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Review Article

EFFECT OF DESIGN AND THE OPERATING PARAMETERS ON THE PERFORMANCE OF CYCLONE SEPARATOR—A REVIEW

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In many industrial processes, such as air pollution control and environmental cleaning processes for removing large particles cyclones have been traditionally used as a precleaners. But in many pollution control applications a high efficiency cyclone designed to remove smaller particles can now be used as the final filter or process collector. A well designed high efficiency cyclone can capture more than 99 percent of particles (by weight) as small as about 5 microns. In order to carry out an assessment of the design and performance of cyclone, parameters like collection efficiency of particle and pressure drop through the cyclone must be considered. The collection efficiency of cyclone separator is directly related to the design parameters and operational parameters. The design parameters such as dimensions of the cyclone separator, operating temperature and particle density affects the cyclone collection efficiency. Operating parameter such as inlet velocity of cyclone separator also affect the collection efficiency of cyclone separator. The purpose of study of this review paper is to focus on the effect of various design parameters and the operating parameter on the performance of cyclone separators.

Keywords: Cyclone separator, Design parameters, Operating parameter, Collection efficiency

INTRODUCTION

For removing industrial dust from air cyclone separators are widely used. There are a number of different forms of cyclone separator but the most common design used industrially is the reverse flow cyclone. Economy and simplicity in design and construction are the primary advantages of cyclone separator. Cyclone separators are maintenance free, as there are no moving parts. Cyclone can be adapted for use in extreme operating conditions such as high pressure, high temperature and corrosive gases by using suitable materials and methods of construction. In general, cyclone consists of an upper cylindrical section and lower conical section. In cyclone separator the gas-dust mixture

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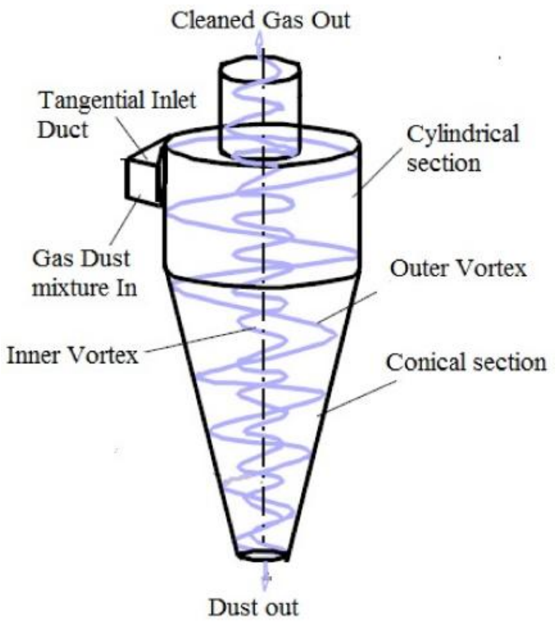
enters tangentially at the top of cylindrical section and travels downward into the conical section, forming an outer vortex. As the air velocity increases in the outer vortex results in a centrifugal force on the particles. The centrifugal force separates the dust from the gas stream. An inner vortex is created when the gas reaches the bottom of the conical section results in reversing direction of gas and the gas exits from the top as clean gas while the dust particulates fall into the dust collector attached to the bottom of cyclone separator.

Figure 1: Cyclone Separator



LITERATURE SUMMARY

The present chapter includes the review of different literature in the field of Technology for Improving the Performance of cyclone separator.

CYCLONE SEPARATOR RELATED REVIEW

Wang *et al.* (2006) presented a new theoretical method for computing number of turns, travel distance and cyclone pressure drop. In this study in a cyclone the travel distance is determine by the flow pattern and cyclone dimensions. Based on travel distance the effective number of turns was calculated. Cyclone pressure drop consists of five pressure loss components. The primary pressure loss is the frictional pressure loss in a cyclone. In this study at different inlet velocities the new theoretical analyses of cyclone pressure drop for 1D2D, 2D2D and 1D3D cyclones were tested against measured data. The Ds in the 1D2D, 2D2D and 1D3D designations refer to the diameter of the cyclone cylindrical part, while the numbers preceding the Ds refer to the length of the cylindrical and conical sections. A 1D2D cyclone, for instance has cylindrical section length equal to the cylindrical section diameter and a cone length equal to two times the cylindrical section diameter. In a cyclone, based on velocity profile air stream travel distance and effective number of turns can be determined. In a 1D2D cyclone 2.27 turns and in 1D3D and 2D2D cyclones 6.13 turns were predicted by this study. Five individual pressure drop components are consists by cyclone pressure drop. In the cyclone the major pressure loss components are the frictional loss in the outer vortex and the rotational energy loss. In this study for different size cyclones (4, 12 and 36 in) the theoretical analysis shows that cyclone pressure drop is independent of cyclone diameter. To verify the theoretical analysis results obtained by the Classical Cyclone Design (CCD) method, this study and several other theoretical models in the literature, experiments were conducted. Comparisons of predicted pressure drops by the experimental measurements and different theoretical models verified that the theoretical predictions of pressure drop by this study are closest to the experimental data. In this study the results shows that the cyclone pressure drop is independent of cyclone diameter and varies with inlet velocity.

