DEVELOPMENT OF A CYCLONE SEPARATING UNIT ATTACHING TO LOCALTHRESHERS FOR CLEAN ENVIRONMENT

EL-TANTAWY, M. M.; Y. Y. RAMADAN;
MERVAT M. ATALLAH and Y.F. SHAROBEEM

Agricultural Engineering Research Institute (AEnRI), ARC, Giza, Egypt

(Manuscript received 28 November 2018)

Abstract

This study aims to obtain a clean environment through agricultural activities by developing and evaluating the performance of a cyclone separating unit attached to threshers. Threshing in traditional method depends on emitting chopped wheat straw (Tibn) off the threshers freely in the air and then collected manually by operators causing air pollution and affecting operators' health. The developed cyclone in this study separates dust from the airstream and simultaneously collect the chopped wheat straw instead of operators. According to the obtained data from theoretical calculations (Table 1), the modifications on 2D2D cyclone. The tested performance parameters of the developed cyclone are: four airstream velocities (ASV) of 2.3, 3.6, 4.7 and 5.5 m/s; cyclone inlet dimensions (CID) of (A) 20x30; (B) 25x35; (C) 35x45 cm for width and height, respectively; vortex finder length (VFL) of 50, 60 and 70 cm; cyclone outlets ratios (COR) chopped wheat straw and airstream outlet diameters of 15, 20, 25 and 20, 25, 30 cm for chopped wheat straw and airstream outlet represents ratios of 0.75, 0.80 and 0.83, respectively. The results were summarized in the following points: Separation and collection efficiency value by developed cyclone was 99.8% at inlet velocity of 4.7m/s, vortex finder length of 50 cm, with inlet dimensions of 25x35 cm under cyclone outlet ratio of 0.8. The maximum values of the rising dust was 6.8 mg/m^{3}under the same mentioned conditions while increased by97.5 % with traditional method (without cyclone). Total costs for packing chopped wheat straw under mentioned conditions decreased by 80% in case of using the developed cyclone comparing to the traditional method. It is recommended to manufacture the developed cyclone with vortex finder length of 50 cm, with inlet dimensions of 25x35 cm at outlet ratio of 0.8 to lessen the environmental pollution and conserve laborers' health.

Keywords: Environment, cyclone, pressure drop, tangential outlet, collection efficiency

INTRODUCTION

Cyclone as a separation unit consists of a lower conical part and an upper cylindrical part as the barrel. The separation units can be either horizontal or vertical. One of separation processes is air-solid separation. There are many figures of cyclones for separating the solid particles. Separation depends on density differences between stages or phases. Centrifugal forces or gravitational forces are used for separation enhancement. The most standard construction of returned flow types are composed of a cylindrical barrel with a fixed diameter and a conical part. Physical types of cyclones are constructed when a set of dimensions is estimated in relation to the diameter. Khoder and Abdel_Hammed. (1999) reported that farmers are exposed to adverse health effects according to high levels of organic dusts while harvesting or post harvesting processes. Davis and Gulson (2005) mentioned that dust with a dust diameter smaller than 10 mm can access through the lower respiratory tract and pulmonary air bags where dust with a diameter larger than 10 μm inhalation can cause irritation of upper respiratory tract. Ahinsa *et al.* (2014) reported that there have been many reports on health effects of husk exposures and unprotected dust exposures The airstream tangentially enters at the barrel top and moves downward into the cone making an outer vortex. The solid particles enters the cyclone bifurcate into two layers of dust according to the eddy current based on the secondary flow on the upper cover surface in the coaxial space between the body of the cyclone and exit pipe. one of them goes around the coaxial space on the upper cover surface and rotates around the exit pipe with the air flow. The other rotates and descends along the surface of the cyclone body. Then, on cone surface, the materials layer, which is pressed onto the cone surface by the centrifugal force, descends aided by gravitational force and descending airflow in. (Wang, 2004).

Hemdan (2007) mentioned that the cyclone is a device with no moving parts and consequently no maintenance. It enables particles of micrometers in size to have been separate from a air stream at about 15m/s without excessive pressure drop. Efficiency of cyclone has typical value of 70-80% solids separation, but if the stream has large amounts of solids, separation efficiency exceeded 99%, (Rus, 2001). Wang *et al.* (2000) reported that the cyclone fractional curves significantly affected the particle size distribution of particulate matter entering. Cyclone dust collectors are used for reducing air pollution originating from chemical plant drier equipment. However in this situation, to control the air pollution is very important and cyclone is used for controlling pollution, (Bernardo *et al.,* 2006). Also the operators who are continuously working on this environment are suffering through this pollution and there is no chance to be off lung diseases. An efficiency improvement is marginal and accompanied with complex structure and additional operating costs. Bryan and William (2006) investigated the 1D3D and 2D2D cyclones at different inlet velocities. For large particles, the collection efficiency of six inches diameter 1D3D and 2D2D cyclones is similar for inlet velocities from 10.16 standard m/s up to the design velocity with significantly lower pressure drop at lower inlet velocities.

Marinuc and Rus (2011) assured that the cyclone efficiency depended on the particle size from the mass of the mixtures. The input air velocity affects both the fan energy consumption and the dust collection efficiency. The maximum tangential velocity in the cyclone decreases with increasing the cyclone inlet dimensions. Increasing the cyclone inlet dimensions decreases the pressure drop. Elsayed (2011) demonstrated that the weakness of the vortex strength resulted in decreasing the cyclone overall efficiency. He also mentioned that, the optimum ratio of inlet width to inlet height was from 0.5 to 0.7. Furthermore, the maximum tangential velocity in the cyclone decreases with increasing the cyclone barrel or cone height. Increasing the cyclone barrel or cone height decreases both pressure drop and cut-off diameter. Increasing the barrel height makes a small change in the axial velocity, whereas increasing the cone height changes it considerably. Breiderhoff *et al.* (2013) mentioned that pressure loss and collection efficiency are the main criteria usedto evaluate cyclone performance. Both are functions of the cyclone geometry. Cyclone efficiency decreases with increasing in the characteristics such as cyclone body diameter; air exit diameter; air inlet duct area; air density and viscosity; leakage of air into the solids outlet. The pressure drop is a function of the inlet velocity and cyclone diameter. Muhammad *et al.* (2016) mentioned that however the pressure drop does not consider any vertical dimensions as contributing to pressure drop, this is a misleading in that a tall cyclone would have the similar pressure drop as a short one as long as cyclone inlets and outlets dimensions and inlet velocities are the same. Prachietal. (2017) investigated that the efficiency of actual cyclone separator by computational fluid dynamics analysis came out to be 53.1 % whereas the experimental value of it was 52 %. The main objectives of this study are keeping environment clean, keeping health of operators and laborers out of contamination, decreasing chopped wheat straw losses and consequently lessen total costs while the specific objectives are to develop a cyclone cleaning unit and demonstrate practically the influence of the inlet dimensions and the input velocity into the cyclone over the collection efficiency and to optimize parameters' performance by some geometrical changes.

