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Effect of Geometric Configuration on Performance of Uniflow Cyclone

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Abstract:- Reverse flow cyclones find wide applications in many industries however, they require a high expenditure of energy and large pressure drops, which can be better overcome by uniflow cyclones**.** A laboratory unit of Uniflow Cyclone has been developed with 45 mm inlet diameter. The performance parameters pressure drop and total efficiency were studied for the effect of geometric configuration. The present study includes the effect of 4 different geometric parameters on performance of uniflow cyclone. The geometric variation of test cyclones includes the Inlet velocity, Vane angles, Outlet to inlet diameter ratio and Separation lengths. The overall experimental results yield and investigated the optimal conditions for uniflow cyclone performance is 45^0 vane angle, 0.5 outlet to inlet diameter ratio, 3D separation length and 9-10 m/s inlet velocity. The experimental pressure drop values are validated with the model equations available in literature and well matched for Ramachandran model.

Keywords:- Inlet Velocity, Vane angle, Do/D Ratio, Separation length, Pressure drop, Total Efficiency

I. INTRODUCTION

Cyclone separators have been widely used for separating air borne particles from gases in a variety of engineering applications like in mineral processing, chemical engineering, petroleum refining, food processing, pulp and paper making, environmental cleaning, and so on.

A cyclone is relatively simple to fabricate and it requires low maintenance and low operation cost. Various kinds of cyclones are in use depending on specific requirements. Reverse flow cyclones have wide applications in industries as dust collector and for gas solid heat transfer. The main drawback of these devices is the large pressure drops associated with them and require a high expenditure of energy. Variants of the standard cyclone that partially address this problem have been developed as well. Uniflow cyclone, developed at the University of Western Ontario and studied in detail by Sumner et al. [1], Vaughan et al.[2] and Gauthier et al. [3], is an example of such a modification in the original cyclone design that, by restricting flow reversal, the pressure is reduced. The study in dust collection performance stationary guide vane swirl separator and the blade geometry, front and back cones, separation distances and slit gaps was discussed by LAC Klujszo et al.[7]. The theoretical and experimental study of an axial flow cyclone for fine particle removal in vacuum conditions of cyclone was designed and tested by Chuen-Jinn Tsai et al.[8]. Another model of uniflow cyclone and axial flow cyclone models were studied by Akiyama T et al.[9] and Frans T M et al[10]. The basic principle of uniflow cyclone is that the centrifugal energy is imparted to particles by guided vanes installed at the entrance of the cyclone. The vortex finder is kept concentric to the cyclone. The dust particles are collected from the annulus and dust free air leaves from the central core. The flow of uniflow cyclone did not reversed anywhere in cyclone.

The present study includes the effect of different vane angles, outlet to inlet diameters ratio, separation lengths and inlet velocities on uniflow cyclone performance. These different parameters of inlet velocities, Outlet to inlet diameter ratio, separation length and vane angles are obtained by adjusting the control valve connected in suction line, varying vortex tube diameter, adjusting the position of vortex tube and fabricated with different swirl generators. A small laboratory unit of uniflow cyclone has been developed, and conducted different experiments with different operational conditions to be tested the uniflow cyclone.

II. MODELS FOR COMPARISION

The following equations available in literature are used for the calculation of pressure drop. According to Ramachandran et al [4] given an equation to calculate pressure drop and tangential velocity by assuming no radial component of velocity.

$$V_\theta = 2\pi R_c \frac{V_i}{P} \qquad \text{-------- (2.1)}$$

$$\Delta P = \frac{\rho V_i^2}{2}\left[\left(\frac{V_{avg}}{V_i}\right)^2\left(1+\frac{L_{hel}}{D_h}\right)f - 1\right] \qquad \text{-------- (2.2)}$$

Aswini-Malotra et al [5] developed and derived a equation to find the pressure drop for uniflow cyclone based on the pressure drop equation of reverse flow cyclone which is given below.

$$\Delta P = \frac{v_i^2 . \rho_g}{2g\rho_P}\Delta \mathrm{H} \qquad \text{--------- (2.3)}$$

