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Effects of the inlet section angle on the separation performance of a cyclone

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ABSTRACT

The improvement of the inlet geometry of the cyclone is conducted in this study based on the previous works, i.e., the cyclone inlet has a certain inlet section angle. The gas flow fields in cyclones for the different inlet section angles were calculated by means of computational fluid dynamics (CFD) technology, and the inner flow field geometry of these cyclones were compared. Additionally, the pressure drops and separation efficiencies of these cyclones were studied by experiments. The results indicate that the inlet section angle can make the flow filed in the cyclone be propitious for particle separation, and improve the separation performance effectively. At the same inlet velocity, with increasing the inlet section angle, both total separation efficiencies and grade efficiencies increase, and the pressure drops reduce greatly. Combining the change tendency of the pressure drop and the separation efficiency, a conclusion can be obtained, i.e., the optimal angle should be 45° for the range of the inlet section angle in this study.

Keywords: Cyclone; Inlet section angle; Pressure drop; Separation efficiency

1. Introduction

With the industry production scale expanding and operating conditions becoming harsher, a stronger ability to capture fine particles and reduce the pressure drop is required for cyclones. Therefore, it is urgent to develop a high-efficiency and low-pressure drop cyclone. A lot of experiments have been conducted by researchers (Plomp et al., 1996; Zhu et al., 2001; Xiang et al., 2001; Xiang and Lee, 2005; Qian and Zhang, 2006), and some practical measures and designs have been presented and used in the actual projects. However, over the past 100 years, the main research directions of the cyclone were focussed on cylinder, cone, vortex finder and dust outlet. Only very few researchers carried out relevant research aiming at the inlet geometry of the cyclone. In fact, for the conventional cyclone, a local vortex was formed in the roof, between the outer wall of the vortex finder and the cylinder wall owing to the existence of the axial and radial velocity, which makes a considerable number of particles flow to the cyclone center, and descend along the outer wall of the vortex finder, then escape from the vortex finder (also known as the shortcut flow), thus effects the separation efficiency of the cyclone. Therefore, it is very important to avoid this adverse effect caused by the shortcut flow in the cyclone design. Zhao et al. (2008) had proposed a new type cyclone that has the spiral inlet. This inlet geometry can make the spiral channel be a pre-separation space before particles entering the cylinder of the cyclone, and reduce the particle concentration near the wall of the vortex finder, thus decrease the shortcut flow. Zhao (2005) had used a cyclone with a double inlet, and the inlet area of this cyclone is twice of the conventional cyclone, which can cause the inlet velocity halve at the same inlet flow rate, and also reduce the pressure drop. Additionally, the double inlet can improve the axial symmetry of the gas flow in the cyclone, and reduce the short cut flow, too. However, due to the fact that the gas flow in a conventional cyclone must traverse the region between the outer wall of the vortex and the inner wall of the cylinder, some of the gas flow will discharge from the bottom of the vortex finder without arriving at the separation space, which has important effect on the separation performance of the cyclone. In order to eliminate the shortcut flow as much as possible, some researchers (Bernardo et al., 2006; Qian and

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Nomenclature

a	height of cyclone inlet (m)
b	width of cyclone inlet (m)
B	dust outlet diameter (m)
D	diameter of cyclone body (m)
D_e	diameter of cyclone vortex finder (m)
h	length of cyclone cylinder (m)
H	length of cyclone (m)
S	deepness of vortex finder insertion (m)
v_{in}	inlet velocity (m/s)
Y, Z	axial distance of Y and Z axes

Greek letters

α	inlet section angle
ξ	cyclone pressure coefficient
ρ	gas density (kg/m^3)

Zhang, 2007) had studied the separation characteristics of the cyclone with a range of inlet section angles by computational fluid dynamics (CFD) technology. However, in order to understand the mechanism of the effect of the inlet section angle on the separation performance of the cyclone further, the experimental study is also required. For this purpose, the gas flow fields of the cyclone with different inlet section angles were calculated using three-dimension numerical simulation technology based on the above-mentioned work in this present study. The pressure drops and separation efficiencies of these cyclones were investigated by experiments, and the effects of the inlet section angle on the separation performance were analyzed, thus, the mechanism that the inlet section angle improves the separation performance was explored further.

