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Review Paper on CFD Analysis of Cyclone Separator with Discrete Phase Modelling

Kunal Tiwari, Jaydeep Sharma, Mayank Bisht, Priyanshu Tiwari, Saad Ameer

Abstract:- The review paper presents the design and development of a Cyclone Separator, a device which uses centrifugal force to separate particulate matter (solid and liquid) from flue gases and its utilization for various particulate matters like vegetable oil, cigarette smoke, wood dry, pollen grain etc. Cyclone Separators are used in variety of places due to their versatile applications, low maintenance and low cost e.g., sawmills, cement industries, residential filtration etc. The main aim of this work is to study about the flow field, velocity and pressure distribution and effect of variation of inlet angle at entry passage of Cyclone Separator using CFD analysis. The study shall help in understanding the working of Cyclone Separator and variation of efficiency with the change in the inlet angle for different particulate matters.

I. INTRODUCTION

Cyclone Separators are centrifugal separators which works on the principle of inertial forces. It consists of a tangential inlet and axial discharge. It uses a high velocity spinning column of air to separate particle of different specific gravity. Cyclone Separator has three control surfaces – Stream Inlet, Dust Outlet, Filtered Air Outlet. The high-speed inlet stream creates a rotational flow which descends downwards into a helical path inside the cylindrical-conical body. The dense particulate matter inheriting more inertia than air collides with the chamber wall and are thrown out of the air stream. This particulate matter is then collected at the bottom whereas the filtered air rises up and ascends from the top. The inside surfaces of the cyclone separator are smooth, bump free and have gradual bends to maintain the laminar flow during the operations.