MATERIALS AND METHOD

The traditional cyclone separating:

The swirling flow (Fig.1) causes centrifugal forces that dependent and moves the solid materials towards the wall and the lighter airstream towards the inside of cyclone. The swirling flow is converted partly into a radial inward flow until the axial component turns. The cleaned air goes up in the center of the cyclone and leaves the cyclone through the upper outlet. The collected particles are moved to the collection part, supported by gravity, via an axial flow at the wall. The main strength of the cyclone is the absence of moving mechanical parts.

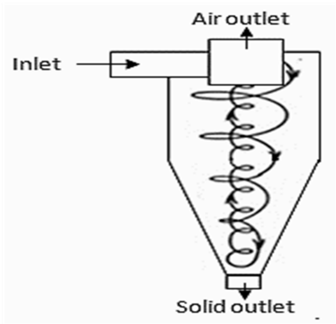


Fig. 1: Schematic presentation of the flow in a 2D2D cyclone before development.

At El-Serw Animal Production Research Station, three common figures of cyclone with three different geometries namely 2D2D, 1D3D and 1D2D (Fig 2a) were examined. A 2D2D cyclone has a barrel and a cone length of two times the barrel diameter. A 1D3D cyclone has a barrel length equal to the barrel diameter and a cone length of three times the barrel diameter. A 1D2D has a barrel equal to the barrel diameter and a cone length of two times the barrel diameter. These three separator cyclones were tested primarily to demonstrate practically the influence of the different cyclone dimensions on the behavior of solid particles, chopped straw (Tibn) and different input velocities into the cyclone over the collection efficiency. Also, to optimize its parameters performance by doing some geometrical changes.

These three cyclones have the same inlet dimensions, referred to as the 2D2D inlet. These cyclones were mainly used for separating dust (spherical shapes) from airstream.

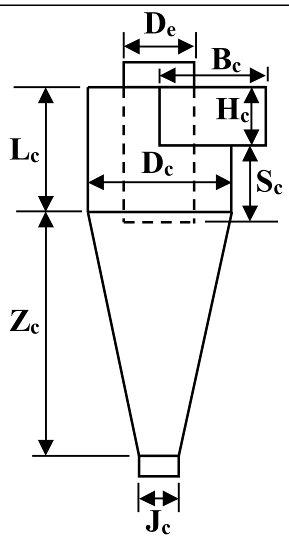
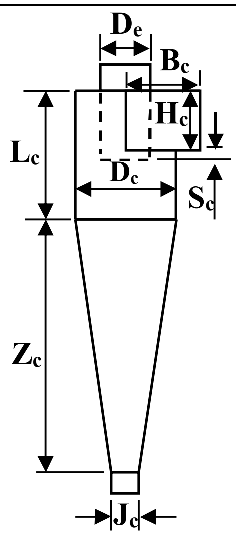
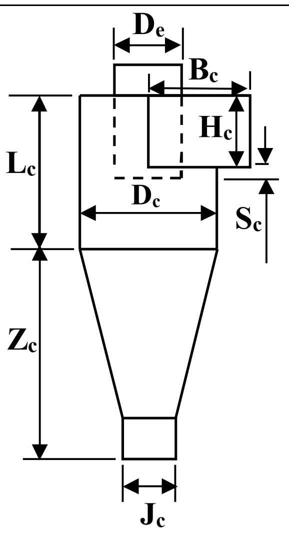
 1D2D	 1D3D	 2D2D
$B_c=D_c/4$ $D_e=D_c/1.6H_c=D_c/2$ $J_c=D_c/2S_c=5D_c/8$ $L_c=1xD_c$ $Z_c=2xD_c$	**$B_c=D_c/4$ $D_e=D_c/2H_c=D_c/2$ $J_c=D_c/4S_c=D_c/8$ $L_c=1xD_c$ $Z_c=3xD_c$**	**$B_c=D_c/4$ $D_e=D_c/2H_c=D_c/2$ $J_c=D_c/4S_c=D_c/8$ $L_c=2xD_c$ $Z_c=2xD_c$**

Fig.2a: Schematic diagram of the three tested cyclones before development

However, the results were extremely different in case of separating chopped wheat straw (oblong shapes). The three cyclones were tested in the field to separate chopped wheat straw from airstream (air-solid) during wheat threshing. Each cyclone was fixed individually on the thresher outlet. The main dimensions of the 2D2D cyclone separator are presented in Table 1_a.

Table 1_a: 2D2D Cyclone separator dimensions before development

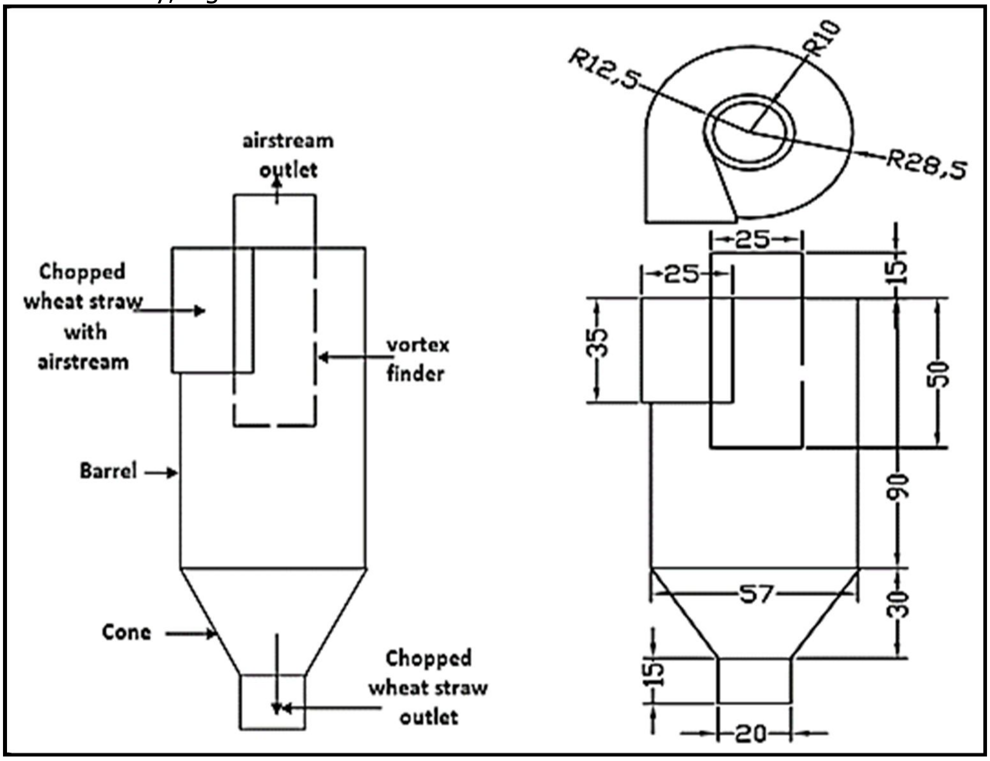
Items	Dimensions	Ratio	Value (m)
Diameter of cyclone Body (Barrel)	D_c	D_c	0.3048
Length of the body	L_c	2D	0.6090
Length of the cone	Z_c	2D	0.6090
Height of the inlet duct	H_c	D/2	0.1524
Width of the inlet duct	B_c	D/4	0.0762
Diameter of air exit	D_e	D/2	0.1524
Diameter of chopped wheat straw outlet	J_c	D/4	0.0762
Length of vortex finder	S_c	0.625	0.1905
Total length of cyclone	L_c+Z_c	4D	1.2192

After carrying out the calculations and estimation to the reasonable 2D2D cyclone geometry, the new obtained dimensions were recorded in Table 1_b. The developed cyclone was made of iron 26 Gauge of thickness.

