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CYCLONE PERFORMANCE BY USING MODIFIED DOUBLE INLET CYCLONE

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Abstract: Cyclone performance is determined by pressure drop and collection efficiency. The result shows that increasing the cyclone dimensions decreases the pressure drop. By changing in inlet geometry of cyclone for two symmetrical inlets the flow gets divided in to two parts. The pressure drop is more in single inlet cyclone as compare to symmetrical inlet cyclone for same flow rate. As the velocity at inlet is increases then the pressure drop is decreases. It is also observed that as inlet velocity increase the cyclone efficiency also increases. Hence for symmetrical inlet cyclone efficiency is more. This model is tested for different flow rate as change in one parameter its effect will be analyzed on the performance parameters. It was concluded that the overall cyclone collection efficiency increased and the pressure drop decreased for both formulations, but the design with two symmetrical inlets showed a large reduction in pressure drop than the other model. All results indicate that these ideas can provide an alternative method for studying fluid dynamics inside cyclones and improve performance parameters.
Keywords: Cyclone, Efficiency, Pressure drop, Performance.

I. INTRODUCTION

Cyclone separators are common and simple particle removal devices and are used in many applications. They are simple devices that use centrifugal force to separate the particles from the conveying gas. Cyclones are constructed from sheet metal and therefore, they have low capital cost and no moving parts. They are very efficient in removing large particles but they are less efficient for collecting small particles of submicron size. External equipment, such as a blower or other source of pressure is required to move the gas stream through the cyclone. Among different types of cyclone separators, the tangential inlet reverse-flow cyclone is the most common type causing the gas stream to be swirled around and the particles to be thrown toward the wall of the cyclone body and as they reach the wall, they move down to be collected. In general, a cyclone consist of an upper cylindrical part referred to as the barrel and a lower conical part referred to as the cone as shown in figure 1,The air stream enters tangentially at the top of the barrel and travels downward into the cone, forming an outer vortex. The increasing air velocity in the outer vortex results in a centrifugal force on the particles, separating them from the air steam. When air reaches the bottom of the cone, an inner vortex is created, reversing direction and exiting out the top as clean air while the particulates fall into the dust collection chamber attached to the bottom of the cyclone. Cyclone performance is usually described in terms of pressure drop and collection efficiency. A large number of semi empirical cyclone models are available in the previous studies which can be used to calculate the pressure drop from cyclone dimensions. These models have been developed for specific conditions which limits their predictions. There is no single expression that will give a reliable estimate of pressure drop for all cyclones operating under all conditions. The experimental tests are the most accurate procedures when cyclone pressure drop must be known accurately. To understand pressure loss mechanism and particle separation in a cyclone, it is important to understand the cyclone gas flow pattern. However, no generalized model of the flow pattern is available that allow the prediction of velocity components in the cyclone.

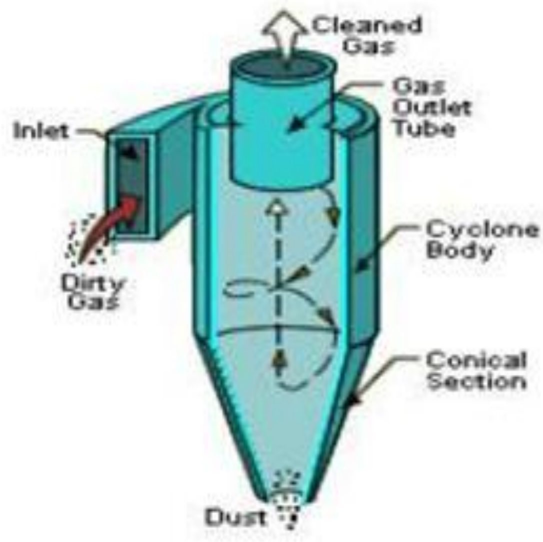


Figure 1 : Cyclone Model

Most of the attention has been focused on finding new methods to improve performance parameters. Some studies were conducted to improve equipment performance by evaluating geometric effects on projects. Cyclone dust collectors have been used in many industrial facilities to collect solid particles from gas-solid flows and to reduce air pollution originating in chimney smoke from chemical plant drier equipment. However in this situation to control the air pollution is very important and cyclone is used for pollution control.

