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CFD Analysis of Symmetrical Inlet Cyclone Dust Separator

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Abstract*: Cyclone dust separators are most commonly used device to separate dust particles from the gas-dust flow. In this paper we use inertial cyclone separator in which we separate dust from the gas with the combination of forces such as gravitational, centrifugal and inertial. The gas-dust stream enters the cyclone with tangential inlet; this tangential flow gives rise to axially descending spiral motion. Thus the spiral motion creates centrifugal force, which throws the dust particles towards the cyclone wall. The wall striking particles fell down and separated. In this paper we design and do CFD analysis of symmetrical tangential inlet cyclone and compare the results with single inlet cyclone separator.
Keywords*: Cyclone separator, Cyclone dust collector, symmetrical inlet, tangential inlet and CFD analysis.

I. INTRODUCTION

Cyclone dust separators separate the dust particles from the industrial gas. The cyclone separators are robust and used in many industrial plants to reduce air pollution. The gas cyclone separators are belong to centrifugal separators. In which the dust gas enters the cyclone from tangential inlet and thus forces the dust gas flow to follow spiral motion. This spiral motion creates centrifugal force and thus throws the dust particles towards the cyclone wall. The wall striking dust particles then fell down due to gravity and separated. In these type of cyclones there are two types of vortexes. In this type of cyclones there are two types of vortexes, one is outer vortex which carries dust particles downward and another one is inner vortex which carries pure gas from downward to upward. The performance of cyclone is most affected by cyclone geometry. The dust particles are bifurcated into two layers as soon it enters the cyclone due to the eddy currents generated in the coaxial space between the cyclone body and exit pipe. One of them goes upper surface around the coaxial space and rates with the gas flow around the exit pipe. The other layer rotates and descends down along the surface of the cyclone. Then in the cone surface the dust layers are pressed by the centrifugal force and descend down due to the secondary air flow in the boundary and flow through the exit pipe. The centrifugal effect, which is responsible for separating the dust particles, depends on tangential velocity must be increased to increase the cyclone efficiency because it relates to the pressure drop.

II. CYCLONE GEOMETRY

In this paper cyclone geometry is constructed using Stairmand's high efficiency method. Stairmand developed the optimized geometrical ratios based on the experiments he conducted. By using these geometrical ratio's cyclone model is constructed in catia V5.

For safe design we choose diameter of cyclone as 0.30m which is close to Stairmand's standard size diameter 0.203m. Thus the other dimensions of cyclone as follows,

Table 1 Cyclone Dimensions

Sr. no.	Geometric data	Dimensions (m)
1	Diameter of cyclone (Dc)	0.30
2	Height of inlet duct (Hi)	0.15
3	Width of inlet duct (Wi)	0.06
4	Diameter of outlet duct (Do)	0.15
5	Diameter of dust outlet (Dd)	0.11
6	Length of cyclone main body (L1)	0.45
7	Length of cyclone hooper (L2)	0.75
8	Total length of cyclone (L1+L2)	1.2

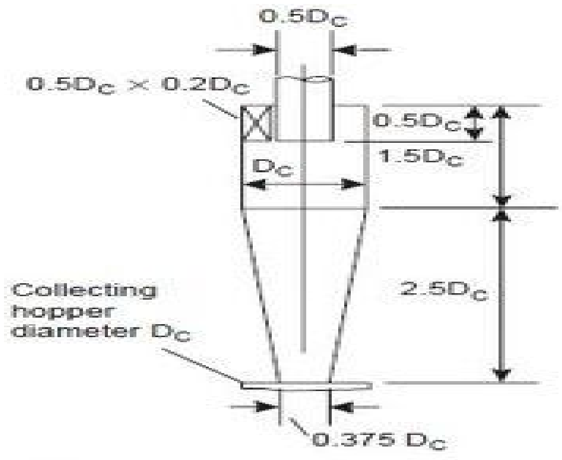

Fig. 1 Cyclone geometrical ratio's

III.GEOMETRY MODIFICATION

By increasing the tangential velocity cyclone performance must be increased. By adding an extra tangential inlet of same dimension to the standard cyclone design tangential velocity will increase.