Table 1_b: 2D2D Cyclone separator dimensions after development

Items	Dimensions	Ratio	Value (m)
Diameter of cyclone Body (Barrel)	D_c	D_c	0.57
Length of the body	L_c	1.58D	0.90
Length of the cone	Z_c	0.52D	0.30
Height of the inlet duct	H_c	D/1.9	0.30
Width of the inlet duct	B_c	D/2.85	0.20
Diameter of air exit	D_e	D/2.7	0.25
Diameter of chopped wheat straw outlet	J_c	D/2.7	0.20
Length of vortex finder	S_c	0.50	0.50
Total length of cyclone	L_c+Z_c	2.1D	1.20

Cyclone construction: According to the previous tabulated characteristics in Table 1_b, the 2D2D cyclone (Fig. 2_b) was subjected to be developed for giving high separation efficiency while threshing wheat to separate chopped wheat straw and dust from airstream. As mentioned by El-sayed (2011), the optimum ratio of inlet width to inlet height is from 0.5 to 0.7, the studied cyclone inlet dimensions are (A) 20x30; (B) 25x35; (C) 35x45 cm for width and height, respectively. All materials are available locally, Figs.2b.



(Dims. in cm.)

Fig.2b: Schematic representation of 2D2D **cyclones separator after development**

Testing and evaluating the developed cyclone separating:

After constructing the developed cyclone with modified dimensions, it was shifted to the farm to be tested practically in the field. A 76 hp (56.7 kW) Universal tractor with drum diameter of 28 cm and Turkish thresher with right, left drums diameter of 17, 40 cm, respectively were used to evaluate the developed cyclone performance after carrying out the modifications. The obtained chopped wheat straw was collected in linen net-sacs and then weighed. A joint is used to connect the thresher outlet to cyclone inlet altogather, Fig.3. Different airstreem velocities were tested with changeable inlet and outlet openings under different fortex finder lengths. According to Wang, 2004, the airstream tangentially enters at the barrel top and moves downward into the cone making an outer vortex. The solid particles enters the cyclone bifurcate into two layers of dust according to the eddy current based on the secondary flow on the upper cover surface in the coaxial space between the body of the cyclone and exit pipe. one of them goes around the coaxial space on the upper cover surface and rotates around the exit pipe with the air flow. The other rotates and descends along the surface of the cyclone body. Then, on cone surface, the materials layer, which is pressed onto the cone surface by the centrifugal force, descends aided by gravitational force and descending airflow in. All obtained results were recorded and analyzed statistically to determine the best dimensions reasonable for giving best efficiency in separtion and clean environment.

Fig. 3: Jointing cyclone inlet to thresher outlet and attaching linen sacs for collecting chopped wheat straw

Theoretical calculations

The number of effects turns: Effective turns number is the number of revolutions the air spins while passing through the cyclone outer vortex.

Lapple (1951) demonstrated the following equations for studying cyclone dimensions. Lapple model for N calculation is as follows, Lapple (1951):

$$N = \frac{1}{H}\left[L_b + \frac{L_c}{2}\right] \quad , \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where:

N = number of turns inside the cyclone (no units); H = height of inlet duct (m);

L_b = length of cyclone body (m);

L_c = length (vertical) of cyclone cone (m).

Pressure Drop (ΔP): Calculating the pressure drop to according to Lapple (1951) converting the number of inlet velocity heads to a static pressure drop (ΔP):

Pressure Drop = Pressure at inlet – Pressure at outlet and he proved that:

$$H_v = K\frac{HW}{D_e^2} \quad , \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(2)$$

$$\Delta P = \frac{1}{2}\rho_g V_i^2 H_v \quad , \quad \ldots.\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..\ldots\ldots(3)$$

Where:

H_v = pressure drop expressed in number of inlet velocity heads;

H, W = height and width of the inlet, (cm);

D_e = diameter of air exit, (cm);

ρ_g = density of fluid, (could be neglected);

K = constant (K = 12 to 18).

Cut point diameter: The cut-point of a cyclone is the aerodynamic equivalent diameter of the particle collected with 50% efficiency. As the cut-point diameter increases, the collection efficiency decreases. Lapple (1951) developed the following equation for determining cut point diameter:

$$d_p = \left[\frac{9\mu W}{2\pi N_e V_i(\rho_p - \rho_g}\right]^{1/2}, \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots..(4)$$

Where:

d_p = the smallest particle diameter,

μ = air viscosity (kg/m.s); W = inlet duct width (m);

N_e = number of turns; V_i = velocity of inlet air (m/s);

ρ_p = particle density (kg/ m^3);

d_p is the size of the smallest particle that will be collected if it starts at the inside edge of the inlet duct.

Air residence time: It could be determined according to Lapple (1951) as follows:

$$\Delta \boldsymbol{t} = \frac{\boldsymbol{path\ length}}{\boldsymbol{speed}} = \frac{\boldsymbol{\pi D N_e}}{\boldsymbol{V_i}} \quad , \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots..(5)$$

Where:

Δt= time spent by air during spiraling descent, (sec);

D= cyclone body diameter, (m); Vi= air inlet velocity, (m/s.) = $\frac{Q}{WH}$;

Q= volumetric inflow (m^3/s.); H, W= height and width of inlet (m).

The maximum radial distance traveled by any particle is the width of the inlet duct. The centrifugal force quickly accelerates the particle to its terminal velocity in the outward (radial) direction with the opposing drag force equaling the centrifugal force. The terminal velocity according to Lapple (1951) will just allow a particle initially at distance W away from the wall to be collected in time is:

$$V_t = \frac{W}{\Delta t} \quad , \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.(6)$$

Where:

V_t = particle drift velocity in the radial direction (m/s).

The particle drift velocity is a function of particle size. Assuming Stokes regime flow ($drag\ force = 3\pi\mu d_p V_t$) and spherical solids subjected to a centrifugal force mv^2/r, with m= mass of particle in excess of air mass displaced, v=Vi of inlet flow, and r=D/2 and accordingly, Lapple (1951):

$$\boldsymbol{V_t} = \frac{\boldsymbol{(\rho_p - \rho_a)\ dp^2 V_i^2}}{\boldsymbol{9\mu D}} \quad , \quad \dots\dots\dots\dots\dots\dots(7)$$

Where:

V_t= terminal drift transverse velocity, (m/s.);

d_p= diameter of particle (m); ρ_p= density of particle (kg/m^3);

ρ_a= air density (kg/m^3); μ= air viscosity (kg/m/s).

All theoretical calculations were found fairly similar to some cyclones in the market namely 2D2D, 1D3D and 1D2D that used in separating dust from air in some factories. The previous calculations were theoretically estimated and the obtained results was carried out on the 2D2D cyclone and then fabricated and tested.

Devices used:

An anemometer (Fig. 4), a personal dust sampler and a sensitive balance were used for measuring speed, rising dust and weighing samples, respectively.

