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Application of Cyclone Separator for Effective Dust Removal in Paddy Pouring Station

Chethan K M
Department of Mechanical Engineering, P. A. College of Engineering (Affiliated to Visvesvaraya Technological University, Belagavi), Mangaluru, India
chethan_mech@pace.edu.in

K Fazlur Rehman
Department of Mechanical Engineering, Anjuman Institute of Technology and Management, Bhatkal, India
kfazlur@rediffmail.com

Avinash
Department of Mechanical Engineering, P. A. College of Engineering (Affiliated to Visvesvaraya Technological University, Belagavi), Mangaluru, India
superavinashtunnel@gmail.com

Navaneeth I.M
Department of Mechanical Engineering, P. A. College of Engineering (Affiliated to Visvesvaraya Technological University, Belagavi), Mangaluru, Indian
navaneeth_mech@pace.edu.in

Maruthi Prashanth B.H
Department of Mechanical Engineering, P. A. College of Engineering (Affiliated to Visvesvaraya Technological University, Belagavi), Mangaluru, India
maruthi_mech@pace.edu.in

Abstract – The main objective of this paper is to report the use of cyclone separator for collecting the dust particles. Dust particles in rice mills are found to be up to a maximum of 70% in paddy pouring station. Paddy dust particles can cause extreme respiratory problems like asthma. Staff in rice mills can often suffer from its quite gradual influence over long periods of time. Younger people appear to be comparatively more susceptible owing to their poor immune mechanisms. With this motivation, in this article use of cyclone separator combined with filter unit to collect dust particles is analyzed. Cyclone separator with different number of turns and several heights of gas outlet tube is analyzed to obtain maximum dust particle collection. The filter unit is employed in order to absorb fine dust particles left out from cyclone separator. From the newly conceptualized application of cyclone separator and filter unit, it is found that the dust particle removal in paddy pouring is very effective. Further, there exists an optimal height of gas outlet tube at which the dust particle removal is highest.

Index Terms – Dust Particles, Paddy Pouring Station, Cyclone Separator, Filter Unit, Pressure Drop.

1. INTRODUCTION

Over 155 million hectare of rice is grown in 114 counties across the globe. 75% of rice is produced from around 55% of rice cultivation area which is irrigated. About an average of 43 million hectares of rice is solely produced in India. And, rice is the chief foodstuff for most of the residents in India. This is the largest source of calories in foodstuffs consumed. Henceforth, due to abundant availability of rice, the largest agro processing industry is rice milling in India [1]. The technologies used for processing milling are mostly indigenous and conventional in nature. Whole paddy grown in the farmland is transported to the processing mills and industrial units to make desired final products. Prior to industrialization, these raw rains used to be conventionally processed at rice mill, mostly located in rural areas near farmlands. Each rice mill has six distinct areas for paddy field calculation. Pouring station, seven-sifting station, polishing whitening station, seven-swing, bran and rice bag station. The paddy pouring platform is the location from the measured data where the biggest number of dust particles (< 10 μm) are reported that contribute to 70 percent of total dust.

Hence it is of prime importance to properly remove and collect these dust particles, especially in paddy pouring station where maximum dust exists. If effective removal of dust particles is not developed, it leads to health deterioration of humans involved in loading/unloading of paddy at the pouring station [2–5].