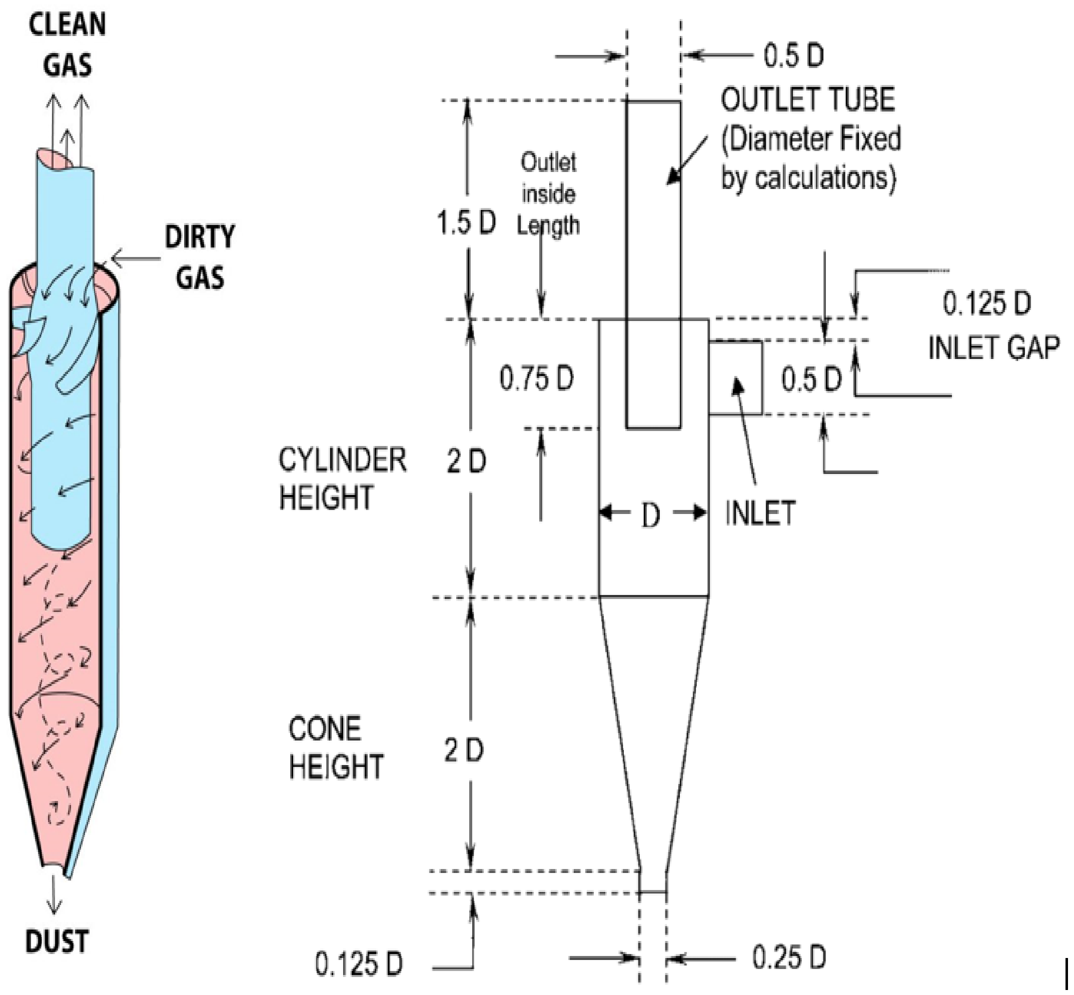

Fig. 1: Dimensions of Cyclone Separator

II. LITERATURE SURVEY

Mahesh R Jadhav [1] investigated the performance of the flour mill cyclone at various flow rates. He examined the efficiency of single inlet cyclone and symmetrical inlet cyclone and found that symmetrical inlet cyclone outperformed single inlet cyclone for the same model. The paper furthermore showed, increase in inlet velocity increases pressure drop and efficiency of cyclone for the same model.

Park et al. [2] studied cyclone separator comprised of continuous declining coaxial cylindrical chambers of three stages connected to one conical section and one vortex finder. The cyclone was devised for selective particles sampling of different sizes. The design enabled separation of heavier particles in the first chamber and consequently finer particles were separated in the proceeding smaller chambers, as a result there was less disturbance and hence less turbulence, which improved separation efficiency. The experiment was carried out at a flow rate of 100 L/min to 40 L/min. Trap 1 of cyclone that had largest diameter amongst the three was able to trap particle ranging between 4.5 µm and 11 µm, Trap 2 was able to collect particles ranging from 3.40 µm to 7.93 µm and particles trapped in third chamber ranged between 1.82 µm and 4.30 µm.

Hsiao et al. [3] worked on the cyclone separator's geometric configuration and recommended appropriate ranges and ratios to improve performance metrics.

Dzmitry Misiulia et al. [4] studied the effects of changing the inlet angle on performance of helical-roof inlet cyclone. Outcome revealed that for inlet angles of 10° to 15°, cyclone exhibited the highest efficiency at acceptable pressure loss.

Lim, Lee and Kuhlman [5] studied parameters that influenced efficiency of electrocyclone for particles ranging between 0.5 µm and 10 µm. The electrocyclone consisted of a central discharge wire operated within the range of 0 to 9 kV. On varying potential difference, diameter and length of discharge wire and it was found that increase in voltage, decrease in diameter and increase in length of wire boosted cyclone efficiency. It was also found that compared to normal cyclones, electrocyclones had higher collecting efficiency and a smaller pressure drop for the same model.

III. CASE STUDY

In this paper the cyclone separator model was first authenticated by using experimental results. The model was then modified by changing its technical parameters, cone section body diameter, at different inlet angles, etc. So, the main objective of these researches and calculations is to design a cyclone separator with minimum required diameter for same capacity showing high efficiency considering different parameters as shown below.

We have considered 4 types of cyclone separators with different inlet angles which were at 0-degree, 8-degree, 15-degree and 30-degree respectively. Then we observed changes when we pass different particles through the inlet, i.e., Vegetable Oil, Cigarette Smoke, Chilli Powder, Perfume, etc. exhibiting different size and density, in which we came to know that the 8-degree radius inlet model provides maximum efficacy as it traps most number of foreign particles in the outbox attached downwards in the model and passes fresh air efficiently unlike others in which only some particles get trapped and most of them are released out (efficiency may differ for different particles as shown in Tab1. As it considers results of flow simulation carried out on a cyclone separator model of inlet radius 8-degree.

