  is the mass of particles separated in the dust bin of the cyclone and  $m_t$  is the total mass of particles into the inlet of cyclone. Both  $m_c$  and  $m_t$  were carried out by measuring the masses with digital balance, Ohaus, before and after experiment.

The velocity ( $V$ ) of air was based on the cross section of the cylindrical body of the cyclone, so that

$$V = \frac{4Q}{\pi D^2} \quad (2)$$

Where  $Q$  is the gas flow rate and  $D$  is the cylindrical inside diameter of cyclone.

## 3. Materials and methods

Figure 1 demonstrates the several descriptions of cyclone including of inlet width (b) and height (a), body diameter (D), vortex finder diameter ( $D_e$ ), vortex finder height (S), cone height ( $h_c$ ), cylinder height ( $h_b$ ), cyclone body height (H) and cone bottom diameter (B). In this experiment to compare the effect of vortex finder heights on the separation efficiency, volume flow rate, cylindrical inside diameter of cyclone was calculated from equation (2) and all dimensions of cyclone geometry are shown in Table 1 and all parameters were performed from the standard size of cyclone [17].

The experimental apparatus set up is shown in Figure 2. The air was induced through flow meter to cyclone with control the velocity by adjusting valve. The particles were made from husk ash and were varied the size into four ranges; 0-150, 150-250, 250-500 and 500-850 micro metres. The particles were fed into the particles feeder to combine with the air and were sucked into cyclone. The flow rates of air were varied from 0.0015, 0.00167, 0.00183 and 0.002 m<sup>3</sup>/s or were converted to velocity from 6.61, 7.35, 8.06 and 8.81 m/s. For each flow rate of air, the experiment was repeated by three times to ensure the accuracy of the result. The separation efficiency was computed by using the mass of the particles before and after separated to calculate by equation (1).

## 4. Results and discussions

### 4.1 Effect of velocity of air

The flow rate was measured by flow meter, Blue Point, with the accuracy  $\pm 5\%$ . The flow rates of air in this

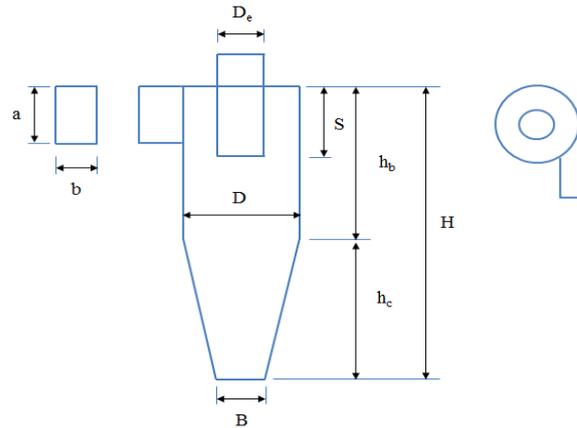


Figure 1 Schematic diagram of cyclone geometry

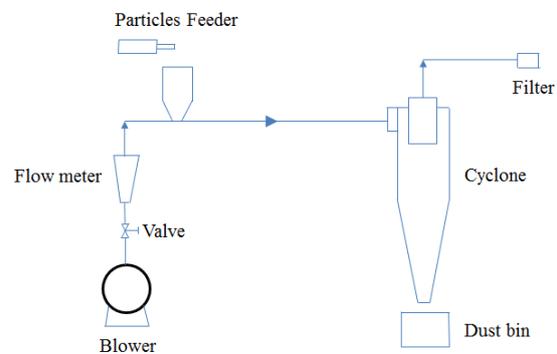


Figure 2 Schematic diagram of the experimental system set up

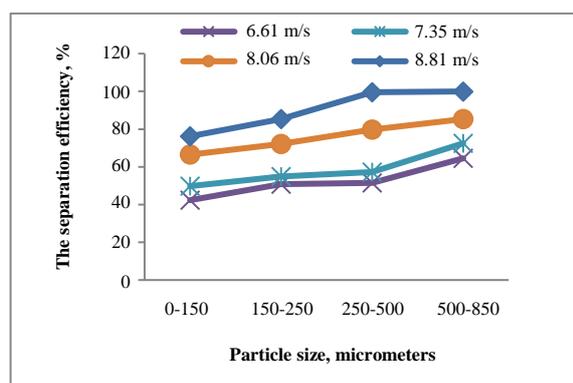
experiment range of 0.0015, 0.00167, 0.00183 and 0.002 m<sup>3</sup>/s, were converted into the velocities of 6.61, 7.35, 8.06 and 8.81 m/s, respectively. The separation efficiency of cyclones with various inlet velocity of air is depicted in Figure 3. For all cases of vortex finder heights, the separation efficiencies were increased when particles of dust and velocities of air were increased. When vortex finder height of 30 and 70 mm, the separation efficiency were increased slowly for all velocity of air when particle sizes were increased. When vortex finder height of 50 mm, the separation efficiency was increased rapidly when particle size lower than 150 micrometres, but the separation efficiency was increased slowly when particle sizes more than 150 micrometres. The maximum separation efficiencies were found with the vortex finder height of 50 mm, the velocity of 8.81 m/s for all sizes of dust particles.