Jolius Gimbun *et al.* (2004) presented that several factors including design parameters, such as dimensions of cyclone separator, operating temperature and particle density affects the collection efficiency. Operating parameters such as the inlet velocity of the fluid and the physical properties of fluid,namely the density and viscosity and the outlet conditions also affects the collection efficiency of the cyclone. In this paper the prediction accuracy of four cyclone collection models, namely Koch and Licht, Iozia and Leith, Lapple and Li and Wang are compared. When compared with the presented experimental data all the predictions proved to be satisfactory. The Li and Wang model could be used in the evaluation of cyclone efficiency because it predicts the cyclone collection efficiency much better than the other three models with only 3% deviation from the experimental data. With decreasing cyclone body diameter the cyclone efficiency increases. With increasing cyclone inlet width the poor vortex formation inside the cyclone decreases the collection efficiency. Separation efficiency will increase with increasing variables like air-particle density difference and inlet velocity because of higher resultant centrifugal force. Increase in air viscosity the cyclone efficiency decreases dramatically as temperature increases from 293 to 993 K.

Faulkner and Shaw (2006) presented that as air pollution abatement devices cyclone separators are widely used in agricultural processing industries. Based on an inlet design velocity the Texas A&M Cyclone Design (TCD) method is a simple method for designing cyclone. For 1D3D and 2D2D cyclones TCD method specifies ideal inlet velocities of 975 ± 120 m/min and 914 ± 120 m/min, respectively. Using different inlet velocities than those specified as the ideal velocity higher dust collection efficiencies may be obtained. For 1D3D and 2D2D cyclones this article quantifies the inlet velocities at which maximum collection efficiencies are obtained. For 1D3D and 2D2D cyclones this article quantifies the marginal pressure drop associated with reaching these collection efficiencies. For large particles, inlet velocities from 10.16 standard m/s up to the design velocity, the collection efficiency of six inch diameter 1D3D and 2D2D cyclones is similar, with significantly lower pressure drop at lower inlet velocities.

Jolius Gimbun *et al.* (2004) presented the prediction and evaluation of the effects of temperature and inlet velocity on the pressure drop of gas cyclones using Computational Fluid Dynamics (CFD) calculation. In this study, using spread sheet and commercial CFD code Fluent 6.1 the numerical solutions were carried out. For the prediction of cyclone pressure drop four empirical models, namely [Chem. Eng. Progress (1993)51] [Doctoral Thesis, Hawarad University, USA, 1988] [Chem. Eng. (1983)99] [Air pollution control: a design approach, in: David Cooper and Alley (Eds), Cyclones, second ed.,Waveland Press Inc., Illinois, 1939, pp. 127-139] was also reviewed. In this study the pressure drop in cyclones is predicted very well by the CFD code FLUENT with the Reynolds Stress turbulence Model (RSM). A very small pressure drop deviation was observed in the CFD numerical calculation, with maximum deviation of 3% from the experimental data. Under different operating conditional inlet velocity both Sheperd and Lapple, and Dirgo models show a good prediction on cyclone pressure drop. However, under different operating temperature Dirgo's model is unable to predict accurately the pressure drop. Shepherd and Lapple's pressure drop model prediction is the best for the various temperature conditions.

Niki Gopani and Akshey Bhargava (2011) presented that from automobiles, industries and house hold fuel burning air pollution is assuming alarming dimensions. Cement industry emitting Particulate Matter (PM) into the atmosphere can be classified as highly air polluting industry. SPM(Suspended Particulate Matter) is the predominant air pollutant emitted from such plant. By installing ESP (Electrostatic Precipitators), Bag houses and Wet scrubbers control of Suspended Particulate Matter (SPM) can be achieved but at such a small scale cement plants on techno-economical front these equipment'smay not be feasible to be installed because these are highly cost intensive. As cyclone is reasonable cheaper and having low operating cost installation of cyclone appears to be reasonable proposition. Using STAIRMAND METHOD the present paper aims at designing of high efficiency cyclone for a tiny cement plant. Against the desired 90% efficiency which is safe design for controlling air pollutant concentration in the form of SPM from kiln attached to the cement plant the designed high efficiency cyclone gives an efficiency of 91.1%.

Khairy Elsayed and Chris Lacor (2010) presented for three Cyclone separators the effect of the cyclone inlet height on the performance and flow field pattern has been investigated computationally using Reynolds Stress turbulence Model (RSM). In this study results show that, with increasing the cyclone inlet height the maximum tangential velocity in the cyclone decreases. And the pressure drop decreases with increasing the cyclone inlet height (but the improvement decreases after a/D = 0.4).In this study it was observed that with increasing the cyclone inlet height the cyclone cut-off diameter increases and due to weakness of the vortex strength the cyclone overall efficiency decreases.

CONCLUSION

From the study and analysis of the various papers it is observed that according to the theoretical approach the pressure drop varies with inlet velocity, where as it is independent of cyclone diameter.

With decreasing cyclone body diameter, cyclone width, cyclone inlet width, operating temperature cyclone efficiency increases. With increase in inlet velocity and particle density the collection efficiency increases.

With increase in inlet velocity the pressure drop increases, but the pressure drop decreases significantly with rise in temperature.

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APPENDIX

Nomenclature
a = cyclone inlet height (mm)
D = cyclone body diameter (mm)