Where

$$\Delta \mathrm{H} = 1 + 2\phi^2\left[2\frac{D}{D_v} - 1\right] + 2\left[\frac{D^2}{D_v^2}\right] \qquad \text{--------- (2.4)}$$

$$\phi = \frac{\sqrt{\frac{D_v}{2D} + 2Y}}{Y} - \frac{\sqrt{\frac{D_v}{2D}}}{Y}, Y = \frac{2A_s}{A_i} \qquad \text{--------- (2.5)}$$

III. EXPERIMENTAL SETUP AND OPERATING PROCEDURE

A laboratory unit of uniflow cyclone has been developed and conducted different experiments with different operational conditions. The uniflow cyclone shown in Figure.1. fabricated with acrylic pipes with dimension 45mm inlet diameter, 22.5mm of outlet diameter and a separation length of 135mm (3D). The vanes are made with Aluminium sheets of 4no. with dimensions 45 mm length, 17.5mm width and 0.5mm thickness were fixed with sticky paste in grooves containing a 10mm diameter cylindrical rod. The vane is fixed at one end of the cyclone and the other end is connected to a vacuum pump with PVC pipes. A control valve is placed in between them to adjust air flow rate.

The uniflow cyclone is tested with different vane angles, inlet velocities, Outlet to Inlet diameters ratio, separation lengths. Digital pressure drop meter is fitted across the cyclone to measure pressure drop. Inlet velocity is measured with an anemometer at the entrance of cyclone. Known amount of cement particles (< 100μm size) is weighed and introduced with air at the entrance of the cyclone with a screw feeder. The particles dispersed in to cyclone with the compressed air. Particles are swirl inside due to the vanes and acquired a centrifugal force then the particles hits the wall and separated from air. These particles are collected at the bunker through annulus space and the clean air exits from the vortex tube. The collected sample is weighed to measure the collection efficiency of sample.

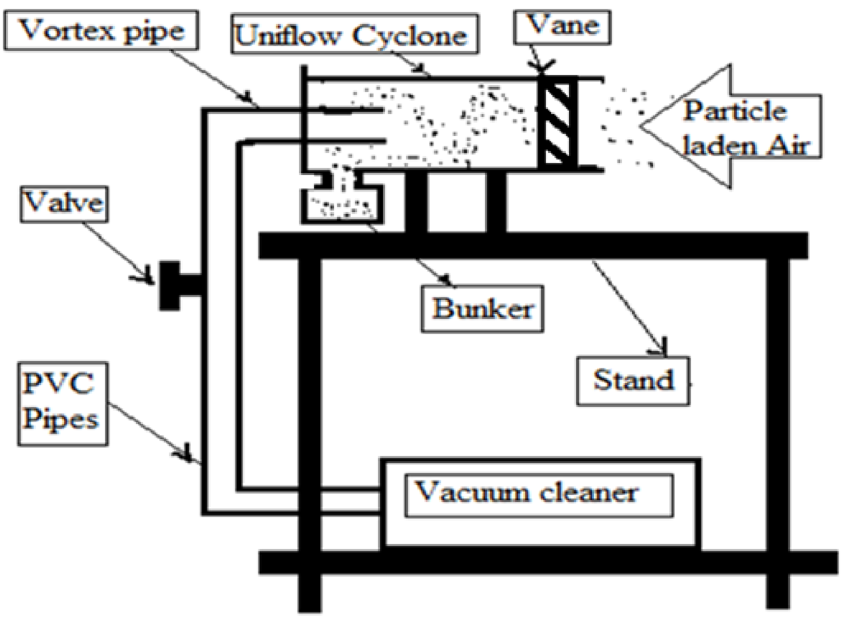

Fig.1: Experimental setup

IV. RESULTS AND DISCUSSION

The experiments are conducted under different operational conditions to test the uniflow cyclone. The geometric variations of different parameters are Air Inlet velocities (4 to 14 m/s), Vane Angles (30^0,45^0, 60^0), Outlet to inlet diameter ratios (0.27, 0.5, 0.61) and Separation Length (1D to 4D). The effects of these parameters on total efficiencies and pressure drop have been studied and the results are summarised in Figures 2 to 8. The overall results yield the optimum conditions for the best performance of uniflow cyclone is Vane Angle - 45^0, Outlet to Inlet diameter ratio – 0.5, Separation Length – 3D and an Inlet velocity 9-10 m/s.