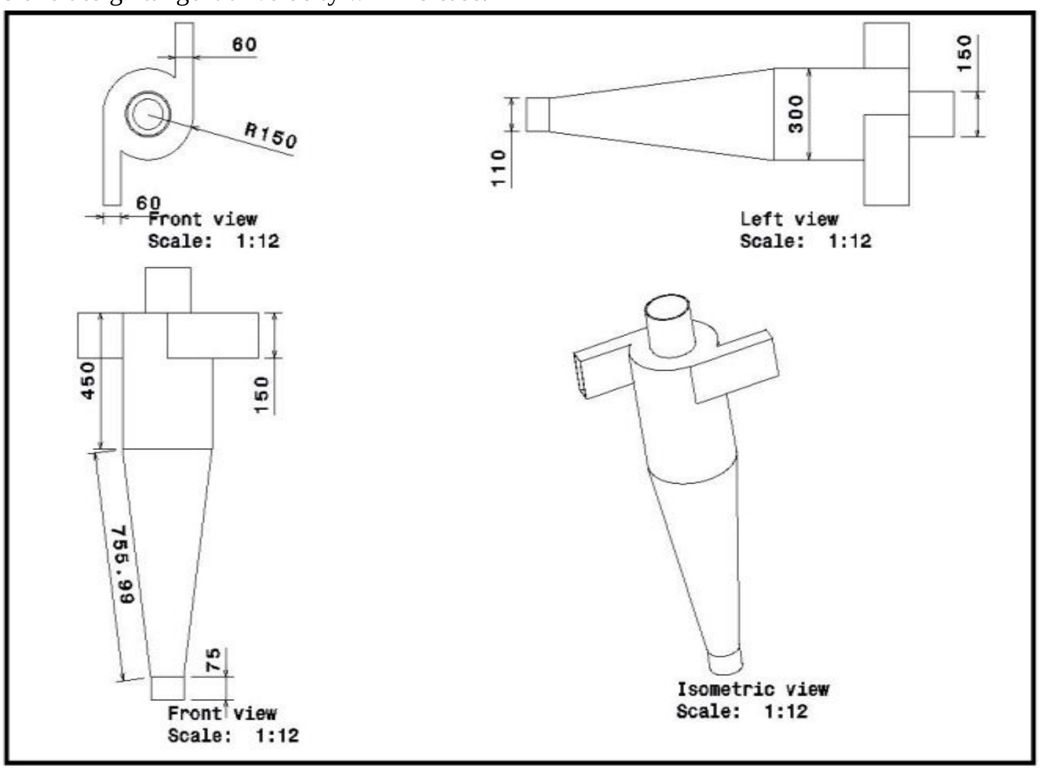

Fig 2 Symmetrical inlet cclone separator CFD Analysis of Cyclone Models

In order to do CFD analysis cyclone models from Catia V5 have been imported into Ansys 14.1 Fluent.

A. Mesh

Open mesh > create named sections

1) Select the inlet face.name it as velocity inle
2) Select the outlet face and name it as pressure outlet
3) Select the rest of the faces and name them as wall. Select mesh in tree outline. In mesh details default conditions are set to be CFD and FLUENT solver. Select mesh and click generate mesh to obtain mesh.