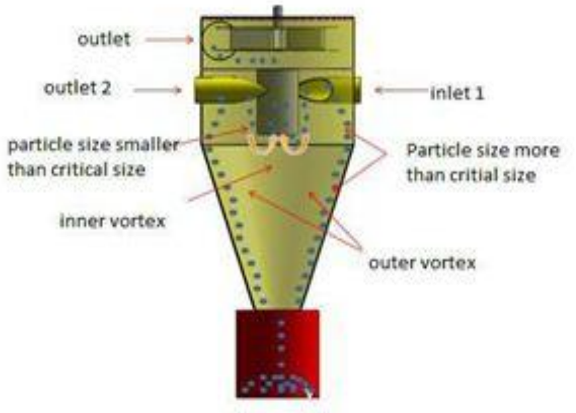


Figure 2: Flow Pattern Inside Cyclone

Currently, with new engineering applications of cyclones as dryers, reactors and particularly in the removal of high-cost catalysts from gases in petroleum refineries, industries require a greater understanding of turbulent gas flows, which could lead to rigorous procedures capable of accurately predicting efficiency, velocity and pressure fields. Also the pollution due flour mill is cannot be neglected, small flour particles in large quantity are coming out through the mill and get mixed in atmospheric air. The operator who is continuously working on this mill is suffering through this pollution and there will be chances of lung deceases. So the aim of study is to design a cyclone for flour mill application and to optimize its performance parameters by doing some geometrical changes. There are many types of cyclones for the of solid particle separation. However, following are the most typical: returned flow or reversed flow, axial flow and rotary gas flow into the cyclone body. The historical transition of cyclones development can be found in Crawford, Storchand Ogawa, where many old and interesting types of cyclones are discussed. The most standard construction of the returned flow type is composed of a cylindrical body with a fixed diameter and a conical part.

Physical models or families of cyclones are established when a set of dimensions is fixed in relation to the diameter. Since its conception over a century ago, many researchers have contributed to the large volume of work on improving the efficiency of cyclones by introducing new design and operation variables. However, in most cases, the improvement in efficiency is marginal and in some cases it is associated with complex structure and additional operating costs.

II. EXPERIMENTAL TEST

Experimentation was performed on a small scale cyclone designed for flour mill, where as to collect the small dust of flour in flour mill with maximum efficiency. For this experimental work a new cyclone model has to be fabricated. Cyclone model have to evaluate for different flow rate and its pressure drop and efficiency need to compare. This study two cyclones are evaluated with same dimensions only difference in their inlet geometry. One cyclone model is having single tangential inlet with same size inlet and outlet pipe and another is having two symmetrical tangential inlets and one outlet. For experimental setup the fabricated cyclone, impeller, dust collector, electric motor, top flange, gaskets etc. Parts area assembled together.

Figure 3: Experimental Setup

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. Electric motor, top flange, gaskets 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.

The cyclone geometric configurations are.

Table 1: Cyclone Geometric Configurations

Sr. No	Geometric Data	Dimension(mm)
1	Barrel Diameter	370
2	Barrel Height	175
3	Cone bottom Diameter	113
4	Cone height	380
5	Inlet pipe diameter for symmetrical inlet	50
6	Inlet pipe diameter for single inlet	86.8
7	Exit pipe dia.	86.8
8	Deep tube dia.	100

9	Deep tube length	150
10	Inlet of cyclone from top of impeller	164
11	Exit of cyclone from top of impeller	50

2.1 Measurement of Velocity

The instrument used to measure wind speed is called anemometer, which is an indicator that will spin in wind. The anemometer rotates at same speed as the wind. It gives direct measure of speed of wind. In vane anemometer axis parallel to direction of wind and therefore horizontal. Thus it combines a propeller and tail on same axis to obtain accurate and precise wind speed and direction measurement.

Figure 4: Measurement of Velocity

Velocity is measured for different 8 values of flow rates, and noted as a reading. The velocity reading sheet is given as follow.