Izadifar and Mowla [6] developed an analytical method to study the dehydrating of wet paddy in a cross-flow nonstop fluidized bed dryer. By applying the partial different equations to paddy properties and elements of dryer they developed a code to understand the variation in paddy moist condition. Their research model was developed and the experimental findings were well-suited. The distribution on lead (Pb) concentration in the system of paddy rice soil and the human health challenges related to it were investigated by Yang et al. [7]. Complete diethylenetetraminepentaacetic acid (DTPA) - extractable bacteria have been found respectively on the scale of 1502 and 286 µg/g in soils. The concentration of lead in paddy rice-soil of China was found to be above safety and tolerable limits. 2.6 mg of lead was consumed by adults and 1.2mg by children's in the local area where investigation was carried out. Yang et al. [7] concluded that this intolerable level of lead could cause potential health risks to residents. In a superheated fluidized bed dryer the characteristic features of rice were investigated using experimental microscopic analysis by Taechapairoj et al. [8]. We also indicated that the moisture content has decreased linearly from 40.68 to 24.98 percent with an increase in drying time and then fell exponentially. Wittayakun et al. [9] used rice husk silica for the synthesis of zeolite Y in sodium form (NaY) effectively. When the crystallization duration was more than 24 hours NaY converted slowly into zeolite NaP. Sharma et al. [10] studied the role of rice husk ash and preheated rice husk in removal of methylene blue from waste water. Several system variables were adopted for sting many batches of experiments. It was proved that Freundlich adsorption model fits perfectly with the experimental data. The adsorption heat and entropy in methylene blue adsorption on preheated rice husk and rice husk ash were found to be positive. Batsungneon and Kulworawanichpo [5] studied the configuration of rice mills that leads to dust elements. The iron type or wooden type rice mills cause's effect on amount and size of dust particles. This study concluded that the workers in oady pouring station had restrictive lung breathing problem due to milling process every day. Majhi et al. [11] used rice husk as a filler material to manufacture lighter composites and studied the tribological properties. It was found that the unmodified rice husk composite was inferior to modified rice husk composite.

Pareja et al. [12] reported the happening and spreading of remains of pesticides during processing/cropping of rice. Two insecticides, nine pesticides and four herbicides were used to apply to a rice crop plant having controlled conditions. It was found that the distribution of pesticides is different for several matrices. Eight pesticides were set up in rice bran, ten in paddy rice, and seven in brown rice. Koide et al. [13] fabricated a one stage, electrostatic precipitator (ESP) of laboratory-scale and analyzed their microbial and physical usefulness. Rice husk obtained from ground was selected as representative model containing microorganisms. At an applied voltage of -5.95kV the best assemblage efficiencies were obtained with no yeasts and molds being detected through ESP. Payman et al. [14] studied the rice grain milling characteristics effected by paddy mixture ratio and moisture content. 8%, 10%, 12%, and 14% of moisture contents and considered five different ratios of paddy mixture. Whiteness index, whiteness percentage, Head Rice Yield, and fissured kernels were the features measured for milling characteristics study. From the study it was inferred that if rice grains reached with higher paddy mixture ratio for whitening process head rice yield obtained would be better. Korotkova et al. [15] estimated the composition of granulometric in the rice dust generated while processing of rice powder in Southern Rice Company which is more prone to allergen. Group cyclone and bag filter located for dust collection at the rice company were selected for experimentation. Battery cyclone efficiently removes dust particles ranging between 1 to 10mm. the bag filter significantly removes particles from dust having less than 0.5mm of size.

From the above detailed literature review of works on paddy dust collection and intensity of its effect on human health is very clear. Lot of scientific studies are focused on proper dust removal. And many works have been reported on effect of paddy dust particles and its importance in removing the particles effectively to avoid the human health issues. The use of cyclone separator along with a filter is none reported in literature. With this motivation, this work reports the effective removal of dust particles from paddy in the paddy pouring station. Cyclone separator is with different turns was applied to check the abstraction of dust particles during the paddy pouring. A filter unit is also used additionally to capture fine dust particles. Optimization is also reported for different heights of the cyclone separator

2. EFFECT OF DUST PARTICLES IN PADDY POURING STATION ON HUMAN HEALTH

The rice processing and milling technologies are indigenous and traditional in nature and are not geared towards reducing emissions by implementing control measures in plant pollution prevention. Apart from long fiber-shaped dust particles, the raw material obtained by the rice mills usually contains much fine dust. Due to wind or rain activity in the field, fine dust may include the actual soil in which the grain was produced. The environmental implications of rice mills are air pollution, these units generate significant amounts of pollution, especially air pollution as a result of fugitive emissions from different operations [16–22].

Sometimes, over the normal acceptance stage, the volume of pollution is surpassed. This is extremely dangerous to humans and animals in the region and impacts the respiratory system of people directly. The human lung can carry particles of dust smaller than 10 µm or so called breathing dust, and the industries of the healthy workers can be gravely damaged [22–27]. The survey on rice mills shows that the workers are facing dust particle problems that will be generated during the rice production process. The method is performed at six rice mill locations as shown in Figure 1. The problem identified on the basis of analysis is Paddy pouring station where the highest value of the overall dust is measured. The rice satchel location is the lowest place the entire particles of dust are weighed. The paddy bucketing station is the locality where the cumulative particle of dust reaches the standard level among all measured locations. The dust protection solution should be identified at these stations to enforce the awareness of respirable location of workers.