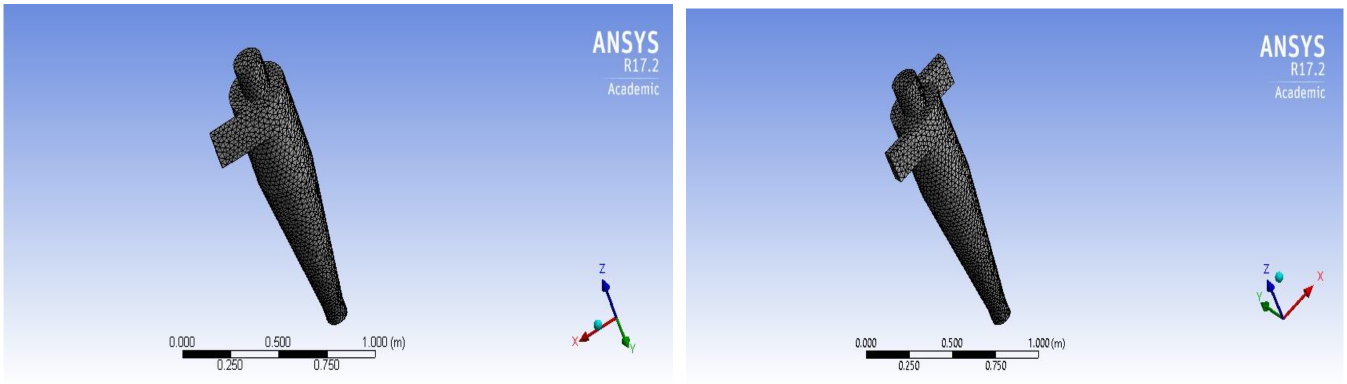

Fig 3 Single Inlet and Symmetrical Inlet Cyclone Meshed models

Table 2 Mesh Properties

	Single inlet	Symmetrical inlet
Nodes	5426	5484
Elements	25809	25791

B. Setup

1) *STEP 1*: General > check mesh (To verify the mesh is correct or not) Enable pressure based type, absolute velocity formulation and transient time steps.
2) *STEP 2:* In models select the realizable k-epsilon (2eqn) Model and RNG model with swirl dominated flow and standard wall functions.
3) *STEP 3* – DPM is set to on and create new injection for both the cyclones. The particles will enter from the inlet surface with 15m/s.

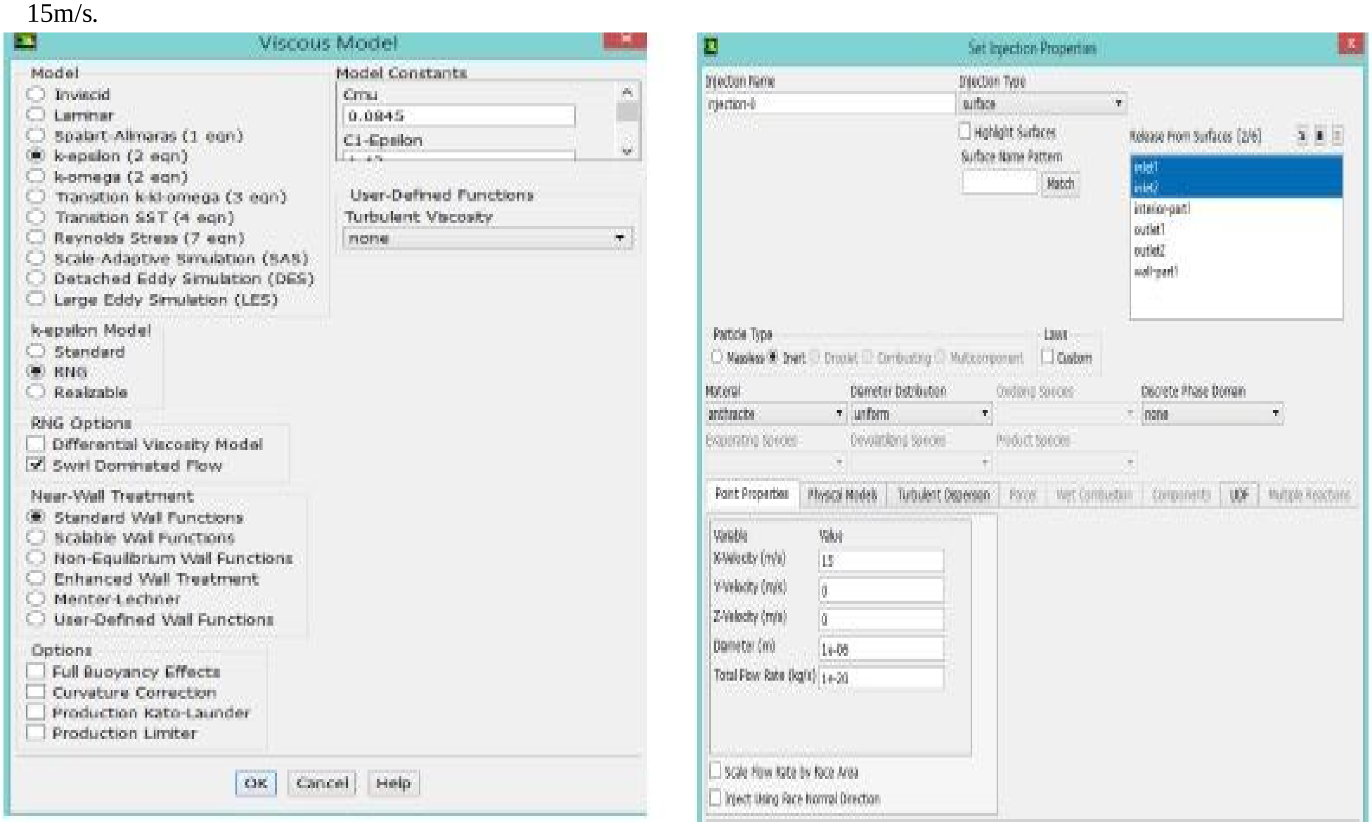

Fig 4 Defining models

Boundary condition Velocity inlet > x-velocity=15m/s.