### 4.2 Effect of vortex finder heights

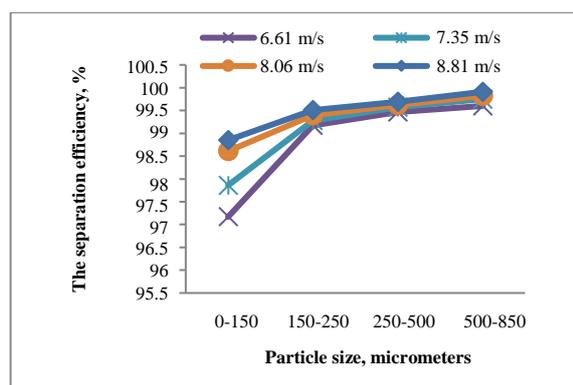
Figure 4 shows the separation efficiency with various vortex finder heights of three cyclones. When the particle size of dust was increased, cyclone 2 was found the separation efficiency more than other ones for all the inlet velocities of air. Because of the vortex finder height of cyclone 2 was corresponded to Stairmand high efficiency of cyclone [17]. The maximum separation efficiencies of cyclone 2 for the particle size ranging from ; 0-150, 150-250, 250-500 and 500-850 micrometres, were showed 98.85, 99.51, 99.69 and 99.91 percentages, respectively.

**Table 1** Dimensions of the cyclone experimented

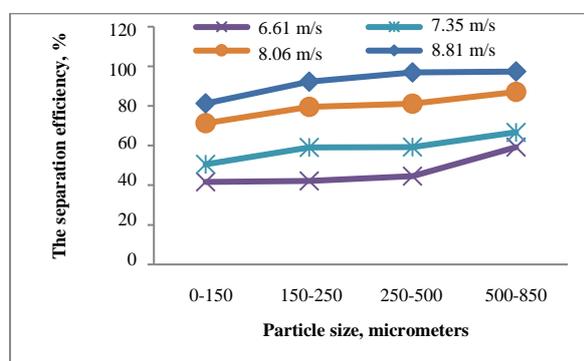
Dimension	Cyclone 1 (mm)	Cyclone 2 (mm)	Cyclone 3 (mm)
Body diameter, D	100	100	100
Vortex finder diameter, $D_e$	50	50	50
Vortex finder height, S	30	50	70
Inlet width, b	20	20	20
Inlet height, a	50	50	50
Cylinder height, $h_b$	150	150	150
Cyclone body height, H	400	400	400
Cone bottom diameter, B	37.5	37.5	37.5



(a)



(b)



(c)

**Figure 3** Comparison of the separation efficiency with different velocity of air, (a) S=30 mm (b) S=50 mm and (c) S=70 mm

### 5. Conclusions

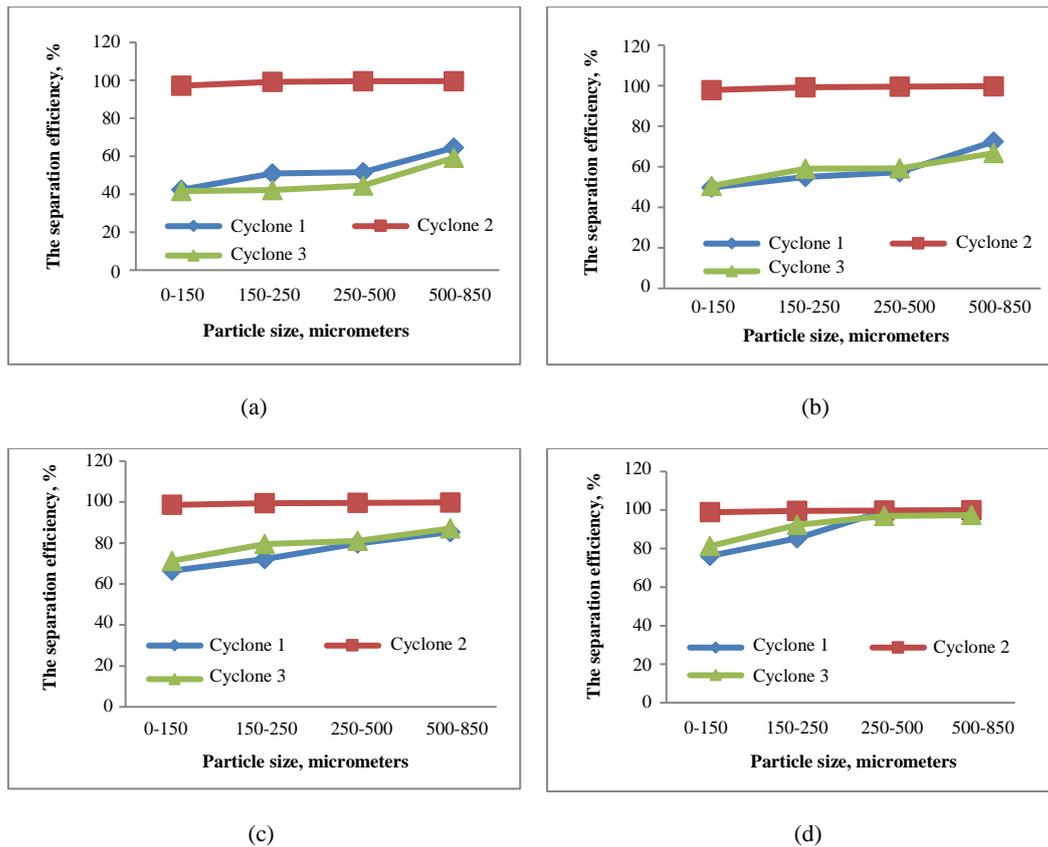
In this work, the effect of vortex finder heights on the separation efficiency of cyclone separator has been experimented. The inlet velocities of air were investigated ranging from 6.61 to 8.81 m/s. The inside diameter of 100 mm for the cyclone was experimented in this study. The vortex finder heights of cyclone in this experiment were investigated including of 0.3D, 0.5D and 0.7D. The results show that the separation efficiency was increased when the particle of dust or velocity of air was increased for all geometries of vortex finder heights. The maximum separation efficiency was found with the vortex finder height of a half of body diameter according to Stairmand height efficiency of cyclone. For the particles ranging from; 0-150, 150-250, 250-500 and 500-850 micro metres, the maximum separation efficiencies of the vortex finder height of 50 mm, were shown 98.85, 99.51, 99.69 and 99.91 percentages, respectively.