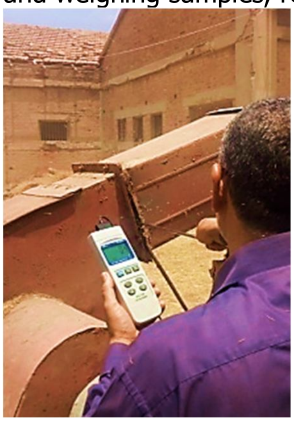


Fig.4: Measuring airstream velocity by the anemometer.

Studied parameters:

The experimental work is carried on various flow rates i.e. for various inlet velocity. The variation in flow rate is obtained by changing the rotational speed. The studied variables are:

- Four airstream velocities (ASV) of 2.3 and 3.6, 4.7and 5.5 m/s. It was measured by using calibrated dynamic pressure anemometer with the following technical specifications:
  - The maximum measuring range of air temperature is 50^{0}C;
  - The maximum measuring range of airflow rate is 80m/s.
  - It is equipped with USB port and software for real time recording. It has internal memory up to 99 measured values.

The anemometer with a sensitive antenna is put through a small hole (Fig. 4) in the inlet opening facing the airstream flow. The antenna is connected to a digital analog shows the direct airstream velocity in m/s.

- Three cyclone inlet dimensions (CID) of (A) 20x30; (B) 25x35; (C) 35x45 cm for width and height, respectively;

- Three vortex finder length (VFL) of 50, 60 and 70 cm;
- Three cyclone outlets ratios (COR): chopped wheat straw and airstream outlet diameters of 15, 20, 25 and 20, 25, 30 cm which represents ratios of 0.75, 0.80 and 0.83,respectively.

The developed cyclone performance was tested individually and then compared to the traditional method concerning cyclone efficiency, environment contamination, field capacity, total costs.

Measurements

1- Cyclone Efficiency (Separation and collection efficiency, η):

Force balance for solid particle of the cyclone can be calculated by the following equation:

$$M_f = M_c + M_e \quad , \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(8)$$

Then;

$$\eta = \frac{M_c}{M_f} = 1 - \frac{M_e}{M_f} = \frac{M_c}{M_c + M_e} x100 \quad , \quad \ldots\ldots\ldots\ldots\ldots\ldots(9)$$

2- The rising dusts: Using the personal dust sampler, the dust rate (mg/m^3) was measured. According to the device manual information for using the device, the personal dust sampler was carried by an operator while carrying out the experiment both in the two cases, traditional method (without cyclone) and by using the cyclone separating unit. There is a slide filter inside the device collects dust. The collected dust in the device in two cases was weighed. This measurement was replicated three times under all studied parameters and the obtained results were tabulated and analyzed statistically.

Rising dust reduction ratio:

$$Dr\ \% = \frac{Dm-D}{Dm} \times 100 \quad , \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$$

Where: D_m: manually packing rising dust, mg/m^3;

D: mechanically packing rising dust, mg/m^3.

3- Cost reduction ratio, (C_r %):

The operating cost was determined using the following formula:

$$Operating\ \cos t(L.e/fed) = \frac{Machine\ \cos t\ (pound/h)}{Actual\ field\ capacity\ (Fed/h)} \quad , \quad \ldots\ldots\ (11)$$

$$C_{r\ \%} = \frac{C_m}{C_L} \times 100 , \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (12)$$

Where:

C_m: economic cost, LE/ton; C_L: labor cost, LE/ton.

The labor cost was estimated from labors wage according to 2018 prices which was about 35 LE/ton includes packing and tying a ton of chopped wheat straw.

RESULTS AND DISCUSSION

Factors affecting the cyclone collection efficiency

Effect of airstream velocity (ASV), cyclone inlet dimensions (CID), represents pressure drop, vortex finder length (VFL) under cyclone outlets ratio (COR)on separating efficiency is shown in Figs 5,6 and 7. It proved that as inlet velocity increases the cyclone, efficiency increases for the same model. The maximum tangential velocity in the cyclone decreases with increasing the cyclone inlet dimensions. Increasing the cyclone inlet dimensions decreases the pressure drop. Consequently, the cyclone overall efficiency decreases due to weakness of the vortex strength. Increasing airstream velocity from 2.3 to 5.5 m/s resulted in increasing collection efficiency from 97 to 98% and from 94.8 to 97 % and from 92.5 to 95.3 % under vortex finder length of 50, 60 and 70 cm, respectively. These results were at cyclone inlet dimensions 20x30 cm and cyclone outlets ratio of 0.75. Pushing particles towards wall resulted in increasing efficiency.

Also, from data obtained decreasing the CID increases centrifugal force and hence efficiency. From the previous figures, it was observed that increasing cyclone inlet dimensions resulted in decreasing collection efficiency under the same airstream velocity. Increasing cyclone inlet dimensions from 25x35 cm to 35x45 cm resulted in decreasing collection efficiency from 98 to 76.7 % at airstream velocity of 5.5 m/s and vortex finder length of 50 cm with cyclone outlet ratio of 0.75. As shown on mentioned figures, all other parameters showed the same trend under the same conditions.

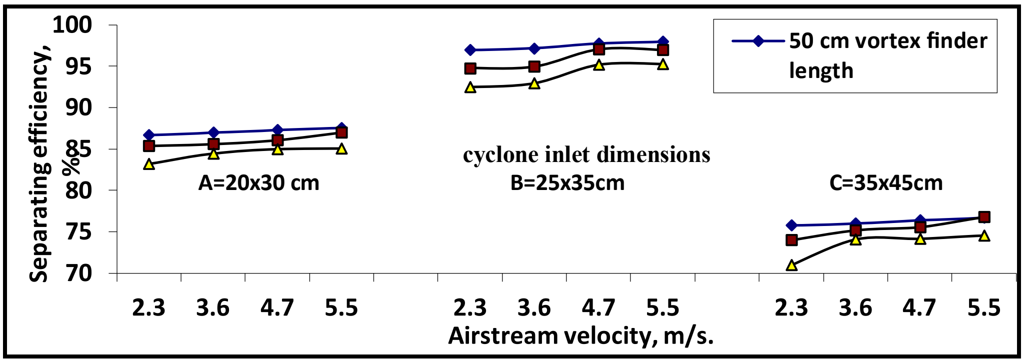


Fig. 5. Effect of airstream velocity, vortex finder length and cyclone inlet dimensions under cyclone outlet ratios of 0.75 on separating efficiency.