C. Solution Methods

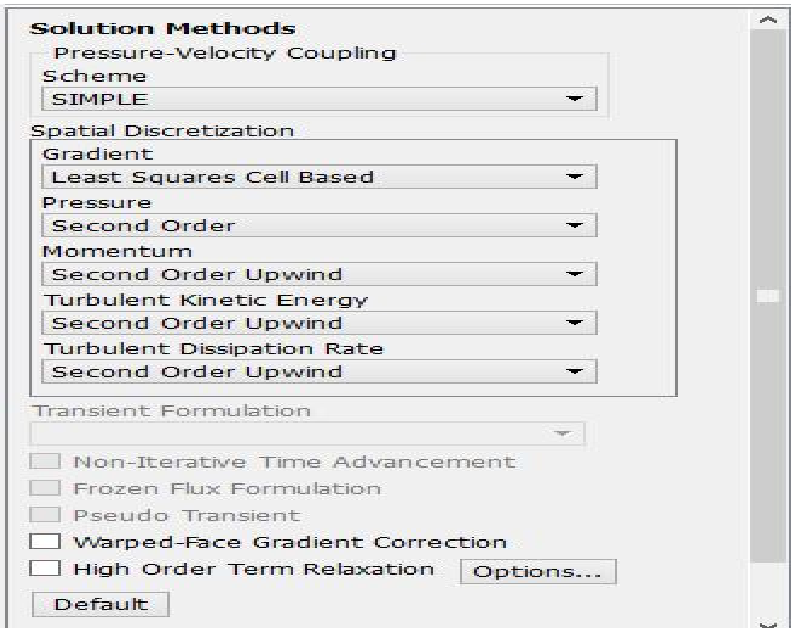

Fig 5 Details of solution methods

Initialization: Select standard initialization and compute from inlet velocity.

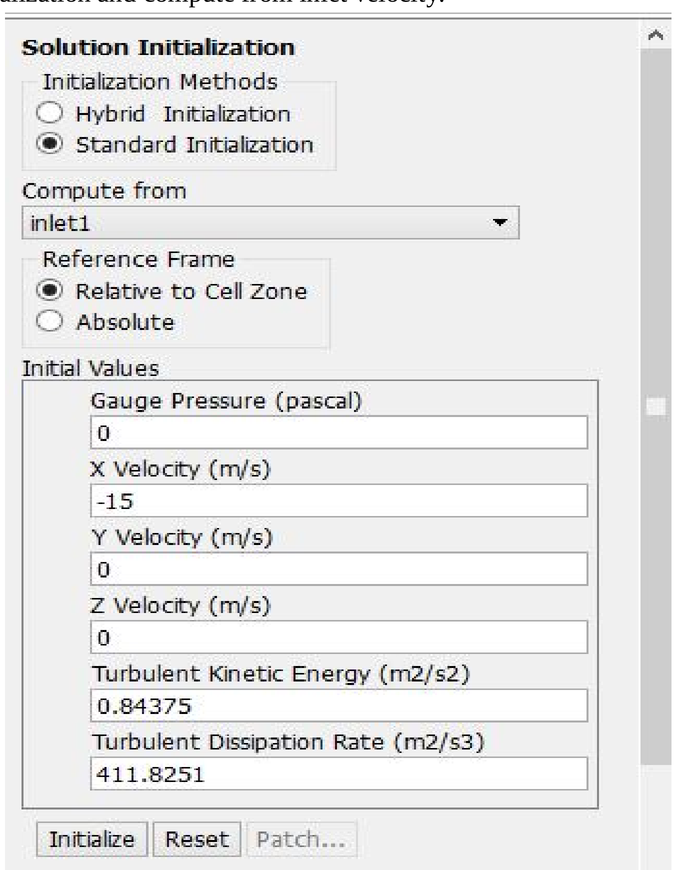

Fig 6 Initialization Conditions

RUN> Check case>close Time step size(s) =1; Number of time steps =50; Max.Iterations = 555/ time step = 20 > calculate.

