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Original Research Paper

Numerical study of flow field in new design cyclone separators with one, two and three tangential inlets

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ABSTRACT

Numerical study of the fluid flow and particle dynamics is presented by numerical techniques to characterize the performance of new design cyclone separators with one, two and three tangential inlets. The design of this cyclone is based on the idea of improving cyclone performance by increasing the vortex length. This cyclone differs from a conventional cyclone with the separation space. Instead of conical part, the separation space of this cyclone consists of an outer cylinder and a vortex limiter. The Reynolds averaged Navier–Stokes equations with Reynolds stress turbulence model (RSM) are solved by use of the finite volume method based on the SIMPLE pressure correction algorithm in the computational domain. The Eulerian-Lagrangian computational procedure is used to predict particles tracking in the cyclones. The velocity fluctuations are simulated using the Discrete Random Walk (DRW). In the results the effects of number of inlets on the different important parameters such as pressure drop, collection efficiency, axial velocity and turbulence are investigated and deeply discussed. Contours of velocity, pressure and turbulent kinetic energy within these cyclones with different number of inlets are shown. The results show that the cyclone with three inlets has more collection efficiency, less pressure drop and less turbulence distribution with respect to cyclones with one and two inlets which is good in cyclones performance. Generally it is recommended to use the new cyclone designs with higher number of inlets.

1. Introduction

Cyclones are widely used in the air pollution control and gas–solid separation for aerosol sampling and industrial applications. With the advantages of relative simplicity to fabricate, low cost to operate, and well adaptability to extremely harsh conditions, the cyclone separators have become one of the most important particle removal devices which are preferably utilized in scientific and engineering fields.

There are many geometric and operational parameters influenced the cyclone performance. Starting with Alexander [1], many researches have been performed to improve cyclone performance by evaluating the effects of geometric and operational parameters. The effect of the cyclone inlet dimensions on the cyclone performance has been performed numerically by Elsayed & Lacor [2]. They found that the effect of inlet width is more significant than the inlet height especially for collection efficiency. Zhao et al. [3] compared the performance of two types of cyclones with the conventional single inlet and spiral double inlets. Their numerical results show that, the new type cyclone separator using the adding spiral double inlet can improve the symmetry of gas flow pattern and enhance the particle separation efficiency. The effects of cone dimension on the cyclone performance were also investigated in the literature [4–6]. Researchers showed that when the cone dimension is larger than the gas outlet dimension, reduction in cone size resulted in higher collection efficiency without significantly increasing the pressure drop. In the investigation of Yoshida et al. [7], various types of apex cones were used at the inlet part of the dust box. They found that the effect of the apex cone angle on the collection efficiency decreases at high inlet velocity conditions. Effects of a cone prolonged with a vertical tube on the collection efficiency of cyclone were also studied [8,9]. The effects of a counter-cone in the bottom of the cyclone on the cyclone performance have performed [10–12]. The effects of the shape and diameter of the vortex finder on the cyclone's performance were also studied by many researchers [13,14]. The effects of the cyclone height were studied by Safikhani et al. [15] and Hoffman et al. [16]. Performances of square cyclones were investigated by some researchers [17–19].

Up to now, different cyclone designs have been presented in the literature. One of them is the double cyclone which was presented

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and analyzed by Zhu et al. [20], Xiang and Lee [4] and Lim et al. [21]. They found that the mentioned cyclone has a lower pressure drop but has not higher collection efficiency than a conventional cyclone. However, the collection efficiency of the double cyclone with electric field increased greatly with the increasing the applied voltage. Another type of cyclone called the circumfluent cyclone was presented and investigated by Wang et al. [22]. They investigated experimentally its collection efficiency and pressure distribution, and compared its characteristics with the conventional one. The results showed that the collection efficiency of this cyclone is higher by 8% than that of a conventional one and the pressure drop within this cyclone is only one half or one third of that of the conventional cyclone.