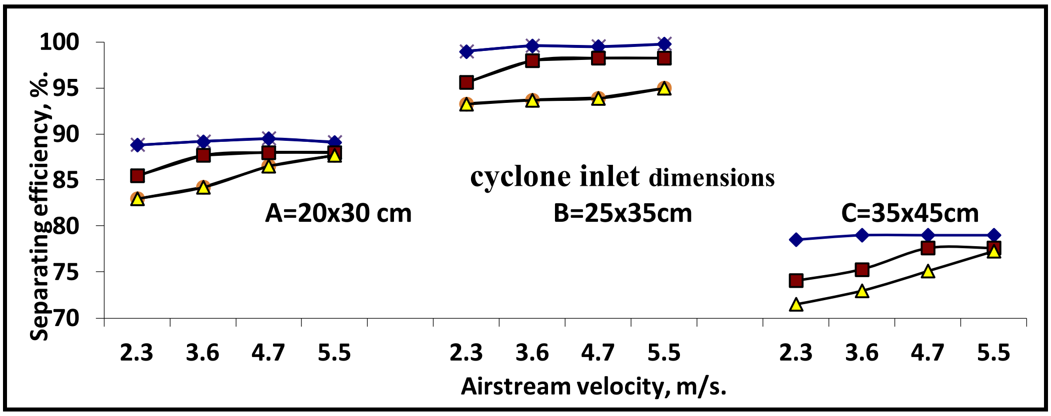


Fig. 6. Effect of airstream velocity, vortex finder length and cyclone inlet dimensions under cyclone outlet ratios of 0.80 on separating efficiency.

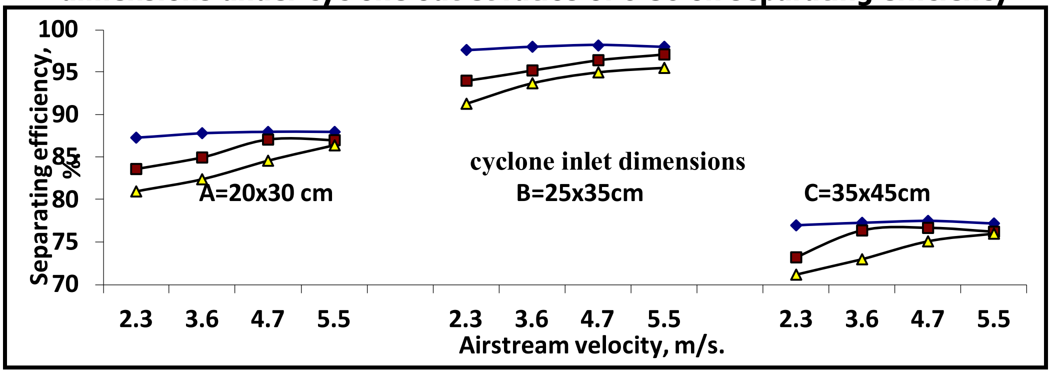


Fig. 7. Effect of airstream velocity, vortex finder length and cyclone inlet dimensions under cyclone outlet ratios of 0.83 on separating efficiency.

Increasing cyclone outlets ratio from 0.75 to 0.80 resulted in increasing collection efficiency while increasing outlets ratio from 0.80 to 0.83 resulted in decreasing collection efficiency. Increasing cyclone outlets ratio from 0.75 to 0.80 resulted in increasing collection efficiency from 98 to 99.8 % while the results decreased from 99.8 to 98 by increasing the outlets ratio from 0.80 to 0.83. all these results were under VFL of 50 cm, ASV of 5.5 m/s and CID of 25x35 cm. these results may be attributed to centrifugal force, the solid particles are thrown to the inner cyclone wall where they lose energy and fall moving under the action of gravity at the bottom of the cyclone where it is discharged (chopped wheat straw mass > air mass). So, air is moving downward spiral, solid particles being driven to the top of the air and then air is discharged through the central tube of the cyclone due to the circulation effect.

It can easily be seen that by increasing airstream flow, the separation efficiency goes up accompanied by a larger pressure drop. Tangential velocity and/or centrifugal force increase cyclone efficiency by increasing inlet velocity, increasing outlet velocity, smaller radius flow path with decreasing outlet diameter. These results are in agree with Marinuc and Rus (2011) who mentioned that if the particle size is larger and the sectional area of entry into cyclone is smaller, the separation efficiency of the cyclone is higher. This is due to reduction in drag force with reduction in VFL.

From Fig. 8 it has been observed that the pressure drop is more for increasing inlet velocity. Under velocities of 2.3, 3.6, 4.7 and 5.5 m/s values of pressure drop were 38.088, 93.312, 159.048 and 217.8 mbar, respectively. These results mean that the pressure drop is depending on the inlet velocity for the same model. These results were under inlet duct dimension of 20x30 cm. Obtained data showed that increasing inlet duct dimension resulted in increasing pressure drop. Increasing inlet duct dimension from 20x30 to 35x45 cm resulted in increasing pressure drop values of 99.8, 244.944, 417.501 and 571.725 under velocities of 2.3, 3.6, 4.7 and 5.5 m/s, respectively. Inlet duct dimension of 25x35 cm showed similar trend on the figs. (8 & 9).

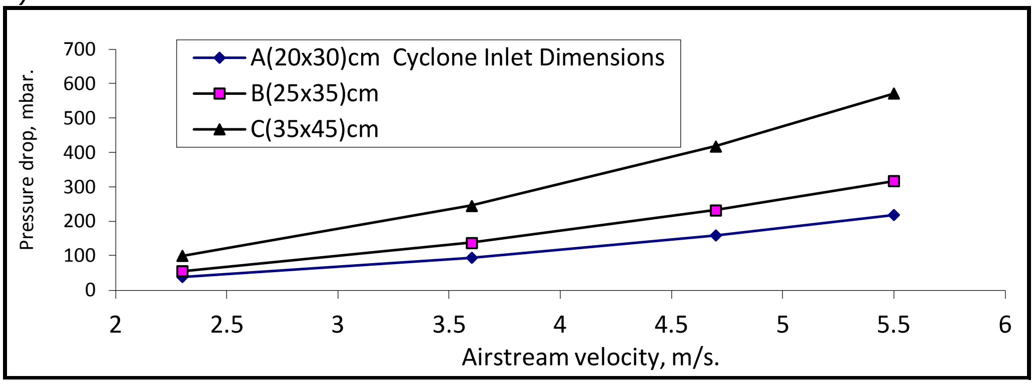


Fig. 8.The pressure drop versus airstream velocity at different cyclone inlet dimensions.

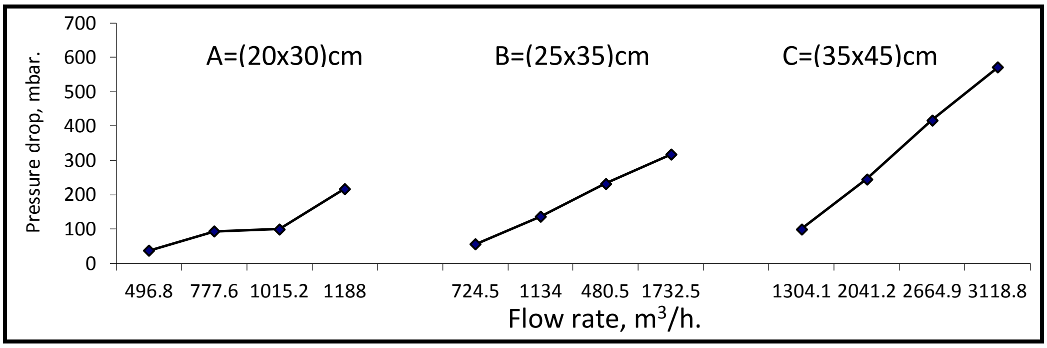


Fig. 9. The pressure drop versus flow rate at different cyclone inlet dimensions.