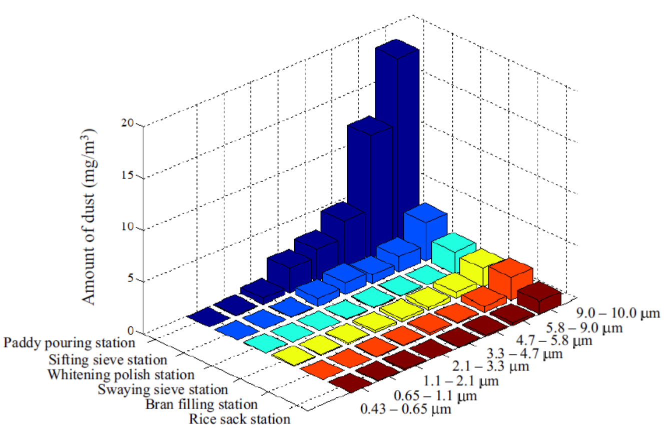


Figure 1 Different sized dust particles identified in rice mills [5]

2.1 Effect on Human Beings

Serious respiratory problems such as asthma can result from dust. Rice mill employees can also suffer from their subtler effects for longer periods. As a result of their immune systems, juveniles appear to be more vulnerable. The clinical and hematological tests indicate that both non-specific and allergic irritations may have adverse consequences. The rice husk (Figure 2) is shown as small needles, as if hair is thrown as sharp, elongated spines, below the electron microscope. The observed spikes are approximately 205-310µ in measurement and nearby 32-41µ in thickness at the base, narrowing to sharp ends as shown in Figure 3 [28–34].

Such spikes' structures indicate that the symptoms of rice husk polish contact, that is to say irritating to the cough, or keratoconjunctival, and pruritus, with or without flegm are irritating. Chronic conjunctival and pterygium growth in the corneal lesions shown in Figure 4 & 5, the final consequences of such non-particular discomfort can be reported.

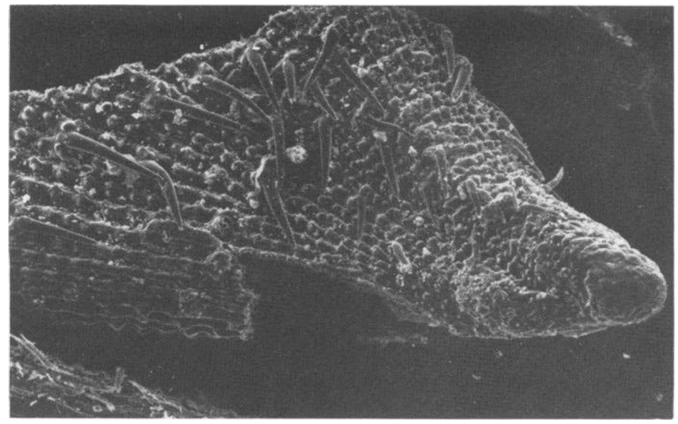


Figure 2 Micrograph of electron having a fragmented rice husk piece. Note long spikes protruding from the surface of the husk.

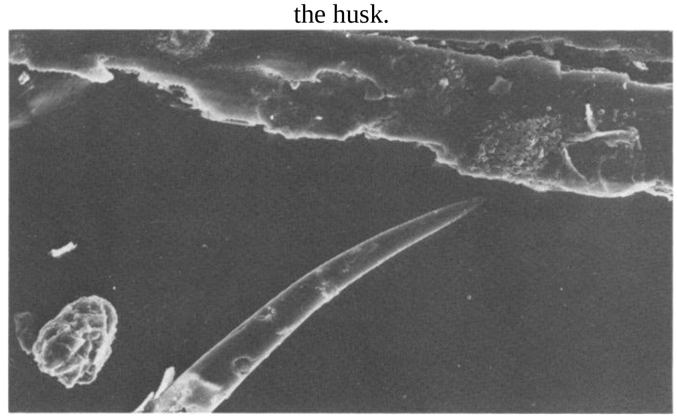


Figure 3 Microgram for the electron with one of the spikes removed from the surface of the rice husk

