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EFFECTS OF GEOMETRICAL CHANGE IN CYCLONE VORTEX FINDER ON PRESSURE DROP AND COLLECTION EFFICIENCY

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Abstract*— Enhancement of separation efficiency is important for cyclone separators to reduce any extra purification process required at the outlet. Therefore, the present research was performed to enhance the performance of cyclone separators with modified cone shaped vortex finder. In this study, a CFD is used to predict and evaluate the effects of vortex finder shape and length on cyclones collection efficiency and pressure drop and results were validate with experimentation. Modelling done in CFD with 12 m/s inlet velocity and with nine different models, pressure drop measured at two different outlets. Experimental setup for model 5 with 200 mm depth and 30° cone angle proved that pressure drop affects collection efficiency and better collection efficiency can be obtained with shape and length change in vortex finder of cyclone separator. The study proved the effectiveness of cone shaped vortex finder reducing the pressure drop. The CFD results are compared with the experimental data and result is observed.

***Keywords*— cyclone separator, collection efficiency, vortex finder, CFD, shape of vortex finder**

I. INTRODUCTION

Cyclones are the most common type of inertial separators. Cyclone separators are devices that use a centrifugal force generated by a rotating gas-solid stream to separate the particulate matter, which could be solid or liquid, from the carrier gas. Many industrial processes, such as petroleum refining, chemical engineering, mining refineries, and environmental cleaning, involve the separation of particles from an air stream. Several technologies, electrostatic precipitators, including fabric filters, vibrator, gravity separator, air classifiers and cyclone separators can be used for gas–solid separation. But some of them like fabric filters and electrostatic precipitators incur high initial and operating costs; they are not suitable for many industrial applications, so in such case cyclone separator is a good choice with good efficiency and low initial and operating cost.

The cyclone separator works by inducing spiral rotation in the primary phase (liquid or gas) and using this rotation to induce radial acceleration on a particulate suspension. In conventional cyclone separator, there are two outlets, one is at top side of the cyclone and other one is at bottom side. Swirling of the gas is done by blower which is at inlet this swirled gas and particulate matter both are come inside the cylindrical body of cyclone and outer vortex is formed. This vortex travelled downward due heavier particles which flow toward the cylindrical wall due to effect of centrifugal force. Due to density difference between gas and particulate suspension there is another vortex generated at the centre of the cyclone because there is low pressure generated. Due to the density difference between primary phase and the suspended particulate phase, denser particles migrate rapidly to the outer wall and then spiral down to the underflow. Particles with low density migrate more slowly, so are captured in an upward spiral near the centre of the cyclone, and leave through the top vortex finder.

Since cyclones have been used in various industries, a considerable number of experimental and theoretical investigations have been performed on cyclone separators to the present. Among these, Stairmand [1] gives design guidelines which suggested that the cylinder height and outlet tube length be, respectively, 1.5 and 0.5 times of the cyclone body diameter for the design of a high efficiency cyclone separator. Particle separation could increase through down-comers by expanding the separation space and creating a high tangential velocity dominant zone suggested by Sakura Ganegama Bogodage [2]. Selami Demir [3] obtained that Pressure drop is a function of both cylindrical and conical heights,To obtain the most cost-effective design with lower pressure drop, one should choose a conical-to-body height ratio of greater than 1.67. particle mass loading is also a considerable thing.

An-Ni Huang [4] experiment suggest that increasing the mass loading will increase the collection efficiency of the cyclone separator. Bryant et al. [5] observed if the vortex touched the cone wall, particle re-entrainment occurred. Bhatia and Cheremisinoff [6] discussed the effects of the cone opening size on the pressure drop. Khairy elsayed [7] suggested as vortex finder diameter decreases, the maximum tangential velocity increases. Qiang li [8] developed a novel vortex finder with guide vane inlet which increases particle collection efficiency. the most important geometrical variables which affects pressure drop and the collection efficiency are the height and the width of the inlet, and the diameter of vortex finder. Other variables also have an effect, but are not as noteworthy reported by Rafaello D. Luciano [9]. P.a. funk [10] designed new radial evasé at the top most outlet which reduced pressure drop 8.7% to 11.9 %.