On the other hand from (Fig. : 9) flow rate values of 496.8, 777.6, 1015.2 and 1188 m3/h caused an increment of pressure drop of 38.088, 93.312, 159.048 and 217.8 mbar respectively under velocity of 2.3, 3.6, 4.7 and 5.5 m/s, respectively and inlet duct dimension of 20x30 cm. The other flow rates through other inlet duct dimensions showed similar trend on the figures. Hence, collection efficiency has to be maximized and pressure loss minimized.

Statistically, as tabulated in Table 2 the interaction between velocity and outlet ratios or velocity and inlet dimensions was non-significant; while the interaction between outlet ratios and inlet dimensions were very significant although velocity and inlet dimensions showed a very significant effect ($P<0.05$) meanwhile, outlet ratios was significant individually (R^2 = 0.95). In the same time the interaction between vortex finder length and outlet ratios or vortex finder length and inlet dimensions (Table 3) was non-significant; while the interaction between outlet ratios and inlet dimensions were very significant ($P<0.05$) although every mentioned factor showed a significant effect individually (R^2 = 0.98).

Table 2. ANOVA analysis velocity and outlet ratios and inlet dimensions

Source	df	Type III SS	MS	F	P	
Main Effects						
Velocity(m/s)	3	93.97	31.32	7.93	.0001	***
Outlet ratios	2	38.24	19.12	4.84	.0102	*
Inlet dimensions	2	5783.48	2891.74	732.53	.0000	***
Interaction						
Velocity(m/s) * outlet ratios	6	2.33	0.38	0.09	.99	ns
Velocity(m/s) * inlet dim.	6	0.85	0.14	0.03	.99	ns
Outlet ratios * inlet dim.	4	1820.83	455.20	115.31	.00	***
Error	84	331.59	3.94			
Total	107	8071.32		R^2 = = 0.95		

Table 3. ANOVA analysis vortex length, outlet ratios and inlet dimensions

Source	df	Type III SS	MS	F	P	
Main Effects						
Vortex length(cm)	2	266.11	133.08	78.51	.0000	***
Outlet ratios	2	38.24	19.12	11.28	.0000	***
Inlet dimensions	2	5783.48	2891.74	1706.07	.0000	***
Interaction						
Vortex length(cm) * outlet	4	8.95	2.23	1.32	.2682	ns
Vortex length* inlet dim.	4	2.79	0.69	0.41	.7996	ns
Outlet ratios * inlet dim.	4	1820.83	455.20	268.56	.0000	***
Error	89	150.85	1.69			
Total	107	8071.32		R^2 = 0.98		

Throughout Table 4 the interaction between velocity and vortex finder length; velocity and outlet ratios; vortex finder length and the outlet ratios showed non-significant effect (R^2= 0.054). similar behavior was shown in Table 5 by the interaction between velocity and vortex finder length; velocity and inlet dimensions; vortex finder length and inlet dimensions (P>0.05) notwithstanding both vortex finder length and inlet dimensions showed very significant effect individually (P<0.05) but velocity was non-significant (R^2=0.76)

Table 4 . ANOVA analysis velocity and vortex fisnder length; velocity and outlet ratios; vortex finder length and the outlet ratios

Source	df	Type III SS	MS	F	P	
Main Effects						
Velocity(m/s)	3	93.97	31.32	0.34	.7930	ns
vortex length(cm)	2	266.16	133.0	1.46	.2370	ns
outlet ratios	2	38.24	19.12	0.21	.8106	ns
Interaction						
Velocity(m/s) * vortex length	6	28.80	4.80	0.05	.9994	ns
Velocity(m/s) * outlet ratios	6	2.33	0.38	0.00	1	ns
vortex length(cm) * outlets	4	8.95	2.23	0.02	.9988	ns
Error	84	7632.84	90.86			
Total	107	8071.326667	R^2= = 0.054			

Table 6 showed the interaction between velocity and inlet dimensions on pressure drop. It is obvious that the interaction between the two factors showed a very significant effect on pressure drop (P<0.05) while the same two factors showed a non-significant effect with the cyclone efficiency (P>0.05). It seems that the pressure drop is a major factor affects cyclone efficiency. Means the pressure drop is depending on the inlet velocity. It is observed that the pressure drop is increases as the inlet velocity increases.

Table 5. ANOVA analysis velocity and vortex finder length; velocity and inlet dimensions; vortex finder length and inlet dimensions

Source	df	Type III SS	MS	F	P	
Main Effects						
Velocity(m/s)	3	93.97	31.32	1.38	.2520	ns
vortex length(cm)	2	266.161	133.08	5.89	.0040	**
inlet areas(m2)	2	5783.48	2891.74	128.16	.0000	***
Interaction						
Velocity(m/s) * vortex length	6	28.80	4.80	0.21	.9718	ns
Velocity(m/s) * inlet dim.	6	0.85	0.14	0.00	1	ns
Vortex length(cm) * inlet	4	2.79	0.69	0.03	.9981	ns
Error	84	1895.25	22.56			
Total	107	8071.32		R^2=0.76		

Table 6. ANOVA analysis for velocity and inlet dimensions versus pressure drop

Source	df	Type III SS	MS	F	P	
Blocks	2	24	12	8.5248e11	.000	***
Main Effects						
Velocity	3	472918.022	157639.34	1.1199e16	.0000	***
Inlet dimensions	2	271854.12	135927.06	9.6563e15	.0000	***
Interaction						
Velocity x Inlet dim.	6	77164.46	12860.74	9.1363e14	.0000	***
Error	22	3.09683e-10	1.408e-11<-			
Total	35	821960.61	R^2 = 1			

According to data tabulated in Table 7, the ANOVA analysis showed a very significant effect of flow rate m^3/h on pressure drop ($P<0.05$) and $R^2=0.99$.

Table 7. ANOVA analysis for flow rate versus pressure drop

Source	df	Type III SS	MS	F	P	
Blocks	2	22.16	11.08	209	.0000	***
Main Effects						
Flow rate	11	852496.95	77499.72	1461423.4	.0000	***
Error	22	1.16	0.0530303<-			
Total	35	852520.2924				
R^2=0.99						

Factors affecting the dust rising from separation process

Fig. 10 showed the rising dust mg/m^3 under different ASV, CID, VFL, and COR. It is obvious that increasing ASV resulted in increasing rising dust mg/m^3 in the two compared systems (developed cyclone and traditional method). Under ASV of 2.3, 3.6, 4.7 and 5.5 m/s, the rising dust was 3.2, 4.9, 5.4 and 6.8 mg/m^3, respectively by traditional system. Whereas under the same ASV with the developed cyclone the rising dust was0.0113, 0.141, 0.0169 and 0.0195 mg/m^3. From Fig. 11, the effect between airstream velocity(ASV) through cyclone inlet and the separation rising dust at the tested factors showed a direct relationship. Increasing the ASV increases separation rising dust (mg/m^3). The maximum values of the rising dust increased by 99.69 % while using traditional method under the same conditions of threshing process comparing to using the developed cyclone under ASV of 4.7 m/s, VFL of 50 cm, COR of 0.8 and CID of 25 x 35 cm. All other parameters under study showed similar trend under the same conditions.