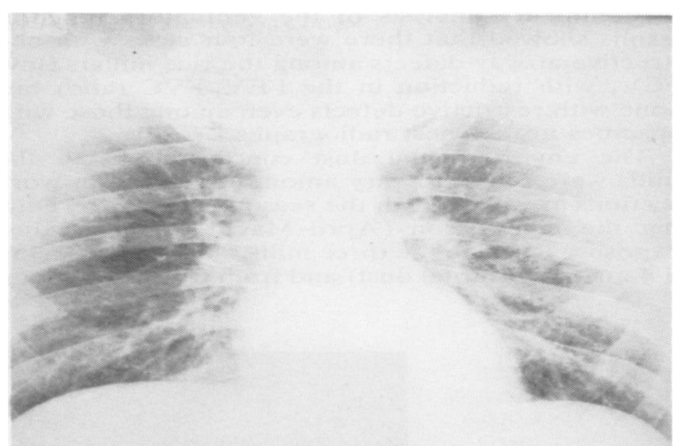


Figure 4 Radiographic chest of a rice miller showing reticular changes in the lower and mid zones of the lungs and fine nodulation. In the right mid-section, there is also a bulla.

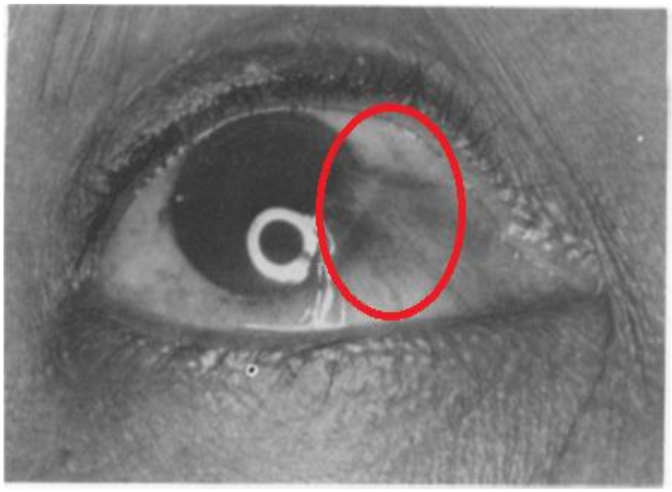


Figure 5 Workers in a rice mill with a pterygia that extends from the medial angle of the eye into the cornea in the red circle with conjunctival injecting. (A reflection of camera lens is the Bright Ring in the middle).

3. CYCLONIC SEPARATION AND FILTER UNIT

The action of centrifugal and gravitational force removes the suspended elements from the air flow in the cyclone separator. The waste particle dust-laden air is tangentially added into the chamber of separation, creating a vortex flow. As a result, the isolation of tiny suspended particles is accomplished in the small diameter cyclone separator and thus a high degree of separation is achieved.

For the effective operation of cyclone dust collection systems. Centrifugal collectors use cyclonic motion to separate dust particles from the gas stream. In a normal cyclone, the dust gas flow enters at an angle and spins rapidly. The centrifugal force produced by the circular flow throws the dust particles into the wall of the cyclone. After the wall has been hit, these particles fall into a hopper below [35–39].

The solution identified to select the suitable blower for design and fabricate a Cyclone Separator to collect and filter the dust particles of different size using filter unit produced in the rice mills. The blower collect the dust air and send to the cyclone separator where the heavy dust particles are settled at the bottom of cyclone separator and remaining dust particles are send to filter unit through the out let of cyclone separator, the sieves of different size and porous material to separate the particulate matter such as air and dust of the same before letting out to the atmosphere to create an eco-friendly atmosphere in the rice mills [22–27]. The isometric view of cyclone separator is shown in Figure 6 for demonstration.

Due to following advantages of cyclone separator, they are engaged to gather the filth elements in paddy pouring station.