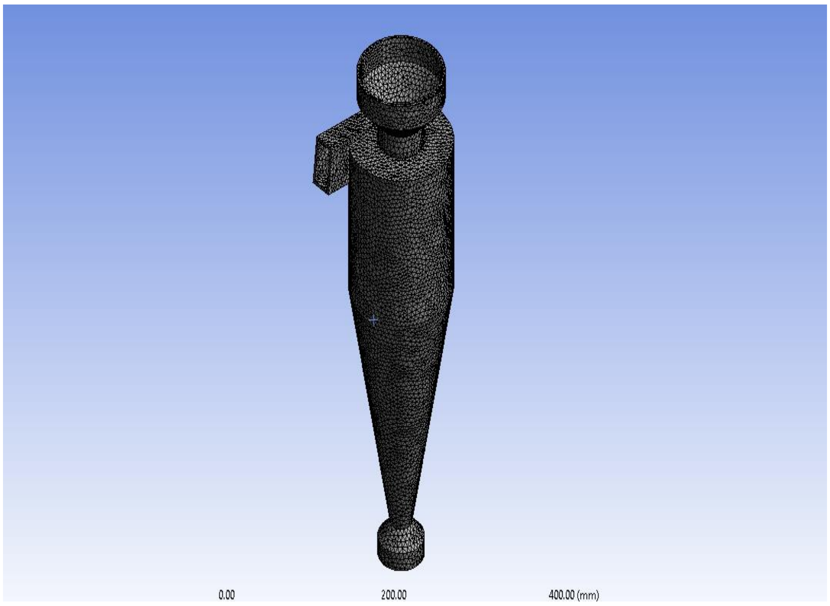

Fig. 2: Static Structural Analysis showcasing 2mm Element-sized Mesh generated using ANSYS

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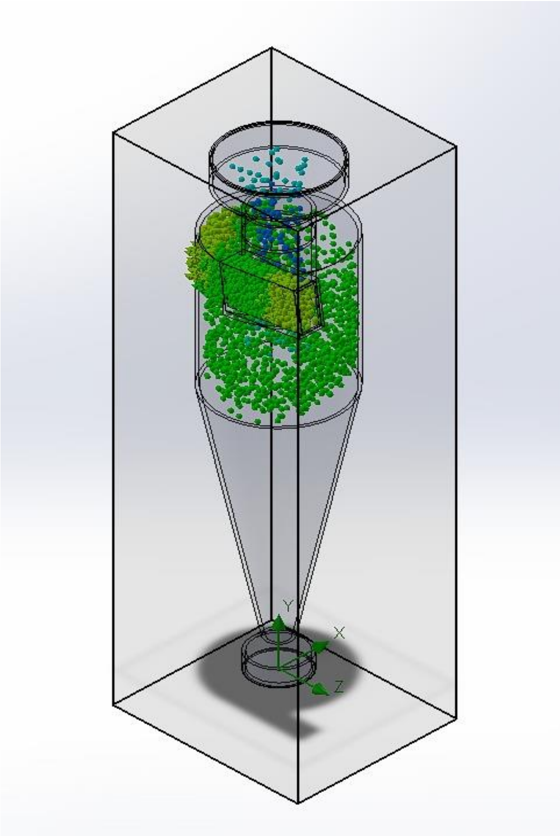

