Studies on Design of Cyclone Separator with Tri Chambered Filter Unit for Dust Removal in Rice Mills

T.K.Chandrashekar[1], R.Harish Kumar, T.B.Prasad[2] and C.R.Rajshekhar[1]

***Abstract*-**Cyclone separators are normally used for dust collection in rice mills from long time. However their dust collection efficiency is lower and is influenced by factors like geometry, exit pipe dimensions and length, humidity, temperature at dust generation place. The design of cyclone has been slightly altered, and the new design has proven to be successful in collecting the dust particles of size up to 10 microns, the major modification was to change the height of exit pipe of the cyclone chamber to have optimum dust collection. The cyclone is coupled with a tri chambered filter unit with three geo text materials filters of different mesh size to capture the dust less than 10 micron.

***Keywords*-**Cyclone,Rice Mill,Geo Text Materials.

I. Introduction

CYCLONES are devices used for removing particulates from air, gas without using filters by vortex rotation and gravity principle used. High speed rotating floe is established with in the cyclone, as the flow follows helical path with wider cross section at the top and conical cross section at bottom, larger particles due to higher inertia follow the outside path strike with outer wall and falls to the bottom. As the flow moves toward the narrow end rotational radius is reduced removing smaller and smaller particles. The cyclone geometry, together with flow rate defines the cut point of the cyclone. This is the size of particle that will be removed from the stream with 50% efficiency. Particle larger than the cut point will be removed with a greater efficiency and smaller particles with a lower efficiency [1, 2]

The cyclone dimensions are always observed for efficient cyclone performance and are generally related to cyclone diameter. The selection and operation of cyclones can be described by the relationship between the pressure drop and the flow rate. The Euler number is a pressure loss factor easily defined as the limit on the maximum characteristic velocity [3,4].

$$E_u = \frac{2\Delta P}{\rho g v^2}$$

The use of cut size to define the efficiency of cyclones plays an important aspect as the particle size is a determining factor for performance. The cut size implies the size of the particles removed.

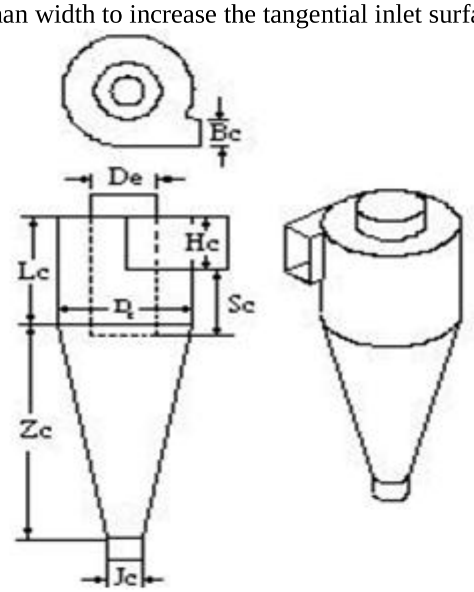
[1]Professor, MITE, Mangalore, Karnataka, India

[2]Professor, SSIT, Tumkur,Karnataka, India

This shows that the particles are influenced by forces exercised on them while they are in suspension. The cyclone inside diameter D_c is one important parameter which has relation to all other geometrical parameters. The cyclone body velocity v is the characteristic velocity given in a simplest equation as under [5].

$$v = \frac{4Q}{\pi D_c^2}$$

Pressure drop and collection efficiency are the two major criteria used to evaluate cyclone performance. Both properties are functions of cyclone dimensions: inlet height, inlet width, gas outlet diameter, outlet duct length, cylinder height and cyclone height. In a cyclone the air and dust enters the top cylindrical section of the cyclone through a tangential opening which is rectangle usually and height of inlet duct should be greater than width to increase the tangential inlet surface.



1D3D: $B_c=D_c/4, J_c= D_c/4, S_c= D_c/8, L_c= D_c, Z_c=3D_c, D_e= D_c/2, H_c= D_c/2$

2D2D: $B_c=D_c/4, J_c= D_c/4, S_c= D_c/8, L_c= 2D_c, Z_c=2D_c, D_e= D_c/2, H_c= D_c/2$

1D2D: $B_c=D_c/4, J_c= D_c/2, S_c= 5D_c/8, L_c= D_c, Z_c=2D_c, D_e= D_c/1.6, H_c= D_c/2$

$\mathbf{L_c - S_c}$=Sliding length of exit pipe into cyclone chamber (can be varied)

Fig. 1 Cyclone Designs With Empirical Design Proportions.