W.I. Mazyan [11] suggested that tangential chamber at the cone section enhances the separation efficiency by 21% in the conventional cyclones. W.P. Martignon [12] applied a new designed to conventional cyclone separator including a double inlet section and a scroll inlet and outlet section an analysed. Zhiyi Xiong [13] his research showed that the vortex finder with the straight gaps and/or spiral gaps in inlet had increased overall separation efficiency and grade efficiency as well as decreased pressure drop.

CFD is great tool to predict the flow field characteristics and particle trajectories inside the cyclone as well as the pressure drop Griffiths and Boysan [14].

II. CONFIGURATION OF CYCLONE DIMENSION

As described earlier the simulations were per-formed on 9 cyclones with different vortex finder shapes and length, which have been tested for pressure drop and collection efficiency by Lim et al. [15]. The dimensions of cyclones are shown in Fig. 1(a) and Table 1. Dimension of modified shape vortex finder with 9 different shape is shown in Fig. 2. cone-shaped vortex finders have different cone length and cone angle as shown in Table 2. All other dimensions remains same.

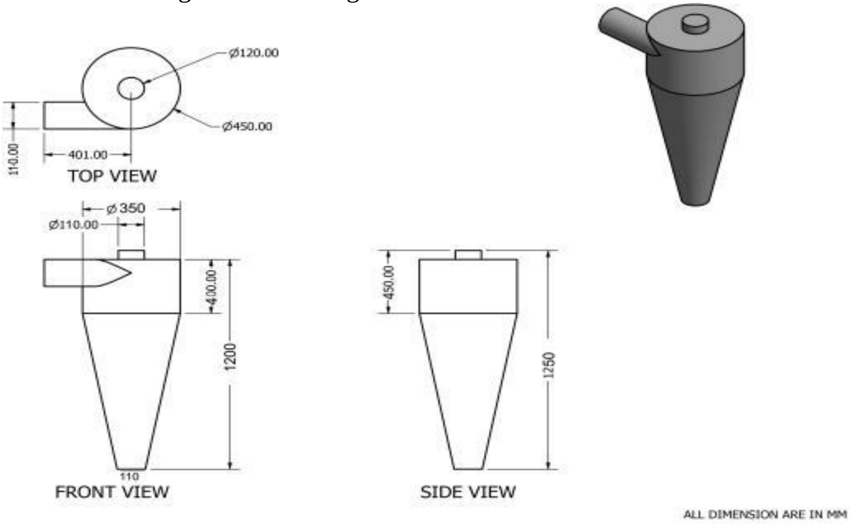

Fig. 1. Dimensions of cyclone

TABLE I
DIMENSIONS OF THE CYCLONE

Parameter	Dimension (mm)
Cyclone diameter	450
Cone length	800
Cylinder Height	400
Vortex Finder Diameter inner Vortex Finder Diameter outer	110 210
Vortex finder length	250
Inlet diameter	110
Outlet diameter	110

TABLE II
DIMENSIONS OF THE VORTEX FINDER

Models	Cone angle	Vortex finder length (mm)
M1	20°	150
M2	20°	200
M3	20°	250
M4	30°	150
M5	30°	200
M6	30°	250
M7	35°	150
M8	35°	200
M9	35°	250