Table 2: Velocity for Different Flow Rates

Sr. No	Flow Rate (/hr)	Velocity (m/s) Single Inlet		Velocity (m/s) Double Inlet		
		Inlet	Outlet	Inlet	Inlet 2	Outlet
1	558.22	26.6	26.4	38.3	38.8	25.8
2	536.58	25.3	24.9	36.5	36.4	24.4
3	512.78	24.7	24.4	36.2	35.8	23.7
4	495.47	23.6	23.3	35	34.9	22.9
5	480.33	22.5	22.3	33.6	33.5	22.2
6	458.69	21.9	21.7	32.3	32.3	21.2
7	434.89	20.8	20.5	30.9	30.7	20.1
8	417.58	19	18.9	29.7	29.3	19.3

2.2 Measurement of Pressure

Manometers are one of the oldest types of pressures measurement instrument. It can be used to measure gauge pressure, differential pressure and absolute pressure. Figure shows the simple U-tube manometer, there are various types of manometer which are used to measure the pressures like U-tube manometer, Incline manometer and Float type manometer etc. A simple U-tube manometer consists of a U-shape glass tube having one of its ends connected to the point, where pressure is to be measured and other end is open to the atmosphere. The tube contains liquid whose specific gravity is greater than the specific gravity of the liquid whose pressure is to be measured. It generally contains water or mercury. The U-tube manometer has no need for calibration, the maximum uncertainties of U-tube manometer is ± 1 mm of H_2O. The pressure is measured by using manometer.

Table 3: Pressure Measurement for Different Flow Rates.

Sr. No	Flow Rate (/hr)	Single inlet (Pa)	Double inlet (Pa)
1	558.22	3476.69	2690.39
2	536.58	3031.85	2510.81
3	512.78	2756.12	2301.34
4	495.47	2503.62	2123.62
5	480.33	2378.44	1998.01
6	458.69	2227.26	1802.34
7	434.89	1956.15	1614.13
8	417.58	1634.15	1495.52

2.3 Measurement of Efficiency

The efficiency of cyclone is measured by giving a feed of flour of 100 grams. The average particle size is 6-10 micron of wheat flour is used. The feed is given to both inlets simultaneously with dispersing the particle by hand. Then the weight of collected flour at duct collector is measured and it's subtracted from the 100 for calculation of efficiency.

Figure: 5 Measurement of Flour Weight for Efficiency

Table 4: Cyclone Efficiency

Sr. No	Flow Rate (/hr)	Efficiency for Single Inlet (%)	Efficiency for Double Inlet
1	558.22	93	99
2	536.58	92	97
3	512.78	90	95
4	495.47	89.6	93
5	480.3	88	90
6	458.69	86.6	89
7	434.89	84	88

III. NUMERICAL SIMULATION USING CFD MODEL

Computational system dynamics is the analysis of the systems involving fluid flow, heat transfer and associated phenomenon such as chemical reactions means of computer.

A. Boundary Conditions and Computational Grids

Following are boundary conditions are given for simulation of cyclone.

Table 5: Boundary Conditions for Simulation

Properties		Value	Unit
Gas Phase	Material	Air	-
	Viscosity of	0.0000185	kg/
	Density of gas	1.142	kg/
Solid Phase	Material	Wheat Flour	-
	Particle size	0.01	mm
	Particle density	561	kg/
	Viscosity of particle	1.983x	Pa.sec

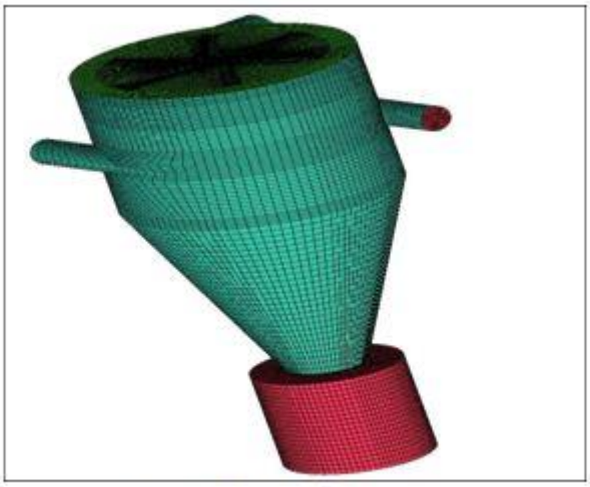


Figure 6: Mesh Model of Cyclone

Figure 7: Mesh Model of Cyclone Top with Impeller

For CFD analysis three different flow rates and results are obtained which are as follows