These results may be attributed to using closed separation system with the developed cyclone which make a protective shield against dust. Also the closed packing cyclone system which tightened well and jointed with the thresher outlet to separate chopped wheat straw from airstream out of the laborer.

Statistically, through ANOVA analysis for inlet velocity versus rising dust Tables 8 and 9, it was found that the inlet velocity showed a very significant effect on rising dust coming out of the both systems (P<0.05). But when comparing the developed cyclone to the traditional method concerning rising dust, it is clearly obvious that using developed cyclone very significantly decreased the rising dust when evaluating the two methods under the same velocity.

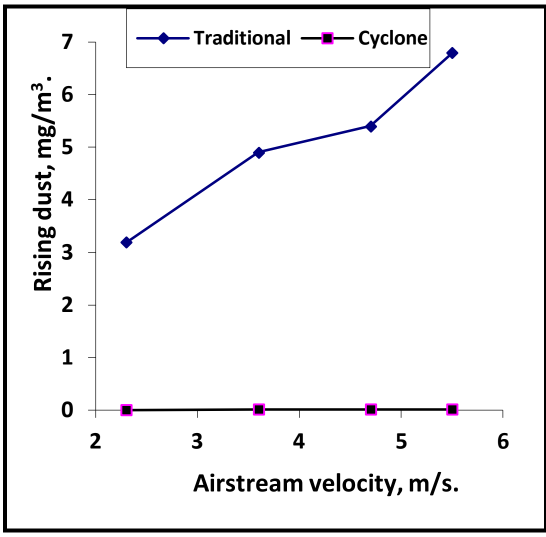


Fig 10. Effect of airstream velocity on rising dust, mg/m³.

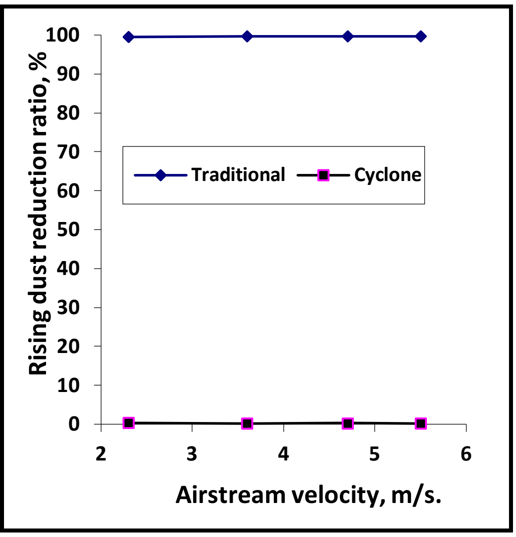


Fig 11. Effect of airstream velocity on rising dust reduction, %.

Table 8. Inlet velocity versus rising dust in cyclone system

Source	df	Type III SS	MS	F	P	
Blocks	2	6.5e-8	3.25e-8	13	.0066	**
Main Effects						
Velocity	3	1.1265e-4	3.755e-5	15020	.0000	***
Error	6	1.5e-8	2.5e-9<-			
Total	11	1.1273e-4				
R2= 0.99						

Table 9. Inlet velocity versus rising dust in traditional system

Source	df	Type III SS	MS	F	P	
Blocks	2	0.061	0.03	37	.0004	***
Main Effects						
Velocity	3	19.92	6.64	7968	.0000	***
Error	6	0.005	8.3333e-4<-			
Total	11	19.98				
R2= 0.99						

Cost estimation:

Total costs of the completely traditional tibn separating end collecting process was estimated and compared to the cyclone separating costs. In case of the cyclone separator and cccording to no mechanical, moving or rotating parts, no gears, no sprockets, no drums, no lubrications in the developed cyclone, costs included fixed costs and maintenance only and the cyclone field capacity depended on thresher field capacity. Generally, concerning the recent prices in Egypt, the costs was determined as follows:

Cyclone body cost	=550 LE;
Joints cost	= 70 LE;
Labor cost	= 120 LE;
Construction expenses cost	=150 LE;
Maintenance cost	= 50 LE;
Testing Cost	= 120 LE,
Total Costs	= 1060 LE

Comparing the mentioned costs to the traditional costs per m^3 of the chopped wheat straw, it was found that each ton of chopped wheat straw costs 175 LE in packing in sacs in traditional method with polluted environment with laborer health abuse, while it costs 35 LE by developed cyclone and the cost reduction ratio Cr approached to 80% apart from clean environment and laborer health conservation which represents achieving the most important goal.

SUMMARY AND CONCLUSION

This study was carried out at El-Serw Animal Production Research Station to obtain a clean environment through agricultural activities by developing and evaluating the performance of a cyclone separating unit attached to threshers. The developed cyclone separates dust from the airstream and simultaneously collect the chopped wheat straw instead of operators. four airstream velocities (ASV) of 2.3, 3.6, 4.7 and 5.5 m/s; cyclone inlet dimensions of 20x30; 25x35; 35x45 cm for width and height, respectively; vortex finder length of 50, 60 and 70 cm; cyclone outlets ratios chopped wheat straw and airstream outlet diameters of 15, 20, 25 and 20, 25, 30 cm for chopped wheat straw and airstream outlet represents ratios of 0.75, 0.80 and 0.83, respectively were tested. The results could be summarized as follows:

1- Separation and collection efficiency value was 99.8% at inlet velocity of 4.7m/s, vortex finder length of 50 cm, with inlet dimensions of 25x35 cm at cyclone outlet ratio of 0.8.

2- The maximum values of the rising dust rising dust was 6.8 mg/m^3 under the same mentioned conditions while increased by 97.5 % with traditional method.

3- Total costs for packing chopped wheat straw under mentioned conditions decreased by 80% in case of using the developed cyclone comparing to the traditional method.

RECOMMENDATIONS

It is recommended to manufacture such cyclones with mentioned dimensions (vortex finder length of 50 cm, with inlet dimensions of 25x35 cm at outlet ratio of 0.8.) in a large scale and subject to fix with all wheat thresher to obtain high separation and collection efficiency and consequently clean environment.

REFERENCES

1. Ahinsa T.; N. B. Singh; F. W. Bansode and R. K. Singh. 2014. Hematological Anomalies in Rice Mill Workers of District Sultanpur, Uttar Pradesh. Res. J. Chem. Env. Sci. Vol 2 [6] December.73-75.
2. Bernardo S., M. Mori and W. P. Martignoni. 2006. Evaluation of cyclone geometry and its influence on its performance parameters by CFD, Powder Technology.
3. Bryan W. and B. William. 2006. Efficiency and pressure drop of cyclones across a range of inlet velocities. American Society of Agricultural and Biological Engineers. 22(1): 155-161.
4. Breiderhoff, B.; B. Thomas; N. Boris; Z. Martin; F. Andreas; F. Oliver; F. Martina; O. Mersmann and J. Stork. 2013. Simulation and Optimization of Cyclone Dust Separators. Faculty for Computer and Engineering Sciences, Cologne University of Applied Sciences, Band 4; p: 1-19.
5. Davis J.J. and B. A. Gulson. 2005. Ceiling (attic) dust: "museum" of contamination and potential hazard. Environmental Research. 99 (2):177-94.
6. Elsayed, Kh. 2011. Brussels, October 2011Analysis and Optimization of Cyclone Separators Geometry Using RANS and LES Methodologies. PhD thesis, Department of Mechanical Engineering, Vrije Universiteit Brussel.
7. Hemdan, H. 2007. On the potential of large eddy simulation to simulate cyclone separators. Germany. Technischen Universität Chemnitz, 2007. Available at: http://www.qucosa.de/fileadmin/data/ qucosa/documents/5333/data/diss.pdf.
8. Khoder, M. I. and A.A, Abdel_Hammed. 1999. Suspended particulate and bio aerosols emitted from agricultural non-point source. Air pollution Dept., National Research Center, Dokki, Egypt Environment Conference.
9. Lapple, C. E. 1951. Processes use many collector types. Chemical Engineering 58 (5):144-151