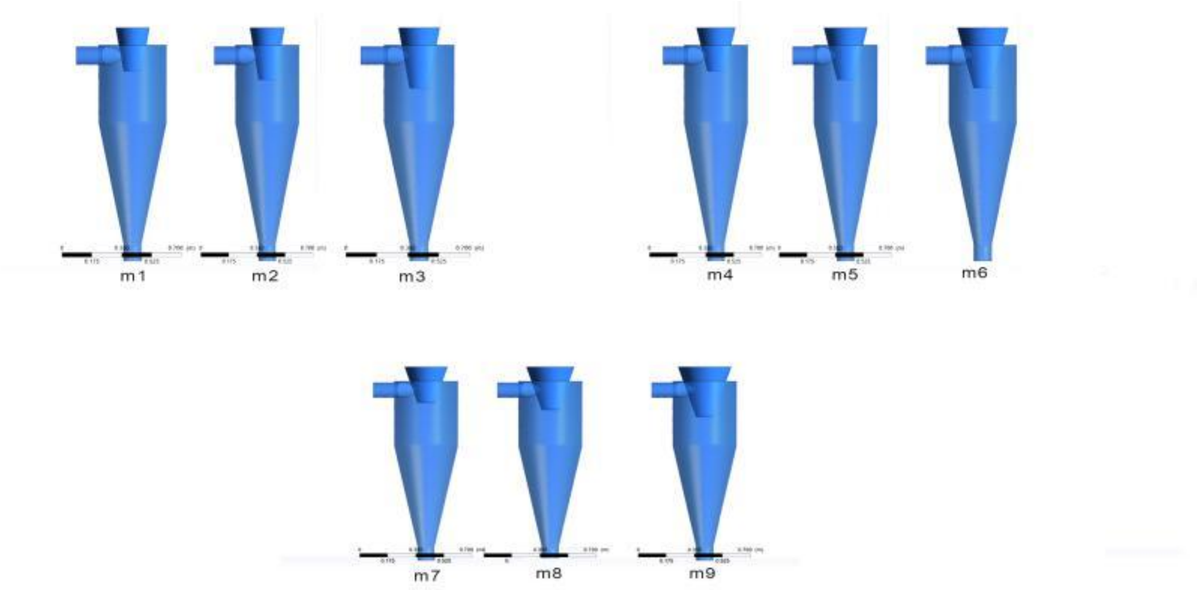

Fig. 2. Shape of vortex finders

III. NUMERICAL MODELING BY CFD

For simulation of the flow in the cyclone CFD is used for conventional model and for 9 modified models. Boundary condition remains same for both.

A. Boundary conditions

Following are boundary conditions are given for simulation of cyclone.

TABLE II
BOUNDARY CONDITIONS FOR SIMULATIONS

Properties		**Value**	**Unit**
Air	**Material**	**Air**	-
	Viscosity of gas	0.0000185	kg/ms
	Density of gas	1.142	kg/m3
Wheat flour	Material	Wheat Flour	-
	particle size	0.01	mm
	Particle density	561	kg/m3
	Viscosity of particle	1.983x10-5	pa.sec

Geometrical models were developed in solid works and then CFD modelling is done with Discrete phase model in which two different phases is analysed. Results were obtained as pressure drop in both case and among 9 models the model m5 gives a better pressure drop reduction.

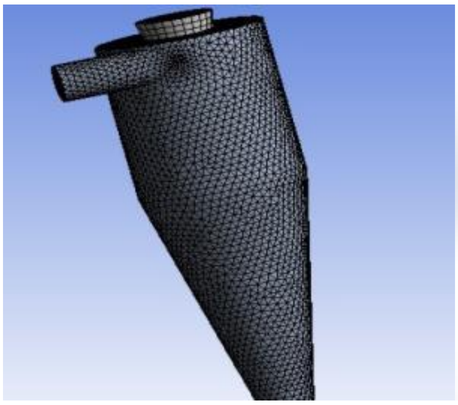

Fig. 3.(a) Meshing of cyclone

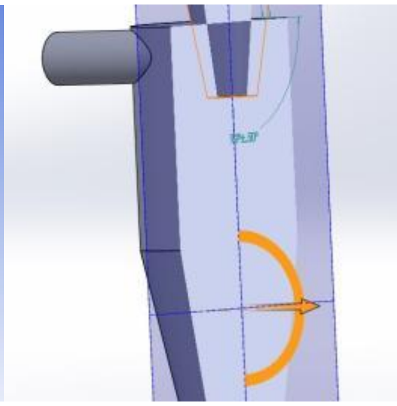

Fig. 3.(b) Meshing of cyclone

Meshing of model is done in Ansys 14.5 for all models. By applying mentioned boundary conditions calculation is initialized and results were obtained.