- The Blower absorbs dust air from rice mill atmosphere and sends to the inlet of cyclone separator
- The cyclone separator separates the dust particles i.e. heavy dust particles are settled at the bottom of cyclone separator, medium and other small size particles are sent to filter unit through the outlet of the cyclone separator
- The user can easily maintain the cyclone separator while cleaning.
- Disassembling/ reassembling of parts can be done easily

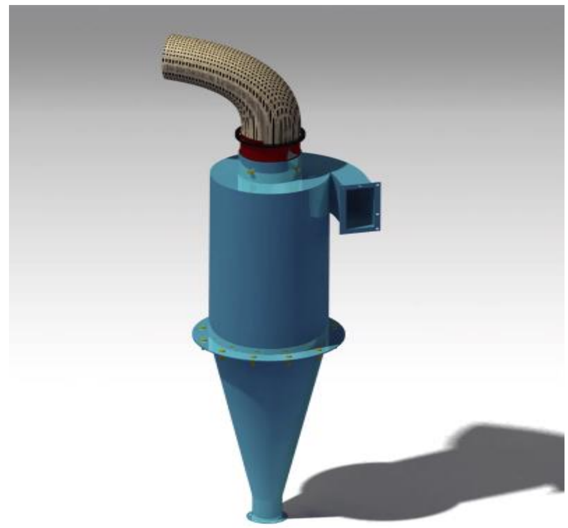


Figure 6. Isometric view of assembly of cyclone separator with flexible tube

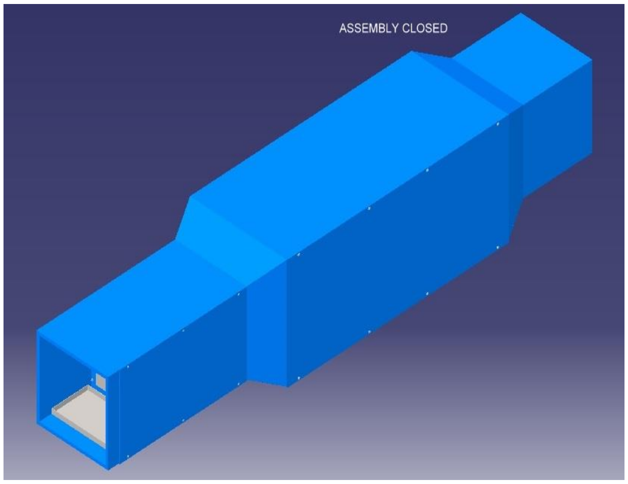
3.1. Filter unit

The filters are able to create sufficient dirt cake to prove any desired filtration level as long as no air is needed. The aim is to follow standards of engineering and say what airflow is supplied with every filtration stage. The filter unit involves 3 different sized meshed filters as shown in Figure 6. The first and second filters used to collect the normal sized dust particles and third filter used to collect the minute particles, which can be achieved through porous material. The closed and open view of filter unit is shown in Figure 7.

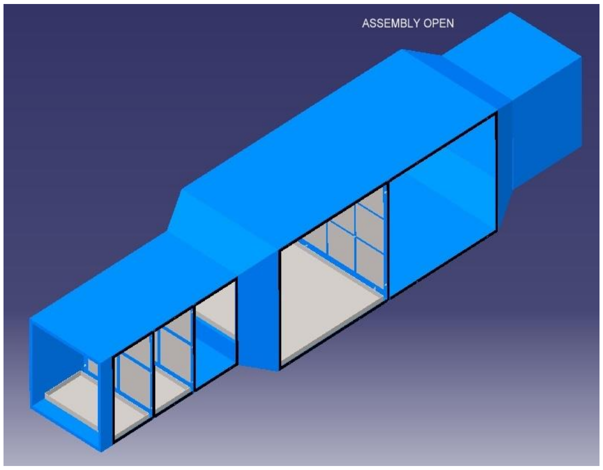
3.2. Wire mesh

Wire mesh is used to collect the dust particles of different size. This is made by using wire mesh of carbon steel material. The wire mesh is available for different dimensions and based on the dust particles size the mesh can be selected. Wire mesh of two different size has been used in first two stages of filter unit to collect or filter the dust from air.

Figure 6 New generation filter unit



(a)



(b)

Figure 7 (a) Isometric view of assembly of closed filter unit (b) Isometric view of assembly of opened filter unit

3.3. Porous material

The porous material is used for collection / filtration of minute particles that failed to control by meshes. This will help to release the pure air through outlet of the filter Unit. This is supported by wire mesh while doing operation.