A. *Effect of Inlet Velocity and Vane Angle:*

Figure.2 shows the variation of pressure drop with inlet velocity for different vane angles in uniflow cyclone for a fixed D_o/D -0.5 and separation length – 3D. The pressure drop increases with increase in inlet velocity and also increases with vane angle. This is because the increase of inlet velocity and vane angle causes an increase in swirl flow, this induces a centrifugal force, which in turn increases the pressure drop.

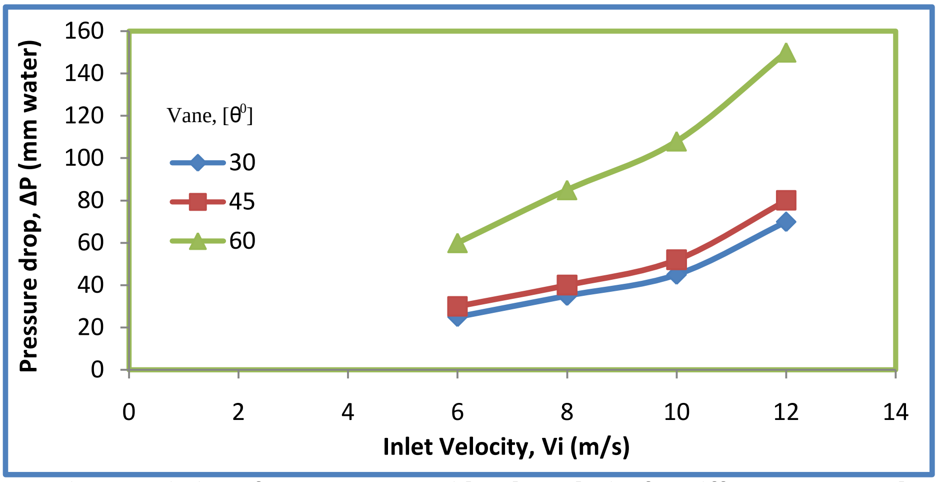

Fig.2: ***Variation of Pressure Drop with Inlet Velocity for Different Vane Angles***

Figure.3 shows the comparison of experimental pressure drop with model equations available in literature for 45^0 vane angle at different inlet velocities. The experimental data has been compared with Ramachandran [4] and Aswini et al [5]. It is observed that the results are followes the same trend as model equations and well matched with Ramachandran model [4].

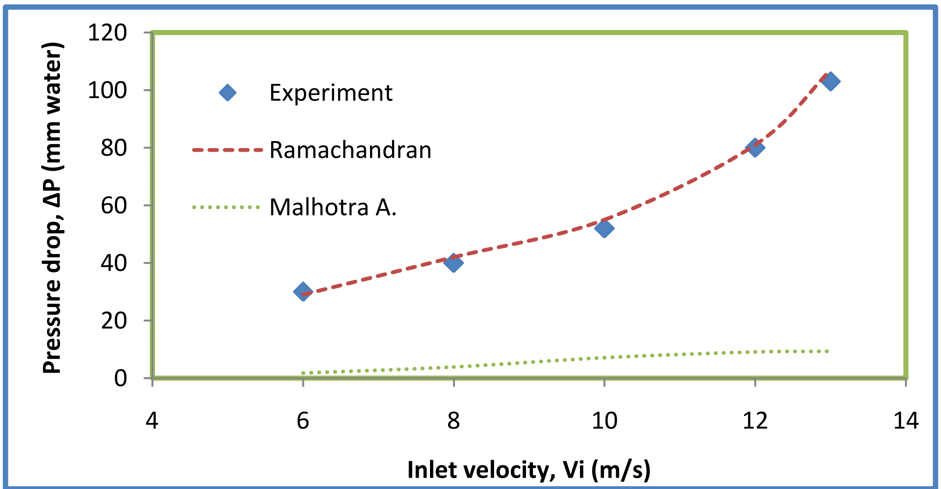

Fig.3: ***Comparison of Experimental Pressure Drop with Model Equation for 45^0 Vane Angle***

Figure.4 shows the variation of total efficiency with inlet velocity, for different vane angles in uniflow cyclone whose D_o/D - 0.5 and separation length – 3D are fixed. The total efficiency is low at 30^0 because of low centrifugal force caused from low swirling of particle laden air inside cyclone. The efficiency is high at 45^0 and 60^0 due to high centrifugal force caused from increased swirling motion of fluid but the pressure drop also high at 60^0 than 45^0.