10. Lapple, C. E. 1951. Processes use many collector types. Chemical Engineering 58 (5):144-15
11. Marinuc, M. and F. Rus. 2011. The effect of particle size and input velocity on cyclone separation process. Agricultural Food Engineering. Vol. 4 (53) No. 2; p: 117-122.
12. Muhammad I. T.; A. N. Mohammed and B.M. James. 2016. Design and analysis of cyclone dust separator. American Journal of Engineering Research (AJER);www.ajer.org, Research Paper Open Access 2016, p: 130-134.
13. Prachi K. I.; S.B. Brave; S.S. Pande and A. R. Nadgire. 2017. Effect of geometric parameters on the performance of cyclone separator using CFD. MITCOE, & DIAT, Pune, AMET-2017, IJCET INPRESSO Special Issue-7 (March 2017): 288-292.
14. Rus, F. 2001. Operaţii de separare în industria alimentară (Separation Operations in Food Industry). Braşov. Transilvania University Publishing House, 2001.
15. Wang, L. 2004. Theoretical study of cyclone design. Texas A & M University.
16. Wang, L.; C. B. Parnell, and B. W. Shaw. 2000. 1D2D, 1D3D, 2D2D Cyclone fractional efficiency curves for fine dust. Proc. of the 2000 Beltwide Cotton Conferences. San Antonio, Tex.: National Cotton Council.

تطوير وحدة سيكلون فصل ملحقة بآلات الدراس من أجل بيئة نظيفة

محمد محسن الطنطاوي، يوسف يوسف رمضان
ميرفت محمد عطاالله ، يوسف فرج شاروبيم

- *معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية-الدقي – الجيزة – مصر.*

أثناء عملية دراس محصول القمح بآلات الدراس الثابتة تخرج مخلفات الدراس على هيئة تبن مدفوع بقوة ومختلط بالأتربة والشوائب الدقيقة التى تنبعث فى الهواء مسببة تلوثاً بيئياً خطيراً ومضراً بالحقول والزراعات المجاورة رغم وضع مفارش تحت التبن قبل الدراس حيث يطير التبن إلى مسافات تصل إلى 50 متر حسب سرعة الرياح وقت إجراء عملية الدراس،ويتم جمعها يدويًا من قبل المشغلين ، فعملية الدراس بالطريقة التقليدية تسبب تلوث الهواء والتأثير على صحة المشغلين،فهي عملية شاقة للغاية.

تهدف هذه الدراسة إلى الحصول على بيئة نظيفة من خلال تطوير وتقييم أداء وحدة فصل سيكلون تكون ملحقة بآلات دراس القمح. السيكلون المطور في هذه الدراسة يفصل الغبار من تيار الهواء وتجميع التبن في وقت واحد بدلا من المشغلين.فقد تم اختبار ثلاثة من وحدات فصل الشوائب (السيكلون) المستخدمة في فصل مواد مشابهة،وبناء على الاستنتاجات الرياضية لحساب أبعاد السيكلون المناسبة تم اختيار أقرب وحدة سيكلون للنتائج الرياضية المتحصل عليها وهو(السيكلون 2D2D) واختباره في الحقل مبدئياً ثم أجريت التعديلات على السيكلون 2D2D حسب الحسابات والنتائج النظرية بالمعادلات الموضحة فى المواد والطرق في جدول (1).

تم اختبار أداء السيكلون المطور حقليا عند سرعات دخول لمخلوط الهواء 2,3 ، 3,6، 4,7 ، 5,5 م/ث ,أبعاد فتحة دخول مختلفة 20×30 ، 25×35 ، 35×45 سم ، كما تم اختبار طول ماسورة دوامة الهواء (vortex finder length) عند 50 ، 60 ، 70 سم ، والنسبة بين قطري فتحة خروج التبن وفتحة خروج الهواء (0,75 ، 0,80 ، 0,83). وقد تم قياس كلا من كفاءة الفصل والتجميع ونسبة الأتربة المتصاعدة وكميتها ومقارنتها بالنظام التقليدي وكذلك تم تقدير التكاليف الكلية بالجنيه المصري.

ويمكن تلخيص أهم نتائج الدراسة في النقاط التالية:

- كفاءة عملية الفصل تأثرت بشدة بكل من سرعة دخول المخلوط والهبوط في الضغط داخل السيكلون. حيث أدت زيادة سرعة دخول المخلوط إلى زيادة كفاءة الفصل بشرط عدم زيادة الضغط التى زادت عندما بلغت سرعة دخول المخلوط 5,5 م/ث.
- تأثرت سرعة دخول المخلوط بأبعاد فتحة دخول المخلوط إلى السيكلون وتأثر نسبة الضغط بين قطر فتحة خروج التبن وفتحة خروج الهواء وكذلك طول ماسورة دوامة الهواء .
- كانت أفضل كفاءة فصل 99,8% عند سرعة دخول 4,7 م/ث وطول ماسورة دوامة الهواء 50 سم مع أبعاد فتحة الدخول 25×35 سم بالنسبة لعرض وطول فتحة الدخول على الترتيب وأيضاً كانت عند نسبة 0,8 لفتحة خروج التبن بالنسبة لفتحة خروج الهواء.

- بمقارنة نسبة الأتربة المتجمعة في النظامين المطور والتقليدي اتضح أن نسبة الأتربة المتجمعة انخفضت بنسبة 97,5% في النظام المطور عن النظام التقليدي وذلك عند عوامل الدراسة المذكورة.
- نظراً لعدم وجود أجزاء متحركة أو دوارة في نظام السيكلون المطور ولا يحتاج طاقة لتشغيله فإن التكاليف الكلية بلغت 1060 جنيه مصري تشمل تكاليف التصنيع والصيانة والاختبار فقط أما بالنسبة لمقارنة تكاليف التعبئة فقد بلغت 175 جنيه/طن في النظام التقليدي في مقابل 35 جنيه/طن من التبن في النظام المطور أى انخفاض في التكاليف بنسبة 80%.

*وتوصي الدراسة بتصنيع وحدة السيكلون المطور بأبعاد فتحة دخول 25×35 سم مع طول ماسورة دوامة الهواء 50سم بنسبة 0.8 بين فتحة خروج الهواء وفتحة خروج التبن وتعميم استخدامه مع آلات الدراس عموما، حماية للبيئة من التلوث، ومحافظة على صحة عمال التشغيل، بالإضافة إلى تقليل الفاقد من التبن.