3.4. Geo- text filter material

Geo-text filter material for very small particles is our product line. The use of micro fibers significantly increases the needle's surface but remains the same in weight. Geo-text filter content with very low emission values and a long period of use. This is used in the final stage of the filter unit.

4. CONCEPT DEVELOPMENT

Concept creation is a process driven by a set of consumer expectations and product specifications that are translated into a set of concept and possible technical solutions. These solutions describe the form, working principles and product features approximately. Models of industrial design and conceptual designs also follow these principles in making final selections.

4.1. Conceptual design sketches: Concept A

2D2D and 1D3D cyclones are the most commonly used abatement systems for particulate controlling in the agricultural processing industry. The numbers that precede the D's are the barrel length and the sections. In previous research, the best cyclone collectors for fine dust (particles less than100 µm in diameter) were 1d3d and 2d2D compared to other cyclone designs.1D3D is barrel-like, and its length is three times that of the barrel.

Ba=De/4 Ja=De/4 Da=De/2

Sa=De/8 Ha=De/2 La=1*De Zc=3*Da.

4.2. Concept B

The classification D in 2D2D refers to the cyclone's barrel diameter. A 2D2D cyclone is two times the barrel diameter in length and cone.

Ba=De/4 Ja=De/4 Da=De/2

Sa=De/8 Ha=De/2 La=2*De Zc=2*Da.

4.3. Concept C

Wang et al. [40] addressed the question of a spinning lint, developed a new low-pressure cyclone called the1D2D cyclone. Similar to 1D3D and 2D2D Cyclones, the 1D2D Cyclone is best designed for high-lint waste. The cone length of a cyclone of 1D2D is twice that of a pump.

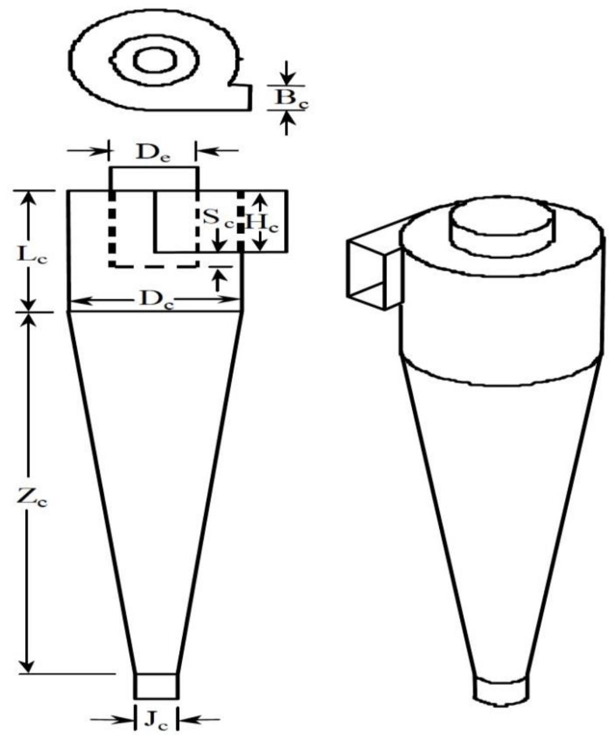


Figure 8 (1D3D) cyclone

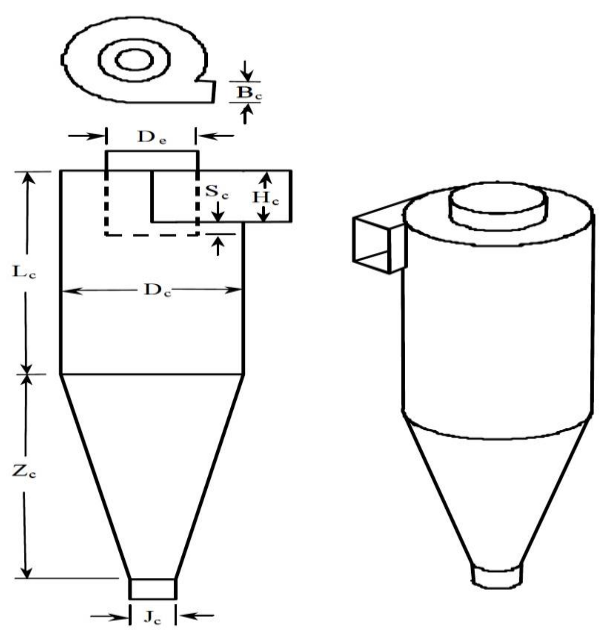


Figure 9 (2D2D) cyclone

Ba=De/4   Ja=De/2 Da=De/1.6

Sa=5*De/8   Ha=De/2 La=1*De Za=2*Da.