D. Residual Graphs

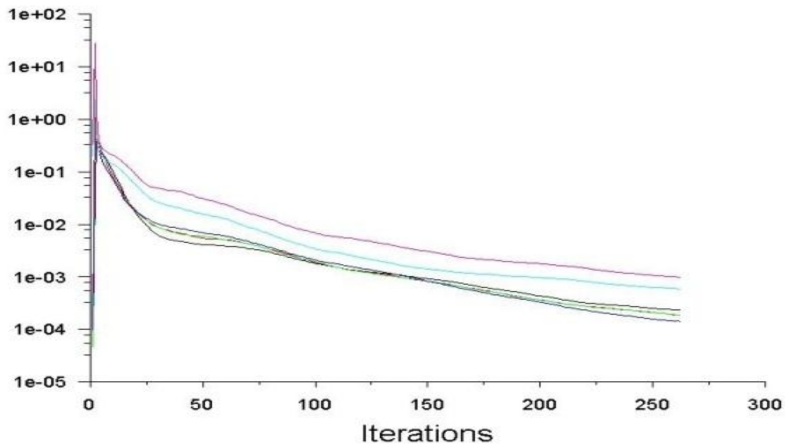

Fig 7 Single inlet cyclone residual graph

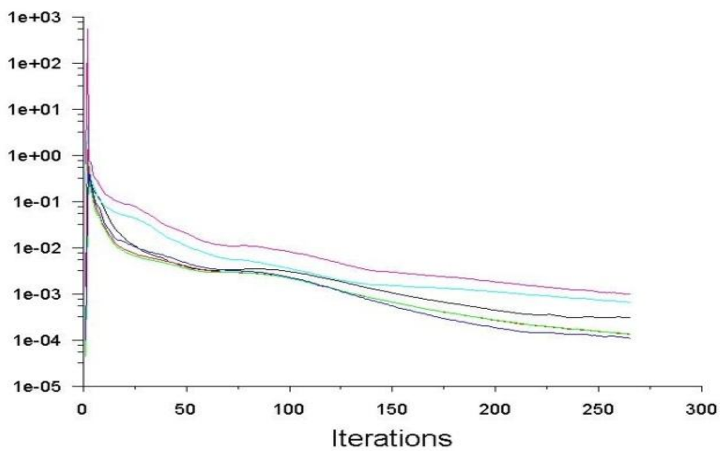

Fig 8 Symmetrical inlet cyclone residual graph

IV. RESULTS AND DISCUSSIONS

A. Pressure Contours

Pressure contours are obtained from Ansys fluent, it observing that, that non-Dimensionalized static pressures are in the range of -22.98 Pa to 248 Pa respectively for single inlet cyclone. The static pressure is increasing from the centre to the wall of cyclone but it is decreasing at the bottom of cyclone.