Fig. 3: CFD Analysis of Cyclone Separator having maximum Efficacy

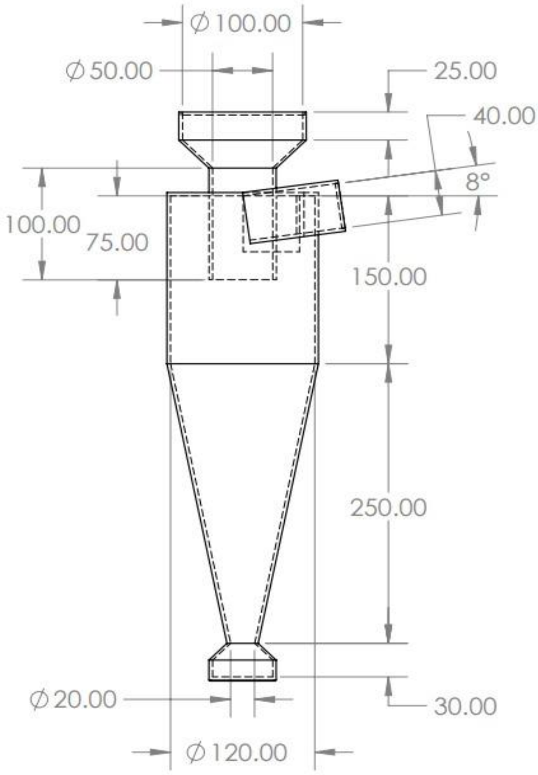

Fig. 4: Dimensional Analysis of Cyclone Separator Model

Sr.No.	Particle Name	Particle Size	Particle Density	Result (At 250 CMH)(At 100 Particles)	Other Results
					Minimum size at 100% efficiency
1	Vegetable Oil	5 micron	920 kg/m^3	100%	<5 micron
2	Cigrette Smoke	1 micron	144 kg/m^3	33%	7 micron
3	Corn Starch	5 micron	540 kg/m^3	100%	<5 micron
4	Chilli Powder	150 micron	541 kg/m^3	100%	<10 micron
5	Perfume	30 micron	944 kg/m^3	100%	<10 micron
6	Wood Dry	1 micron	380 kg/m^3	31%	4 micron
7	Becteria	2 micron	1100 kg/m^3	97%	3 micron
8	Pollen Grain	10 micron	1050 kg/m^3	100%	<10 micron
9	Fly Ash	10 micron	540 kg/m^3	100%	<10 micron
10	Dry Soil Dust	5 micron	1900 kg/m^3	100%	<5 micron
11	Polystyrene Foam	12 micron	46 kg/m^3	100%	11 micron
12	Cork Ground	10 micron	150 kg/m^3	100%	<10 micron
13	Kaolin Brick	10 micron	300 kg/m^3	100%	<10 micron

Table 1: Results of Flow Simulation on Particles with different Particle Size and Density

The cyclone separator model was authenticated by considering the experimental results and results obtained from the computations performed in ANSYS CFD as well as in SOLIDWORKS. The CFD analysis of these modified cyclone separators was performed. Collection efficiency obtained from this analysis was then used as a means to select the final design of the cyclone separator. The model with maximum collection efficiency is then selected. For the study of research paper and observation of effect of parameter of cyclone separator to the collection efficiency and what is impact on efficiency when we reduce the dimensions of cyclone separators, i.e., variation in inlet angle which may further differ the efficacy at the outlet for different particles.

IV. CONCLUSION

From the study and analysis of various research papers it is observed that with decreasing cyclone body diameter, cyclone width, and cyclone inlet width or angle, cyclone efficiency is increased and with increase in inlet velocity, the pressure drop increase but decreases with rise in temperature. We are achieving maximum efficiency at 7-degree inlet angle and based on particle sampling cyclone is best suited for residential filtration. Here, centrifugal force is inversely proportional to the radius so the diameter is to be reduced thus making force increase. So, less diameter cyclone work more high efficiency compares to others.