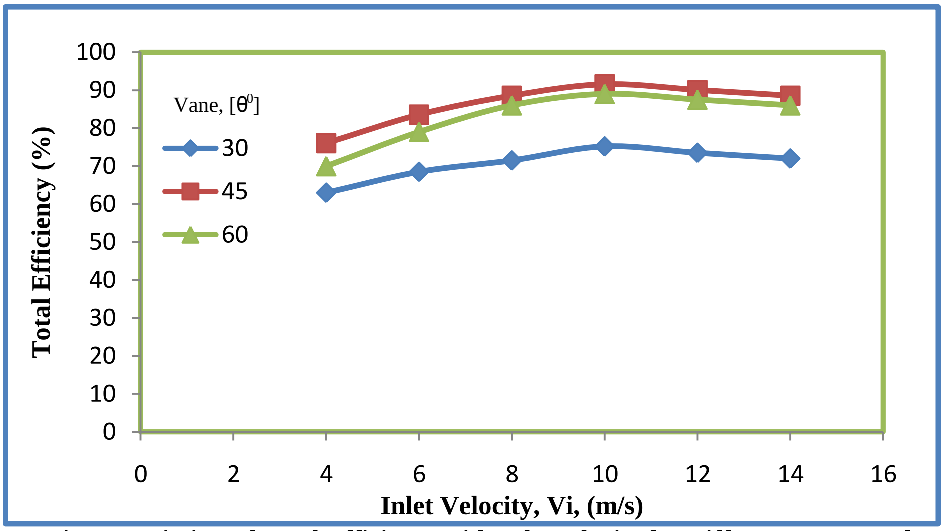

Fig.4: ***Variation of Total Efficiency with Inlet velocity for Different Vane Angles***

The total efficiencies are increases with inlet velocity from 4 to 10 m/s then decreases from 10 to 14 m/s, this is because increased turbulence by the increase of inlet velocity. Some of fine particles are carried away along with air due to turbulence, hence efficiency decreases.

The cyclone performance greatly depends on pressure drop and efficiency, which requires low pressure drop and high efficiency. From these observations we concluded that the optimum conditions for the performance of uniflow cyclone is 45^0 vane angle and an inlet velocity of 9-10 m/s, which gives reasonably low pressure drop and high efficiency.

B. Effect of Inlet velocity and Do/D Ratio:

Figure.5 shows the variation of pressure drop with inlet velocity for different outlet to inlet diameter ratios of uniflow cyclone for a fixed vane angle - 45^0 and separation length 3D. It has been observed that pressure drop across uniflow cyclone increases with increase in inlet velocity and decreases with increase in Do/D ratio. The pressure drop that occurs in cyclone is due to velocity head, frictional losses and sudden contraction losses. As Do/Di ratio decreases sudden contraction losses increase. Therefore pressure drop across cyclone also increases.