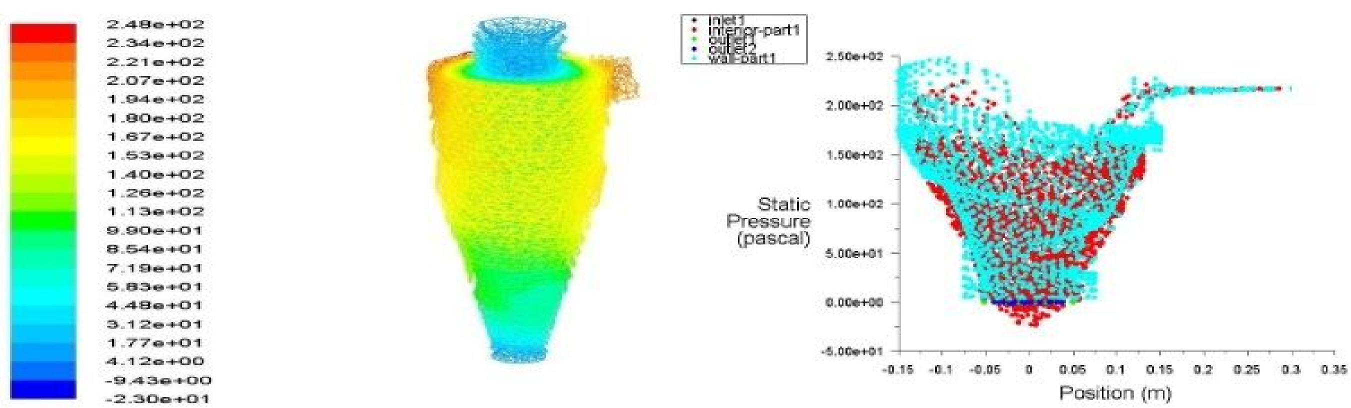

Fig 9 Pressure contour of Single inlet cyclone

For symmetrical inlet cyclone separator non-Dimensionalized static pressures are in the range of -133 Pa to 567Pa respectively. The static pressure is increasing from the centre to the wall of cyclone. The static pressure is uniform throughout the cyclone as compared to the single inlet cyclone.

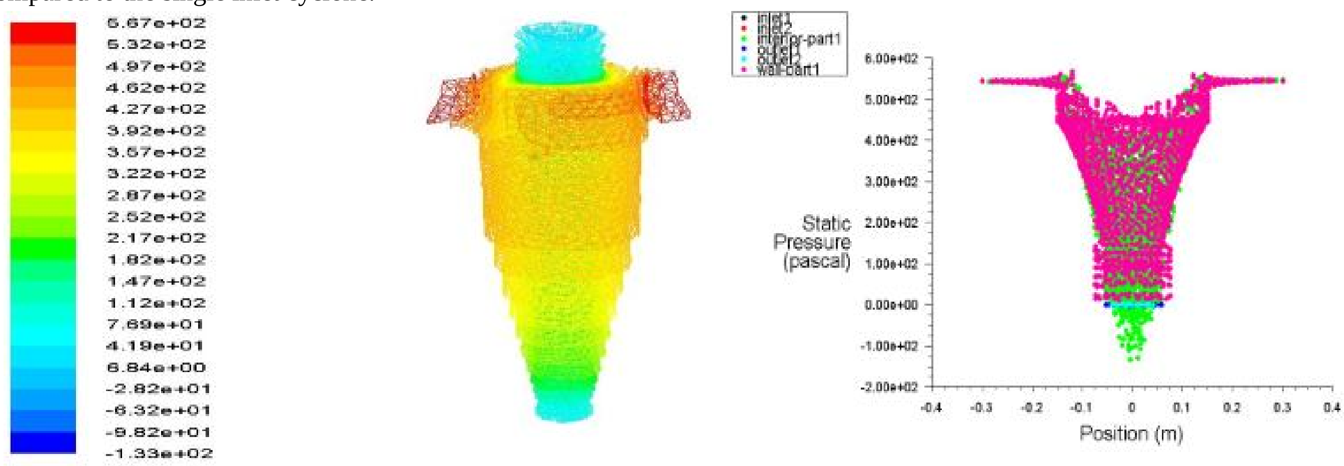

Fig 10 Pressure contour of Symmetrical inlet cyclon

A. *Velocity Contours*

Table 3 Velocity magnitudes for both cyclone models

	Velocity magnitude (m/s)		Tangential velocity (m/s)	
	Min	Max	Min	Max
Single inlet cyclone	0.071	19.61	-2.156	18.83
Symmetrical inlet cyclone	0.3086	24.00	-1.2926	23.88