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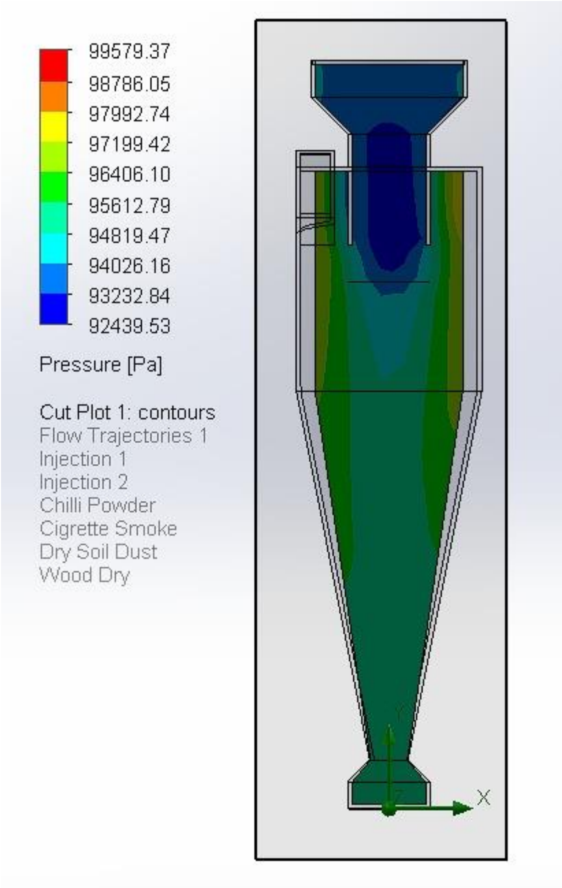

Fig. 5: Pressure Cut Plot

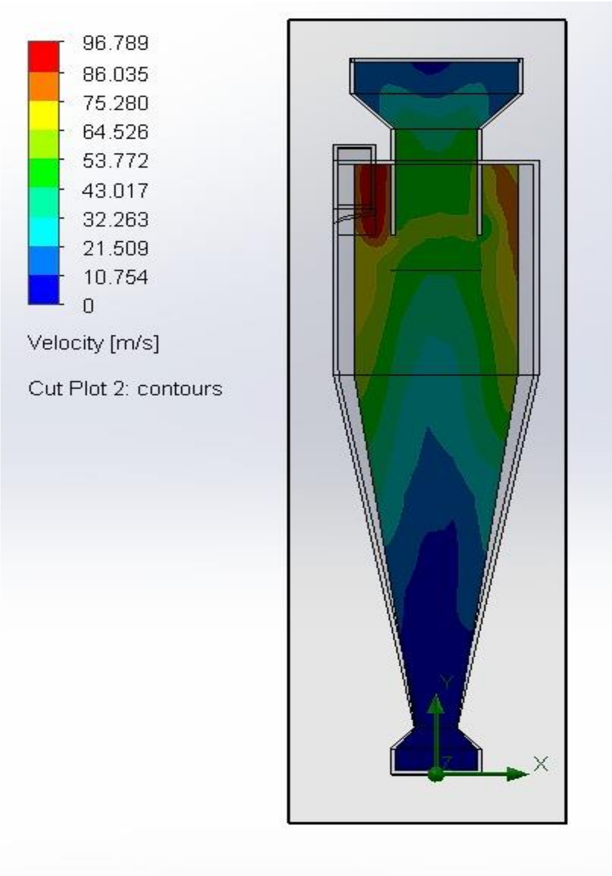

Fig. 6: Velocity Cut Plot

REFERENCES

[1.] Mahesh R. Jadhav, “Design of Cyclone and Study of its Performance Parameters”, *International Journal of Mechanical Engineering and Robotic Research*, Vol.3, No. 4 2014

[2.] Park, C. W, Song, D. H., &Yook, S. (2015), “Development of a single cyclone separator with three stages for size-selective sampling of particles”, *Journal of Aerosol Science*, 89: 18-25, DOI: 10.1016/j.jaerosci.2015.07.001

[3.] Ta-Chih Hsiao, Sheng-Hsiu Huang, Chia-Wei Hsu, Chih-Chieh Chen, Po-Kai Chang (2015),“Effects of the geometric configuration on Cyclone performance”, *Journal of Aerosol Science* DOI: 10.1016/j.jaerosci.2015.03.005

[4.] DzmitryMisiulia, Anders Gustav Andersson, T. Staffan Lundström, “Effects of the inlet angle on the collection efficiency of a cyclone with helical-roof inlet” ,*Powder Technology (2016)*,DOI: 10.1016/j.powtec.2016.09.050

[5.] K.S. Lim, K. W. Lee & M. R. Kuhlman (2001), “An Experimental Study of the Performance Factors Affecting Particle Collection Efficiency of the Electrocyclone” ,*Aerosol Science and Technology*,DOI: 10.1080/027868201753306732