B. Results of analysis

TABLE III
CFD RESULTS

Models	Actual	M1	M2	M3	M4	M5	M6	M7	M8	M9
Pressure drop	551.23	517.18	510.12	508.25	450.21	385.14	350.25	200.12	198.56	195.63
velocity	10.23	10.88	9.66	9.55	9.10	10.11	8.33	8.02	7.21	6.22

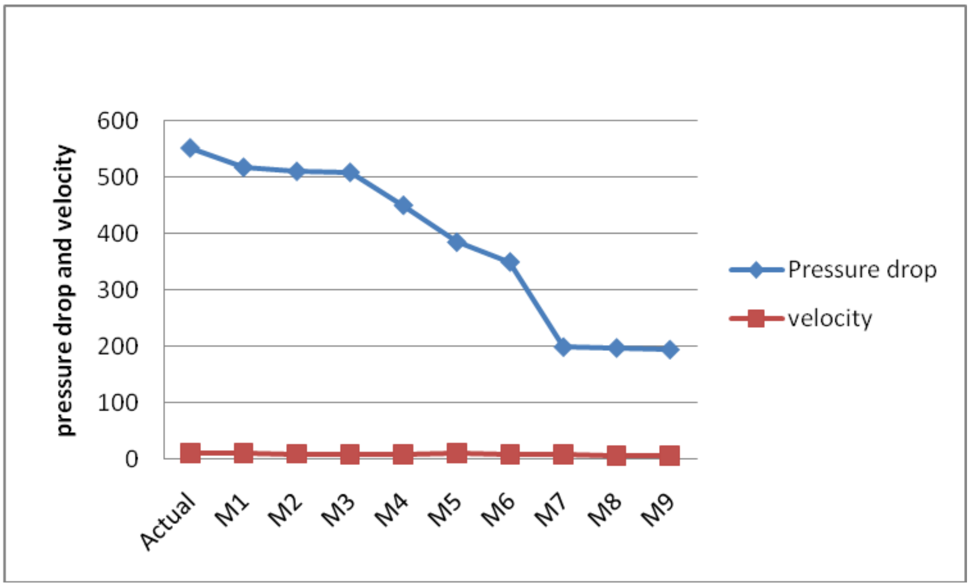

Fig. 5. Pressure drop and velocities of different models

IV. EXPERIMENTAL WORK

As per results obtained by CFD model no. 5 gives better results with minimum pressure drop and less reduced velocity. So for justification of CFD results experiment of m5 model and actual model done by making a model with required dimension as shown in fig.4 (a) and Fig. 4 (b).

Fig. 5(a) Actual model

Fig. 5(b) modified m5 model

In this Experiment two cyclones are evaluated with same dimensions only difference in their cone geometry. One cyclone model is having simple vortex finder and another is having cone shaped vortex finder with different length. For experimental setup the fabricated cyclone, blower, dust collector, anemometer, pressure gauge etc. Parts area assembled together. For measurement of inlet and outlet velocity an anemometer is selected, Anemometer gives reading of velocity in m/s. For measurement of pressure at various points the connectors are provided at both inlet and an outlet port. Manometer is used to measure the pressure in water column.

Model	Actual	Modified m5
Pressure drop	520.56	370.86
Velocity (outlet)	9.88	9.12

V. CONCLUSIONS

Pressure drop is major factor that affects the collection efficiency of the cyclone separator. Shape of the outlet section must affects the pressure drop between outlet section and inlet section hence pressure losses is reduced with cone shape vortex finder which increases collection efficiency shape of the vortex finder effects collection efficiency of the cyclone separator and reduced the pressure drop.

Validation with CFD analysis its nearby value found as Practical experiment. So the optimization with CFD the particle collection efficiency of cone shape vortex finder is higher than cone shape vortex finder cyclone separator is better than vertical cone cyclone separator with no extra fabrication cost.

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