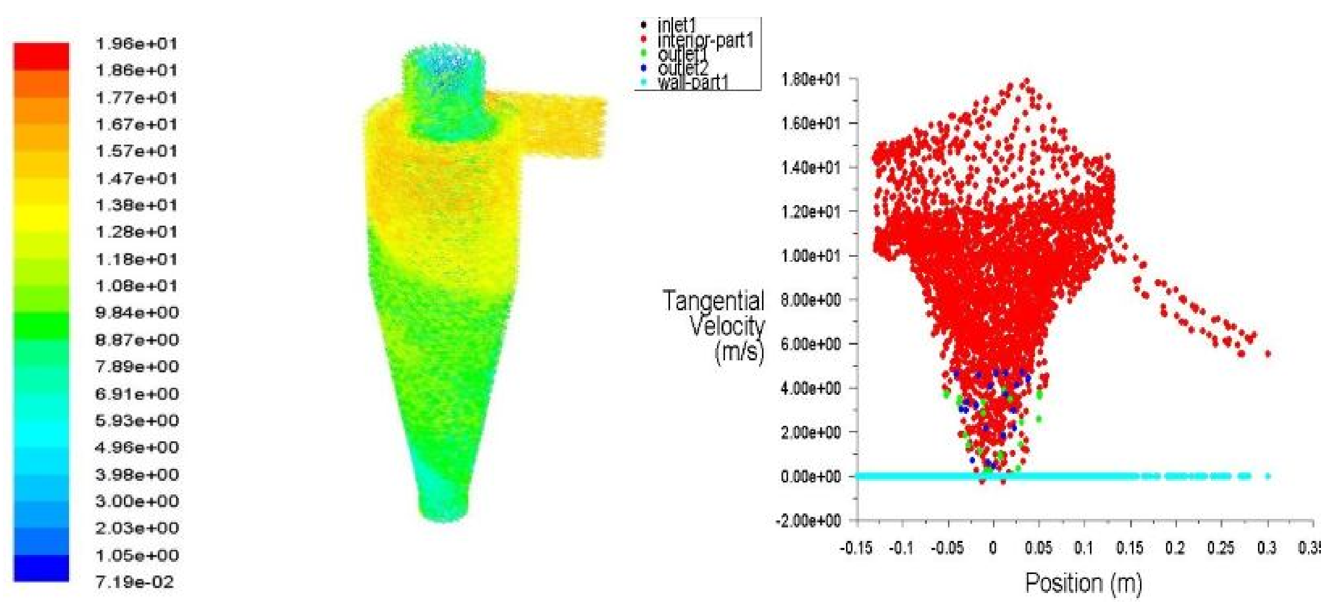

Fig 11 Tangential velocity contours for single inlet cyclone

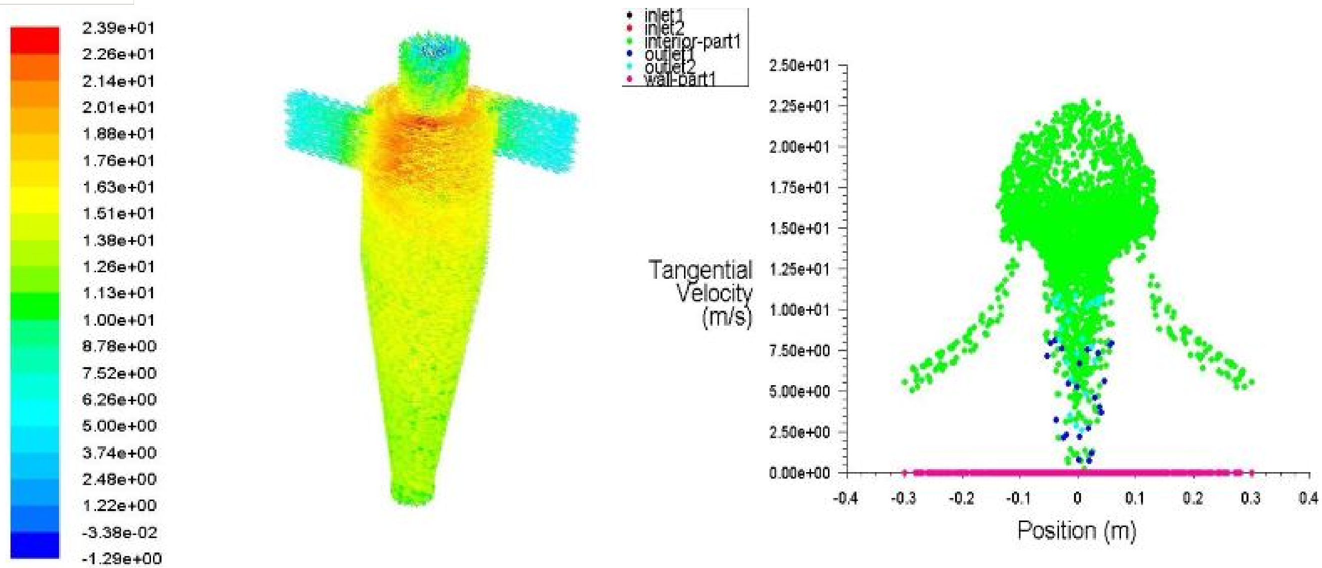

Fig 12 Tangential velocity contours for symmetrical inlet cyclone

As we can see from the data that velocity magnitudes are increased in case symmetrical inlet cyclone separator as compared to the single inlet. In case of single inlet cyclone velocity is decreasing from top to bottom but in case of symmetrical inlet cyclone velocity is uniform throughout the cyclone.