Table 6: Boundary Condition and Results for Case 1

Sr. No	Inlet 1	Inlet 2	Outlet
1	0.05	0.05	0.086
2	0.0019	0.0019	0.0060

3	1.142	1.142	1.142
4	270	270	540
5	0.075	0.075	0.15
6	0.085	0.085	0.17
7	38.18	38.18	24.94
8	2500.24	2506.3	-6.06
9	3212.24	3218.30	732.89
10	2479.35	2485.41	——

Table 7: Boundary Condition and Results for Case 2

Sr. No	Inlet 1	Inlet 2	Outlet
1	0.05	0.05	0.086
2	0.0019	0.0019	0.0060
3	1.142	1.142	1.142
4	240	240	480
5	0.067	0.067	0.134
6	0.076	0.076	0.150
7	34.11	34.11	22.28
8	1868.14	1873.19	-5.05
9	2353.14	2363.58	502.28
10	1850.86	1861.30	——

Table 8: Boundary Condition and Results for Case 3

Sr. No	Inlet 1	Inlet 2	Outlet
1	0.05	0.05	0.086
2	0.0019	0.0019	0.0060
3	1.142	1.142	1.142
4	200	200	400
5	0.06	0.06	0.12
6	0.068	0.068	0.1370
7	30.54	30.54	19.96
8	1329.46	1331.63	-2.17
9	1629.46	1631.63	312.22
10	1317.24	1319.41	——

3.2 Velocity Plots

For studying the flow of the solid particles in the cyclone, below are velocity plots for different particle sizes for case 1.

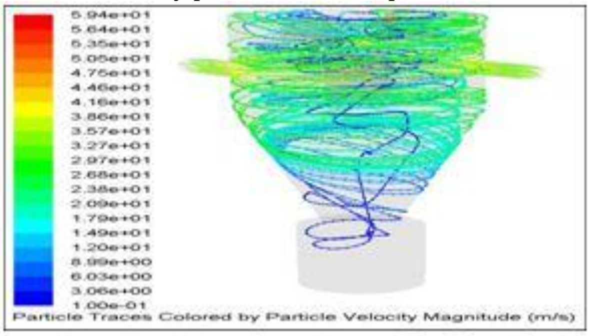


Figure 8: Particle Trace Colour by Particle Velocity for 1 Micron Particle Size

3.3 Contours of Total Pressure

Figure 9 shows the contours of static pressure, it shows pressure decreases radially from wall to center and reached their minimum values near the central axis of the cyclone Contours of Velocity Magnitude.

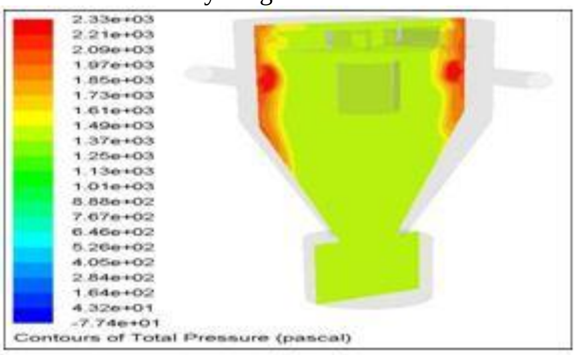


Figure 9: Contours of Total Pressure

3.4 Contours of Velocity Magnitude

Figure 10 shows the contours of velocity magnitude, it shows the velocity vector distribution inside axial flow cyclone separator. The air stream enters axially through the inlet and rotates downward from pure axial motion due to guide vanes.