The design of cyclones follow the popular designs like 1D-2D, 2D-2D and 1D-3D, where D represents the cyclone diameter. The first part represents the straight barrel portion length and the later part representing the length of tapered portion of the cyclone. Previous research shows that 1D-2D, 2D-2D are more efficient.For best efficiency the outlet duct should be 1 to 1.2 times the height of the inlet duct to prevent the inlet particles from going out, as the gas spins through the number of revolution N_e in the outer vortex, which is expressed as

$$N_e = \left(\frac{1}{H}\right)((L_b + L_c)/2)$$

The particle terminal velocity is a function of particle size and is given by

$$V_t = W/\Delta t$$

$$V_t = \frac{(\rho_p - \rho_g)D_p^2 V_i^2}{9\mu D}$$

The diameter of the particle collected is given by

$$d_{pc} = \left[\frac{9\mu W}{(\rho_p - \rho_g)2\pi N_e V_i}\right]^{0.5}$$

A survey about the pollution caused by rice mills in and around Tumkur was taken up as a pilot study, and it was observed that dust emitted at various points inside rice mills are approximated as under,

TABLE I
.QUANTITY OF DUST EMITTED AT DIFFERENT LOCATIONS IN RICE MILLS.

Sl No	Location	Amount of dust, mg/m^3
1	Paddy pouring station	18
2	Paddy shifting/sieve station	9.8
3	Swaying/conveyers	8.5
4	Polishing station	8.5
5	Bran filling station	7.68
6	Rice sack station	6.6
Total average dust		9.8

II. EXPERIMENTATION

In the present work a 2D-2D design has been adopted with a assumed discharge of 1500 m^3/hr and a velocity at inlet as 10 m/s having matched with 5 HP blower that was used in the experimentation. The exit pipe of the cyclone is designed to slide inside the cyclone barrel so as to optimise the dust collection, during sliding cyclone chamber is provided with flange and screw arrangement with rubber packing to ensure that there is no loss of air pressure and leakage. The outlet of the exit pipe is clamped to a square cross section filter unit. This filter unit has three chambers separated from each other by filter plates that could slide through guide ways provided. The filter plates are made with sieves of geo-tex material having different porosity. The first plate can trap particulate of 100µm (sieve size 90 µm), second plate can trap 20-60 µm particulates (sieve size 20 µm),and third plate 8 to 20 µm (sieve size 8 µm).Behind each filter plate there is a tray for collection of dust.

The unit (both cyclone and filter unit) was mounted near the paddy pouring station of Manjunatha Rice mill located in Tumkur. One of dust emitting point near the conveyer belt is selected and suction pipe from that point is connected to cyclone inlet through the blower. The exit pipe of the cyclone is now connected to the filter unit by flexible rubber tubing and care is exercised to make the unit air tight. Two water U-tube manometers are connected, one connected at cyclone inlet and outlet to measure the pressure drop of cyclone and another connected at filter inlet and outlet to measure the pressure drop of filter unit. Trails were conducted for interval duration of one hour. After each trail dust collected from each section were carefully collected in plastic covers and weighed in digital balance. The trails were repeated and results were checked for repeatability. Further it was also ensured that the paddy that was processed during the trails were from the same source.


Fig. 2 Dust suction point and blower


Fig. 3 Cyclone, Filter unit and Manometers

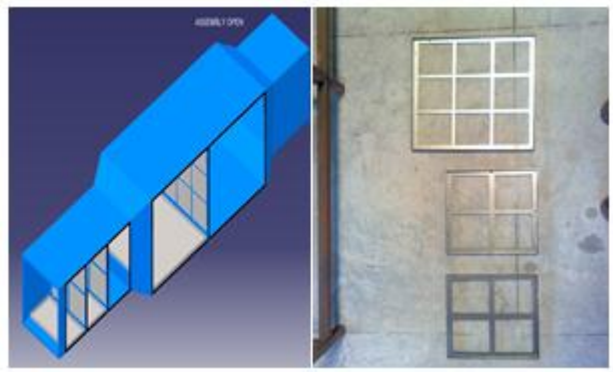


Fig. 4 Filter unit and Filters

III. RESULTS AND DISCUSSION

TABLE II.
DETAILS OF DUST COLLECTED AND MANOMETER READINGS.