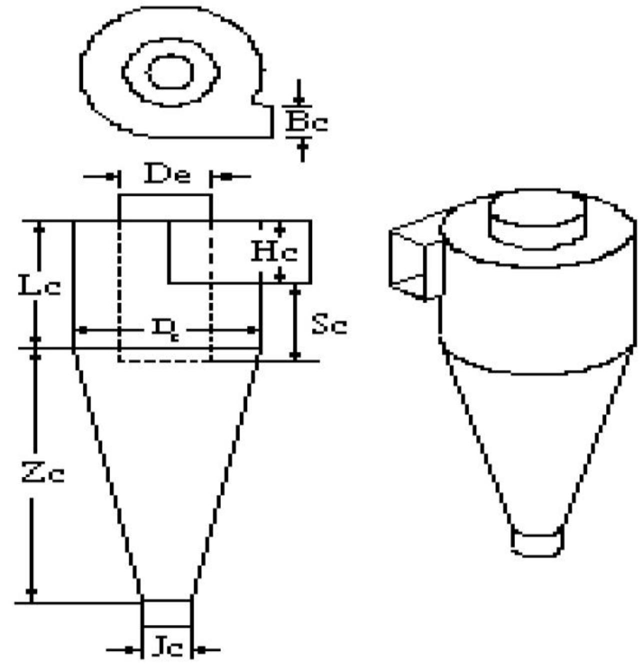


Figure 10 (1D2D) cyclones

4.4. The effective turns (in numbers)

The effective turns in a cyclone are the number of turns of the air stream leading to a higher efficiency in collection. The lapple model Na is computed according to:

Na = 1/He (Le + Ze/2)

Cyclone	Turns (number)
1D3D	4
2D2D	6
1D2D	5

Table 1 The effective turns number (Na) for 2D2D, 1D3D, and 1D2D Cyclone separator

5. RESULTS AND DISCUSSIONS

In Figure 11 the dust particles collected from the cyclone separator with increase in gas outlet tube height is depicted. It can be seen that when the gas outlet tube height is raised from 11 inches to 15 inches the dust collected at the bottom jumps from approx. 7 grams to a maximum of about 10 grams. Further increase in gas outlet tube height leads to decrease in amount of dust collected from the cyclone separator. The fact behind the sudden rise and then drop in dust collection at this particular height is due to creation of suction and pressure drop with increase of height. Their exists an effective height at which the dust collection is maximum, above and below which the duct collection deteriorates. As the height of gas outlet tube reduces, the dust particles get lodged at the opening of turns and hence this collection causes the incoming particles to stick and reduces the effective removal of dust from paddy. Upon further increase in this height, the reduced pressure causes easy flow of particles and hence increased dust collection. At the same time if any further increase in height is made, the gap between the opening and the connection to the filter unit reduces hence blocking the inflow of particles. Now it can be deduced that, for a particular design of cyclone separator, efficient dust removal of particles can be achieved provided that the relative optimum height needs to be determined.

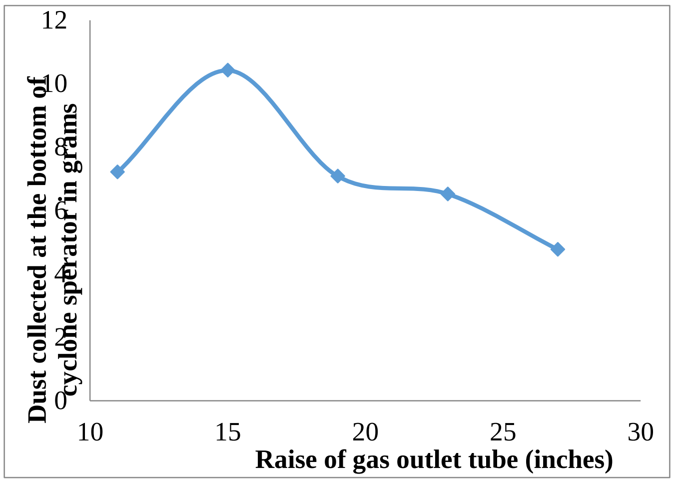


Figure 11. Gas oultlet tube at 15 inches showing maximum collection of dust particles