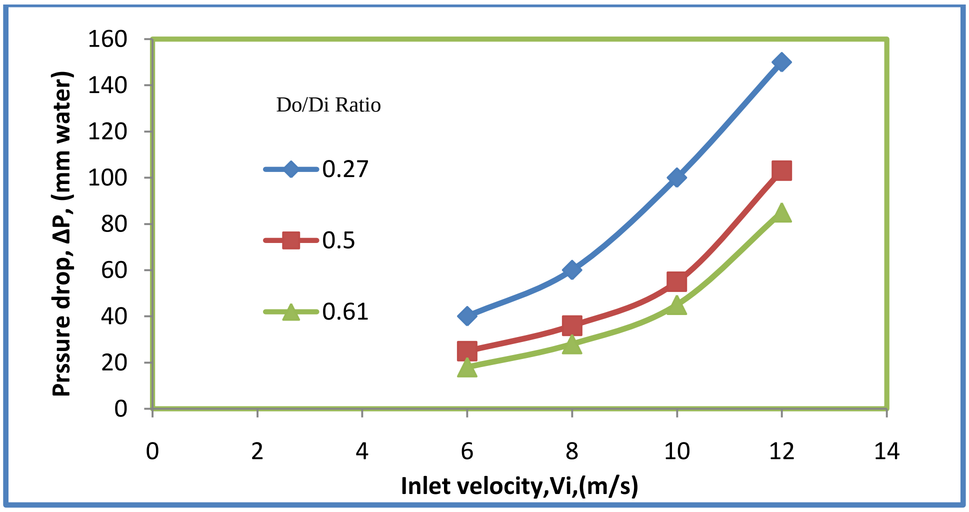

Fig.5: ***Variation of Pressure Drop with Inlet Velocity for Different Do/Di***

Figure.6 shows the variation of total efficiency with inlet velocity for different outlet to inlet diameter ratios of uniflow cyclone for a fixed vane angle - 45^0 and separation length 3D. It has observed that the efficiency across uniflow cyclone increases with increase in inlet velocity and decreases with increase in Do/Di ratio. The collection efficiency is low for Do/Di is 0.61, it is due to increased vortex tube diameter some of the particles are carried away along with exit stream without being separated. The efficiencies are high at 0.27 and

0.5but at the same time pressure drops are also high and which are not suitable for cyclone performance. From these observations we concluded that the optimum Do/Di ratio for uniflow cyclone is 0.5 which gives reasonable low pressure drop and high total efficiency.

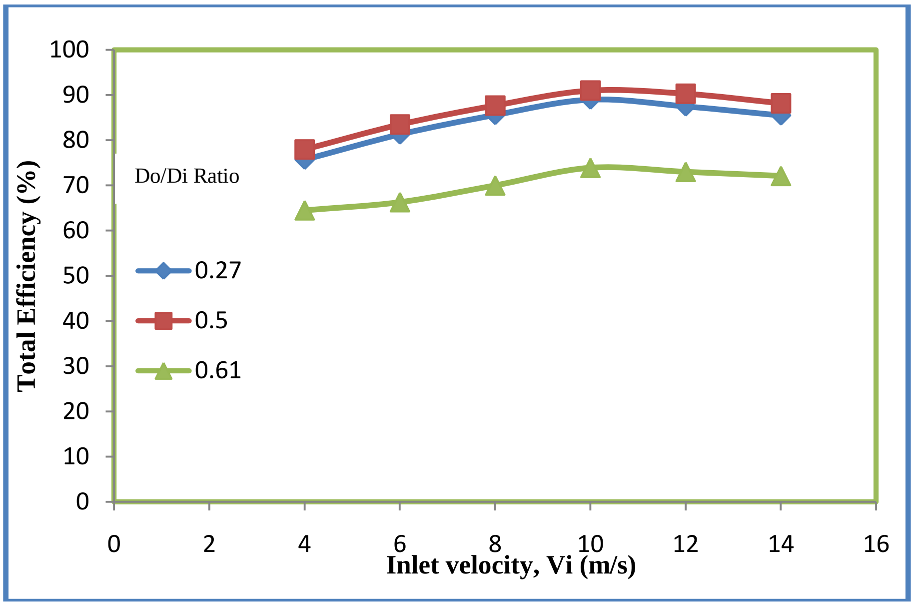

Fig.6: ***Variation of Total Efficiency with Inlet Velocity for Different Do/Di Ratio***

C. Effect of Inlet Velocity and Separation Length:

Figure.7 shows the variation of pressure drop with inlet velocity for different separation lengths of uniflow cyclone for a fixed D_o/Di ratio - 0.5 and vane angle – 45^0. The pressure drop increases with inlet velocity and shows almost same results for all separation lengths. The result shows that there is a negligible variation in cyclone pressure drops for different separation lengths. Therefore separation length of uniflow cyclone has insignificant effect on the pressure drop in uniflow cyclone.