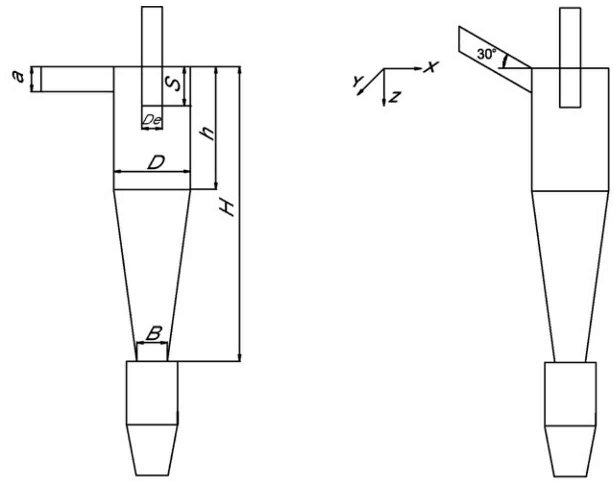
2. Experimental set-up and method

The objective of this experiment is to measure the separation efficiencies and pressure drops of these three cyclones. The test facility is illustrated in Fig. 1.

To facilitate visual observation all cyclone parts are constructed of Perspex. The geometry of the cyclone is fully described in Table 1 and Fig. 2. The diameter of the cyclone is 0.2 m. Experiments were conducted at 15 m/s inlet gas velocity. Talcum powder of wide size distribution (mean particle size: 6.39 μm, particle density: 2750 kg/m^3) was employed as the test dust (Fig. 3), and the inlet particle load was 10 g/Nm^3. Inlet size distribution was periodically checked and remained constant. Solid flow rate and overall collection efficiency were obtained at the end of each test run by weighting collected solids inside the dustbins. Samples of solids were collected to obtain grade efficiencies. Size analysis was performed by centrifugal particle size analyzer (SA-CP3, SHIMADZU Corporation).

Table 1 – Cyclone dimension.

a/D	b/D	D_e/D	h/D	H/D	B/D	S/D
0.46	0.203	0.307	1.310	3.795	0.399	0.9



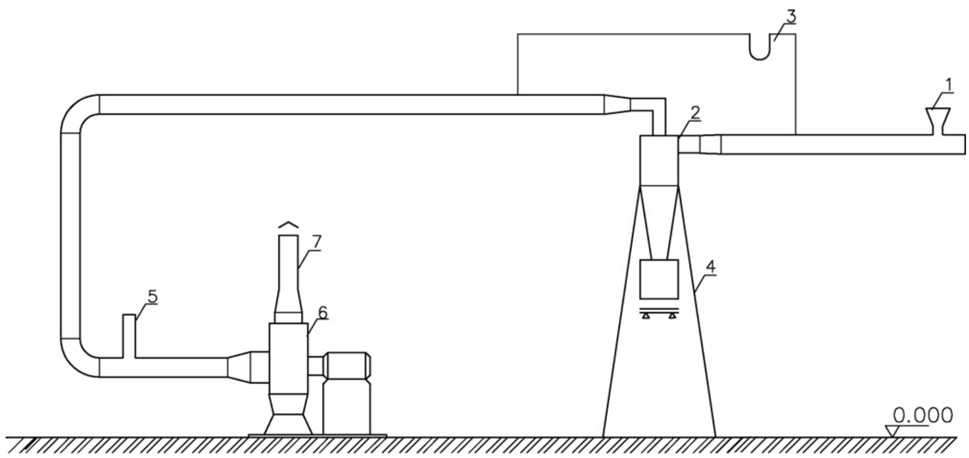
(a): general geometry (b): geometry with the inlet section angle

Fig. 2 – Cyclone geometry.

3. Numerical model

3.1. CFD grids

The hexahedral, tetrahedral and wedge-shaped computational grids were generated by dividing the whole cyclone geometry into a number of blocks and then meshing each



1. powder feeder, 2. cyclone, 3. U-shape tube, 4. underprop, 5. sluice valve, 6. suction fan, 7. gas outlet

Fig. 1 – Experimental set-up.