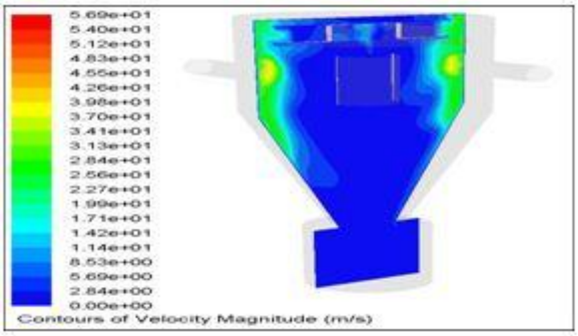
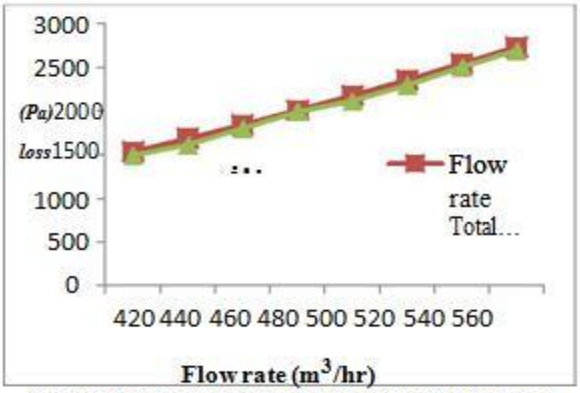


Figure 10: Contours of Velocity Magnitude

IV. RESULT AND DISCUSSION

4.1 Theoretical and Experimental Effect of Flow Rate on Pressure Drop

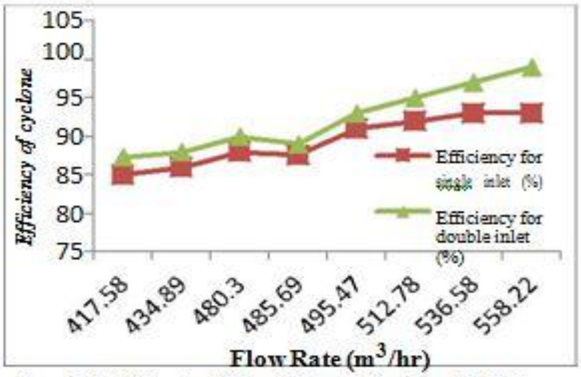
Pressure drop in modified double inlet cyclone is less than the pressure drop in single inlet cyclone which is 489.46 Pa theoretical. Also the pressure drop is depending on the inlet velocity for the same model. It is observed that the pressure drop increases as the flow rate increases. Here in actual model pressure drop is more for single inlet cyclone as compare to symmetrical inlet cyclone.



Graph 1: Theoretical and Experimental Effect of Flow Rate on Pressure Drop

4.2. Effect of Flow Rate on Efficiency for Single Inlet and Double Inlet Cyclone

Pressure drop in symmetrical inlet cyclone is less than the pressure drop in single inlet cyclone which is 556.69 Pa Experimental. Also the pressure drop is depending on the inlet velocity for the same model. It is observed that the pressure drop is increases as the flow rate increases.



Graph 2: Effect of Flow Rate on Cyclone Efficiency

V. CONCLUSION

Cyclone results are computed for single inlet and modified double inlet is as follows,
Theoretical results for flow rate and pressure drop with increase in flow rate pressure drop increases. Pressure drop in modified double inlet cyclone is less than the pressure drop in single inlet cyclone which is 489.46 Pa.

Experimental results for flow rate and pressure drop as flow rate increases pressure drop increases. Pressure drop in symmetrical inlet cyclone is less than the pressure drop in single inlet cyclone which is 556.69 Pa

As the flow rate increases the efficiency of cyclone also increase which is 3.97% more than single inlet cyclone. The efficiency of cyclone is more for symmetrical inlet cyclone for same flow rate. Hence operating power required for single inlet cyclone is less than the existing.

The theoretical and experimental values of pressure drop for same flow rate are near about same for symmetrical inlet cyclone. Hence whatever theoretical calculations are done for same flow rates those are correct and showing same values in experimental trials.

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