SL NO	Cyclone Pr drop mm of water	Filter Pr drop mm of water	Cyclone Dus gms	Filter1 Dust gms	Filter2 Dust gms	Filter3 Dust gms
1	9	11	6.06	2.31	1.51	3.23
2	6	13	9.27	1.8	1.1	2.84
3	5	14	5.93	1.21	0.79	2.02
4	4	15	5.37	1.73	1.5	2.39
5	2	17	3.62	1.83	1.95	2.07

Fig. 5 Dust collected from Trail 1

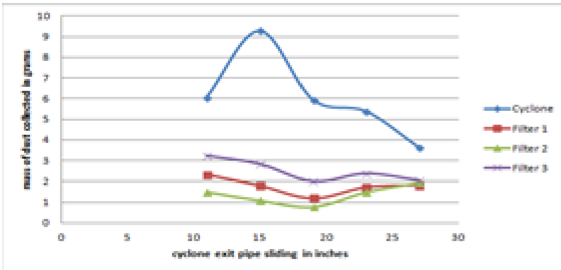


Fig. 6 Variation of Cyclone, Filter dust with exit pipe insertion into cyclone

Fig 6 shows the variation of exit pipe sliding distance with amount of dust collected. The amount of dust collected is maximum at a pipe insert distance of 15 inches in case of cyclone, where as in filter unit there is not much variations in the dust collection for various length of pipe insertion, therefore the 15 inch inserting the exit pipe inside the cyclone seems to be best operating condition.

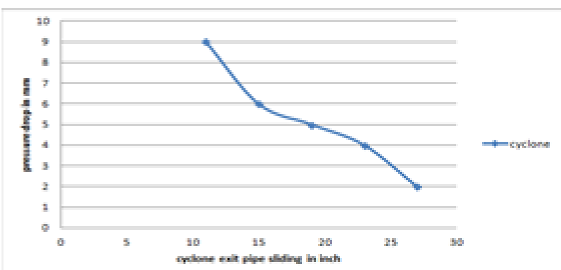


Fig. 7 Variation of Cyclone Pressure Drop In Mm Of Water With Exit Pipe Insertion Into Cyclone

Fig 7 shows variation of pressure drop in mm of water column with exit pipe sliding distance into cyclone, here we see as the pipe is lowered the pressure drop decreases.

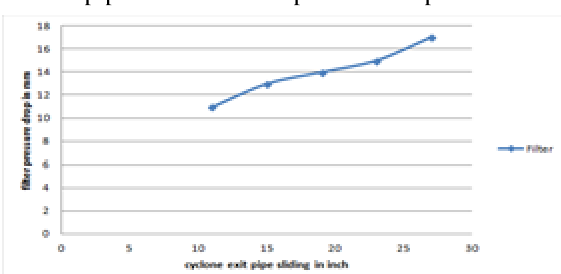


Fig. 8 Variation Of Filter Pressure Drop In Mm Of Water With Exit Pipe Insertion Into Cyclone

Fig 8 shows variation of pressure drop in mm of water column with exit pipe sliding distance into cyclone for filter unit, here we see as the pipe is lowered the pressure drop increases. It would be obvious to have a moderate pressure drop that is at inserting distance of 15 inch from the top of cyclone

IV. Conclusion

- The present work has thrown some light on the best position of exit pipe length protruding inside the cyclone chamber (15 inches) for the 2D2D cyclone to collect more amount of dust.
- The work also describes that the tri chambered filter unit used in combination with cyclone collects the dust particulates ranging from 5 µm to 50 µm.
- Cyclone efficiency can be improved with the use of tri chambered filter unit with a nominal additional pressure drop.

V. Acknolwdgement

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VI. References

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Nomenclature; SI units

D_p = diameter of particulate
D_{pc} = diameter of particle collected
D=diameter of cyclone
ρ_p =density of the particulate matter
μ =viscosity of the fluid
ρ_g =density of the fluid
V_t = tangential velocity of dust laden air
V_i = inlet velocity of dust laden air
N_e= Number of effective turns
W= angular velocity