V. CONCLUSION

The CFD analysis conducted for both the cyclone models under the same conditions of pressure, velocity and material properties. The results showed that pressure and tangential velocity distribution in case of symmetrical inlet is uniform throughout the cyclone as compared to the single inlet cyclone. The tangential velocity which has to be increase in order to increase the cyclone efficiency. And as we can see from the results tangential velocity for single inlet is 18m/s and for symmetrical inlet is 23m/s. Thus the objective of the paper is achieved.

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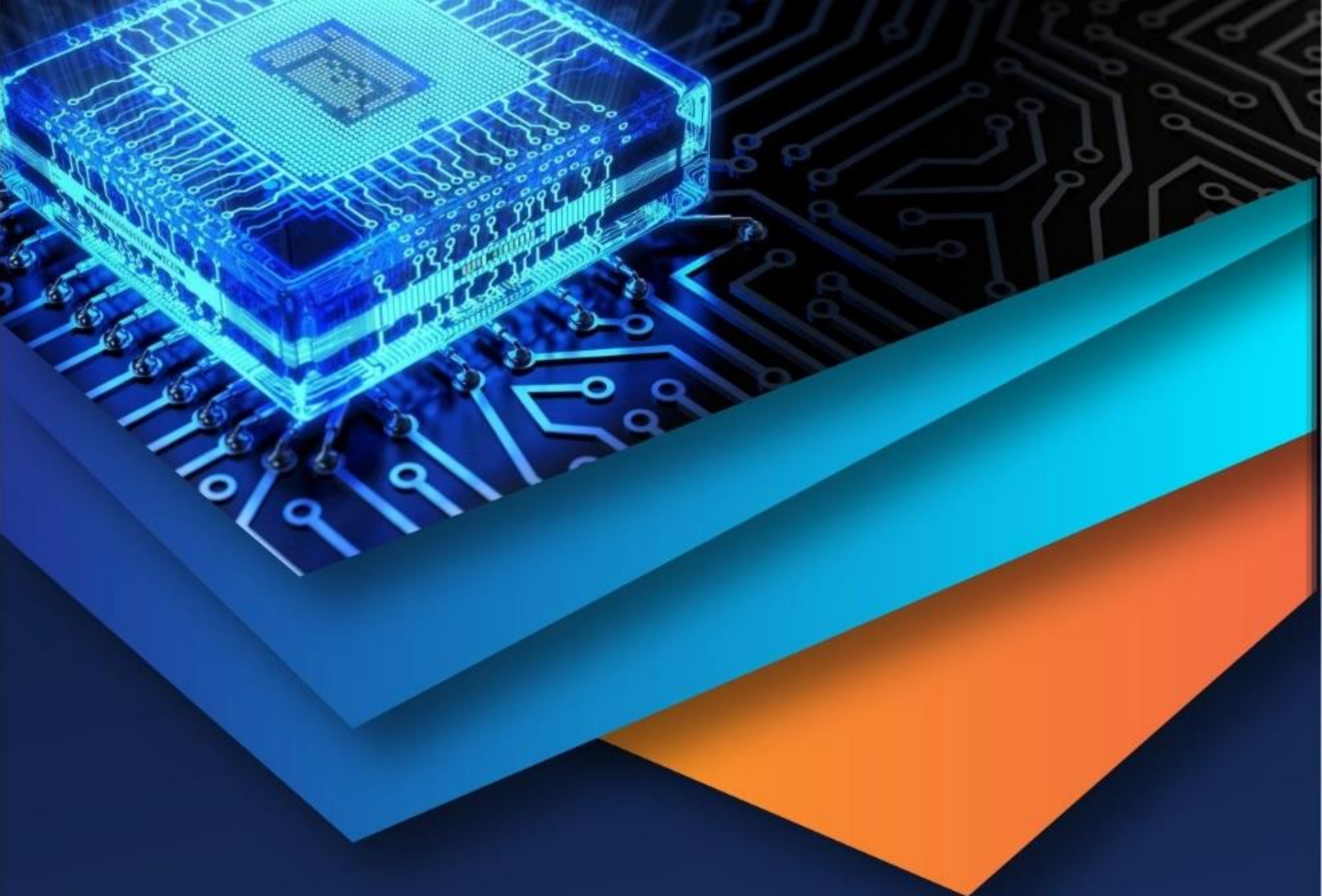

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