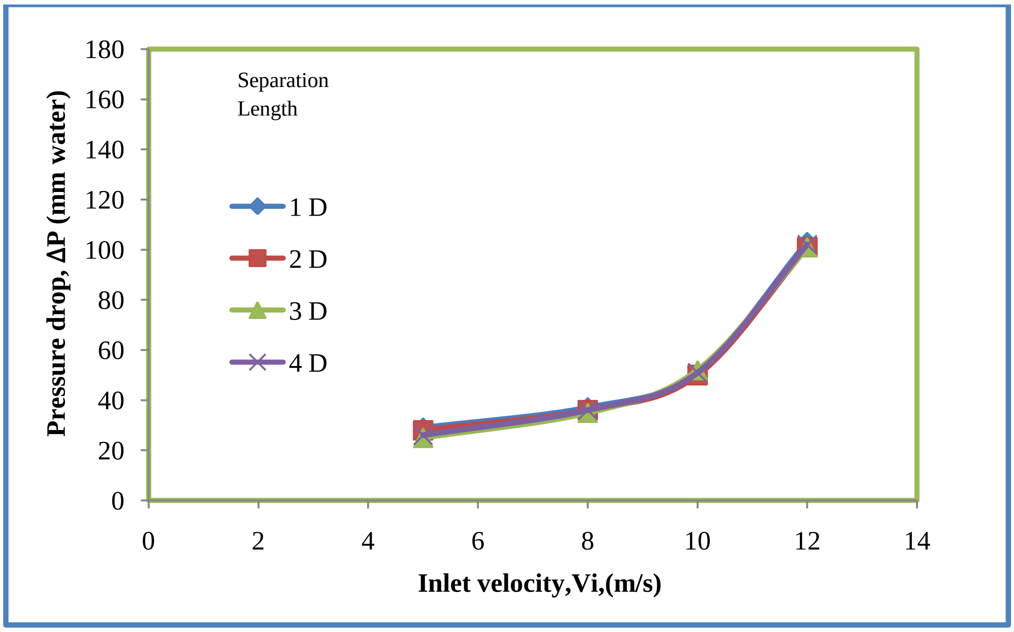

Fig.7: ***Variation of Pressure Drop with Inlet Velocity for Different Separation Lengths***

Figure.8 shows the variation of total efficiency with inlet velocity for different separation lengths of uniflow cyclone for a fixed D_o/Di ratio - 0.5 and vane angle – 45^0. The total efficiency increases with the increase in inlet velocity from 4 to 10 m/s then decreases. This is because as the inlet velocity increases swirling and turbulence increases inside. The total efficiency increases with increase in separation length from 1D to 3D, then decreases. As the length increases the intensity of swirling motion of fluid decreases, therefore after 3D of separation length the intensity of swirling starts to decrease, hence efficiency also decreases. From these observations it is concluded that the optimum conditions of uniflow cyclone is 3D separation length and an Inlet velocity of 10 m/s, which gives reasonably low pressure drop and high efficiency.