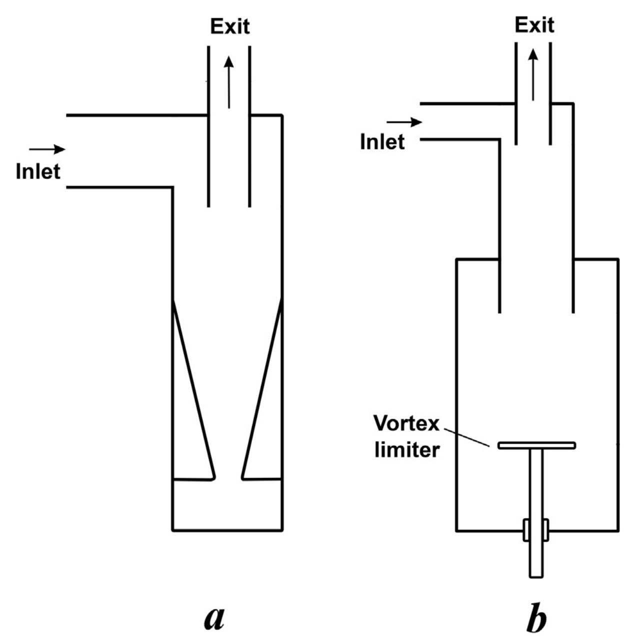

Fig. 1. Schematic comparison of new cyclones and conventional ones.

Recently Karagoz et al. [23] presented a new design cyclone separator. The design of their cyclone was based on the idea of improving cyclone efficiency by increasing the vortex length. Their cyclone was different from the conventional cyclones with the separation space. In fact instead of conical part, the separation space of that cyclone consists of an outer cylinder and a vortex limiter. They experimentally investigated the effects of the vortex limiter position on the cyclone performance. Safikhani and Mehrabian [24] investigated the numerical simulations for the parametric study of Karagoz cyclones. They showed the effects of different geometrical parameters on the new cyclones performance. Safikhani [25] has investigated multi-objective optimization on new design cyclone separators and finally presented the Pareto front of such cyclones.

The complexity of the gas–solid flow pattern in cyclones has long been a matter of many experimental and theoretical works. At present, laser Doppler anemometry (LDA) and hot-wire anemometry are frequently employed to study experimentally the flow structure in the cyclones. As for the theoretical work, computational fluid dynamics (CFD) codes have proven to be a useful tool for simulating cyclonic gas flows. Recently, research efforts by computational fluid dynamics are frequently carried out for the resolution of flow field and dust particle behavior with different degree of numerical and modeling accuracy in order to assist in the time consuming experimental works. In conjunction with the complex flow structure, numerical simulation is momentarily

Table 1
False time steps used for the simulation.

Parameters	False time step
Pressure	0.2
u (x-velocity)	0.4
v (y-velocity)	0.4
w (z-velocity)	0.4
k (turbulent kinetic energy)	0.5
ε (turbulent dissipation rate)	0.5
Reynolds stresses	0.5

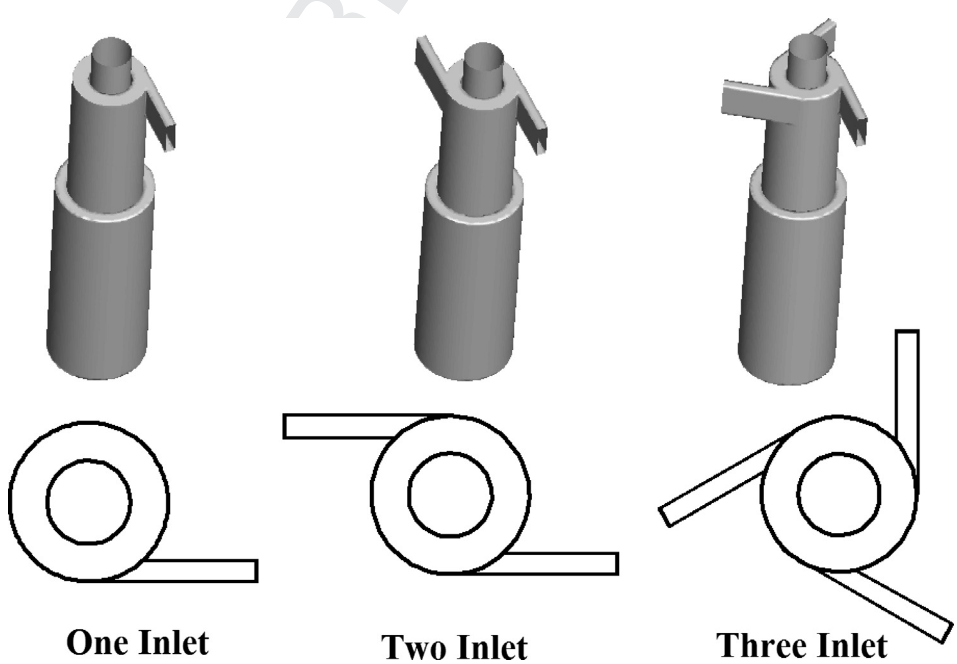

Fig. 2. Perspective and top views of new cyclones with one, two and three tangential inlets.

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