### 6. Acknowledgements

The authors gratefully acknowledge the financial support from the Office of Research Department, Udon Thani Rajabhat University, Udon Thani, Thailand.

### 7. References

- [1] Altmeyer S, Mathieu V, Jullemier S, Control P, Midoux N, Rode S, Leclerc JP. Comparison of different models of cyclone prediction performance for various operating conditions using a general software. *Chem Eng Process.* 2004;43:511-22.
- [2] Karagoz L, Avci A, Surmen A, Semdogan O. Design and performance evaluation of a new cyclone separator. *J Aerosol Sci.* 2013;50:57-64.
- [3] Hsu CW, Huang SH, Lin CW, Hsiao TC, Lin WY, Chen CC. An experimental study on performance improvement of the stairmand cyclone design. *Aerosol Air Qual Res.* 2014;14:1003-16.
- [4] Jiao J, Zheng Y, Wang J, Sun G. Experimental and numerical investigations of a dynamic cyclone with a rotary impeller. *Chem Eng Process.* 2008;47: 1861-6.
- [5] Ji Z, Xiong Z, Wu X, Chen H, Wu H. Experimental investigation on a cyclone separator performance at an extremely low particle concentration. *Powder Tech.* 2009;191:254-9.
- [6] Park K, Hong CH, Han JW, Kim BS, Park CS, Kwon OK. The effect of cyclone shape and dust collector on gas-solid flow and performance. *Eng Tech.* 2012;61: 252-7.
- [7] Souza FJD, Salvo RDV, Martins DDM. Effects of the gas outlet duct length and shape on the performance of



**Figure 4** Comparison of the separation efficiency with various vortex finder heights, (a) velocity = 6.61 m/s (b) velocity = 7.35 m/s (c) velocity = 8.06 m/s and (d) velocity = 8.81 m/s

- cyclone separators. *Separ Purif Tech.* 2015;142:90-100.
- [8] Pishbin SI, Monghiman M. Optimization of cyclone separators using genetic algorithm. *Int Rev chem Eng.* 2010;2:683-91.
- [9] Zhao BT. Effects of flow parameters and inlet geometry on cyclone efficiency. *Chin J Process Eng.* 2006;6:178-80.
- [10] Sakura GB, Andrew GB, Leung YT. Experimental study of particle collection efficiency of cylindrical inlet type cyclone separator. *Int J Environ Sci Dev.* 2015;6:160-4.
- [11] Qian F, Wu Y. Effects of the inlet section angle on the separation performance of a cyclone. *Chem Eng Res Des.* 2009;87:1567-72.
- [12] Elsayed K. Design of a novel gas cyclone vortex finder using the adjoint method. *Separ Purif Tech.* 2015;142:274-80.
- [13] Li Q, Xu W, Wang J, Jin Y. Performance evaluation of a new cyclone separator-part I experimental results. *Separ Purif Tech.* 2015;141:53-8.
- [14] Ghodrat M, Kuang SB, Yu AB, Vince A, Barnett GD, Barnett PJ. Numerical analysis of hydrocyclones with different vortex finder configuration. *Miner Eng.* 2014;63:125-38.
- [15] Raoufi A, Shams M, Farzaneh M, Ebrahimi R. Numerical simulation and optimization of fluid flow in cyclone vortex finder. *Chem Eng Process.* 2008;47:128-37.
- [16] Lim KS, Kim HS, Lee KW. Characteristics of the collection efficiency for a cyclone with different vortex finder shapes. *J Aerosol Sci.* 2004;35:743-54.
- [17] Stairmand CJ. Design and performance of cyclone separators. *Int Chem Eng.* 1951;29:356-83.