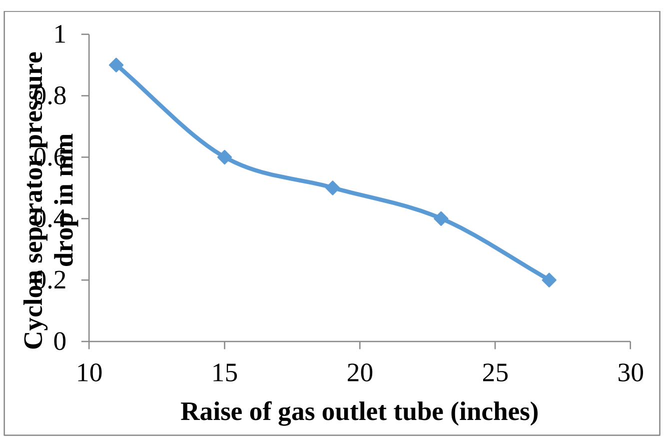


Figure 12. Pressure drop v/s raise of gas outlet tube

Pressure drop is another important parameter in the design of a cyclone system. In estimating the cyclone pressure drop, two steps are involved in the lapple method. The first step is to assess the pressure drop of the number of heads of inlet velocity (Hv). In Figure 12 the drop in pressure for increase in height of gas outlet tube is illustrated. It is quite obvious that inverse relation exists between the opening of the tube and the upper constraint of the filter unit pipe. Obviously, an increase in the tube height the pressure reduces due to increased velocity. But very high velocity and reduced pressure is not suitable for prompt dust removal during the paddy pouring process.

5.1. Comparision of actual value with therotical value

Power Equation (Theoritical) :

$Y = ax^{(bx+cxx)}$ where constants a = 4.275, b = 0.03948, c = -0.001455

X is the actual value of gas out let tube raised by 4 inches from top dead center of cyclone body.

Y is the actual value of dust collected at the bottom of cyclone seperator.

Percentage Error:

It is calculated to know the actual performance of the cyclone seperator and percentage efficiency of the same unit, and time taken for each trail is one hour.

% error = Error / actual value × 100

Error = simulated value – actual value.

Trial No.	**Y Actua**	**X Actua**	**Y(simulated value)** $Y = ax^{(bx+cxx)}$	**% Error**
1	7.21	11	7.94	10.13
2	10.42	15	8.75	15.95
3	7.08	19	8.28	17.07
4	6.52	23	6.59	1.175
5	4.77	27	4.34	8.8

Table 2 Actual Value, theoritical Value and percentage error

6. CONCLUSION

An improvised cyclone separator has been conceptualized for collection and separation of the dust particles before letting out air to the atmosphere. The fabricated cyclone separator has been successfully used with the newly designed filter unit for effective productive control in rice mills. This newly designed cyclone separator can be assembled / disassembled easily for cleaning and it is convenient for handling. The following are the conclusions made by the study on design and fabrication of improvised cyclone separator-outlet section in rice mills.

- It was observed that with increase in height of gas outlet tube the dust particle collection increases initially and then decreases
- Their exits an optimal height at which the dust collection is maximum
- Drop in pressure decreases due to increase in gas outlet tube height

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Authors

Chethan KM assistant professor @ PACE. Very dynamic in administration and event co-ordination. He is involved in several activities to up bring the research domain in the institution. Coordinator of several research related workshops and talks.

K Fazlur Rehman Professor and Head @ AITM. He has evaluated several PhD thesis and also PG thesis. Involved in quality publications.

Avinash assistant professor @ PACE. Very dynamic in administration and event co-ordination. He and Chethan KM hold the same reputation. Coordinator of several research related workshops and talks

Navaneeth I. M assistant professor @ PACE. Very dynamic in NBA activites and event co-ordination.. Coordinator of several research related workshops and talks.

Maruthi Prashanth assistant professor @ PACE. Talented and active reseracher in the field of composite materisl. Published good articles in SCI and scopus indexed articles.