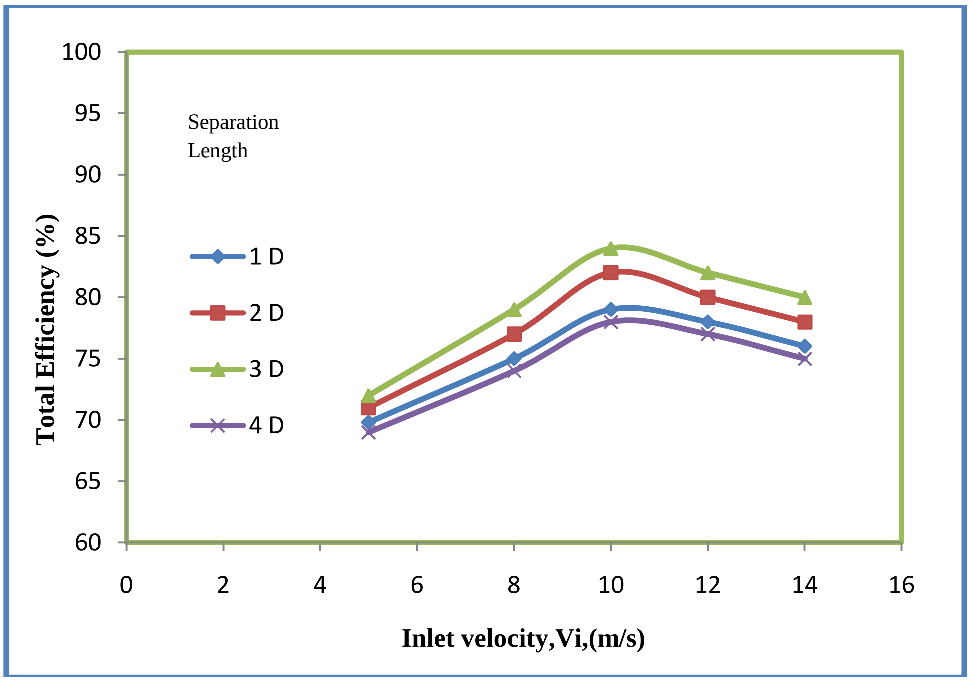

Fig.8: ***Variation of Total Efficiency with Inlet Velocity for Different Separation Lengths***

V. CONCLUSIONS

The uniflow cyclone has been evaluated experimentally for different geometric configurations to investigate the effects of Inlet Velocity, Vane Angle, Outlet to Inlet diameter Ratio and Separation Length on pressure drop and total efficiency.

The overall experimental results yield and investigated the optimal conditions for low pressure drop and high total efficiency - Vane Angle - 45^0, Outlet to Inlet diameter Ratio – 0.5, Separation Length – 3D and an Inlet Velocity 9-10 m/s.

The pressure drop values are validated with the model equations available and the experimental values are well matched with Ramachandran [4] model.

NOMENCLATURE

V_i	Inlet axial velocity	[m/s]
V_{avg}	Average velocity of the gas in the helix	[m/s]
V	Average Velocity	[m/s]
V_θ	Tangential velocity	[m/s]
D_h	Hydraulic diameter of the cyclone	[m]
f	Friction factor,	[-]
L_{hel}	Average length of path of gas in the helix	[m]
ρ_g	Density of gas	[Kg/m^3]
ρ_P	Density of particle	[Kg/m^3]
P	Pitch	[m]
Rc	Cyclone Radius	[m]
A_s	Cross section area of vane core	[m^2]
A_i	Cross section area of cyclone body	[m^2]
D	Diameter of cyclone	[m]
D_v	Diameter of vane core	[m]

REFERENCES

[1]. Sumner, R.J., Briens, C.L., Bergougnou, M.A., (1987), *Study of a novel Uniflow cyclone design for the ultra-rapid fluidized pyrolysis reactor*, Can. J. Chem. Eng., 65, 470-475.

[2]. N.P. Vaughan, (1988), *Construction and testing of an axial flow cyclone pre separator, Journal of Aerosol Science*, 19, 295–305.

[3]. T.A. Gauthier, C.L. Briens, M.A. Bergougnou, P. Galtier, (1990), *Uniflow cyclone efficiency study*, Powder Technology, 62, 217-225.

[4]. G. Ramachandran, P.C. Raynor, D. Leith, (1994), *Collection efficiency and pressure drop for a rotary flow cyclone*, Filtration and Separation, 631-636.

[5]. Ashwani. Malhotra, (1995) "*Studies in Fine Particle Collection in Uniflow Cyclone*", Ph.D Dissertation, Dept. of Chemical Engineering, Indian Institute of Technology, Delhi.

[6]. A.D. Maynard, (2000), *A simple model of axial flow cyclone performance under laminar flow*, Journal of Aerosol Science, 31, 151–167.

[7]. LAC Klujszo et.al. (1999), 'Dust *collection performance of swirl air cleaner*' Powder Technology, 103, 130-138.

[8]. Chuen Jinn Tsai et al. (2004) '*Theoritical and Experimental study of an axial flow cyclone for fine particle removal in vacuum conditions*' Aerosol Science, 35, 1105-1118.

[9]. Akiyama, T. and et al "*Dust Collection Efficiency of a Straight Through Cyclone Effects of Duct Length, Guide Vanes and Nozzle Angle For Secondary Rotational Air Flow* ", Powder Technology, 58,181-185,1989.

[10]. Frans, T. M. and et al., "*A Fluid Mechanics Model For an Axial Cyclone Separator* ", Ind. Eng. Chem. Res., Vol. 34, No. 10, 3399-3404, 1995.