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Studying the effect of Cyclone’s dimensions on the separation efficiency of wheat using computational fluid dynamics method

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Abstract

Cyclone is one of the most important components of pneumatic conveying system which is used for separating particles from gas stream. A CFD study was conducted to investigate the effect of Cyclone’s dimensions on its efficiency during wheat separation process. The main aim was alignment of the particles from different parts of the input and understanding the movement and separation of wheat particles. Cyclone type was high efficiency Stair and. It was designed in Solid works 2010 and meshed using Gambit software. In Fluent software based on a comparison with experimental results, the second order Reynolds stress model (RSM) was selected as the most appropriate method to model cyclone separation performance. It was found that at ratio of De/D=0.45 resulted high collection efficiency for particle size less than 4mm. In general at high 0.5 the separation efficiency for small seeds (d<4mm) was significantly less in comparison with the other ratios. Results showed that for wheat grains with approximate size of 3 mm and more, the ratio of h/d= 0.75 was the most appropriate option. However, for seeds size less than 3 mm h/d=0.5 was more appropriate. Considering the numerical results of this study, it was found that the smaller outlet diameter cyclone has a high collecting efficiency in comparison with large diameter cyclones.

Keywords: Cyclone’s, wheat grain. separation efficiency.

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Introduction

The application of cyclone in separating solid particles started from 1886 in America, and during these years, comprehensive studies have been undertaken on the subject so that the researchers can act upon based on their needs and conditions.

Pneumatic conveying system has found wide application for agricultural products in the related industry. One of the more secure systems for transporting agricultural products in ports, silos and milling is the pneumatic conveying system. Cyclone is one of the most important components of pneumatic conveying system. Here are some characteristics of the cyclone:

- Simple structure, but causing high centrifugal force
- Low cost to repair, maintenance, fabricate and establish, hence making them unique in the field of their capabilities.
- Ability to work at high temperatures and pressures. With high reliability, they are used in 10 kPa to 107 kPa pressure, and temperatures more than 1000 C°.

Gas and solid particles flow usually enters the cyclone body from the upper wall. Gas inlet duct has usually rectangular cross-section, in some types of cyclones it is circular. The rectangular has this preference that the tangential flow enters the cyclone better. This channel is tangent to the cyclone cylindrical. Inlet gas flow enter either in the forms of tangential, spiral or axial. In fact, the force of separation is caused by a sudden change in direction of input gas stream. Stream gets rotated first in the cylindrical space between the inner surface of the cyclone cylinder and side surface of outlet tube and next in the cyclone chamber, thus creating a vortex environment(3).

To conduct a study on particle separation, let’s consider a Particle in a fluid in cyclone. Cyclones’ calculation formulas are balanced by assuming that the particles move radically (to the side wall of the cyclone), and considering the force exerted on the particle, Centrifugal force and the tension applied by air. When the forces reach equilibrium, the particles are rapidly driven to the wall of the cyclone because of the inertia(19)

One of the most important parameter in the designing of the cyclones is the separation efficiency. It is mean the form of the proportion of collected particles to duct outlet pipe to the total weight of the incoming particles. One reason for the limited use of the cyclone is unavailability of appropriate theory for estimating the separation efficiency of the cyclone. In recent years, highly legal regulations of environment protection and the subsequent increase of demand for improving the separation efficiency of the cyclone has necessitated the extensive research for an appropriate theory for determining the cyclone separation efficiency(19).

One of the most important parameters that is considered in the design cyclone is cyclone’s pressure drop. The smaller the diameter and larger the height of the cyclone, the higher the separation efficiency. However, proportional to this, the pressure drop increases which is an undesirable effect. Therefore we always have to optimize between decreasing the pressure drop and increasing the separation efficiency(5).

Over the past half century, many researchers have been undertaken in the field of gas flow in a cyclone, with inputs, outputs, and different discharges. A large amount of experimental data, such as the work done by Ter linden (18), Stairmand (17) and Linoya (15) are dedicated to the cyclone efficiency, leading to the semi-empirical equations that have been widely used. Experimental work has been done since then, including the work of Kessler and Leith (13), Hoffman *et. al*.(11) and Kim and Lee (14), in conjunction with the improved performance of the cyclone. Experiments conducted on core cyclone are found in the papers by Ter linden (18), Abrahamson *et al*.(2) and Hsieh and Rajamani (12).

All researchers agree that, when air enters the cyclone tangentially, scrolls down to produce an external vertex that twists down, after reaching the particles collecting in cyclone core, it rises to the top and exits. Harasek *et. al*.(9) have reported that with a smaller diameter pipe, the probability of having an axial flow reversal at the core of the cyclone decreases. Xiang *et. al.* (20) investigated the diameter of the dust outlet tube of cyclone on its performance. In this study, extensive experiments were done on cyclone diameter of the dust outlet tube, and some models were analytically evaluated and it was ultimately concluded that the collection efficiency and the pressure drop decreases with increases the diameter of dust outlet tube.

Using laser detection. Obermair *et. al*.(16) investigated the effect of manner of connecting barrel to conical section of the cyclone and concluded that if a piece of pipe is added between the lower conical portion of the cyclone and the barrel the separation efficiency will be increased.

Based on the RSM(Reynolds stress model)model. Fredrickson(3) investigated the reduced diameter of vortex finder. Hoffman *et. al*.(11) studied the effects of the cyclone height on the separation efficiency and pressure drop experimentally and theoretically by changing the height of the barrel. Experimental were accomplished as the barrel height to its diameter ratio increased from 2.65 to 6.15. It showed an improvement in performance of up to ratio of 5.5 and after that it decreased. They concluded that the decline in the performance of separation occurs due to natural circulation phenomena.

Abrahamson *et. al*.(1) studied the effects of the cyclone inlet flow and showed how performance varies with different inputs, they showed that a spiral inlet can modify efficiency. Hoekstra (10)analyzed the intensity of turbulence, boundary layer thickness and lift force on the particles, they concluded that the separation efficiency decreases with increasing turbulence intensity, and reducing the thickness of the boundary layer increases efficiency. They also found that the lift force affects only on fine particles and can increase the residence time of particles.

By analyzing the experimental and the exact solution, Yoshida *et. al.*(21)studied the effects of secondary flow on the performance of the cyclone and concluded that adding a high speed secondary flow in the upper part and in the symmetry of the input current, the collection efficiency increased significantly.

Creating a model using computational fluid dynamics (CFD) methods, by which the pneumatic separation of some agricultural products such as wheat in a pneumatic transfer system (negative-positive pressure) to be described and understood. But in general, some of the important objectives this research are as follow:

1. Finding the impact of the cyclone inlet and outlet dimensions on the cyclone separation efficiency

2. Alignment of the particles from different parts of the input and understanding the movement and separation of solid particles

3. Finding the most important factors that influences the separation efficiency

Materials and Methods

Cyclone was designed based on cyclone classification standard. It was Stair and high efficiency type cyclone. In this way, all geometric dimensions of the cyclone are constant fraction of the cyclone diameter, design parameters are in the form of Q/D^2, the ratio of the inlet gas flow rate to the square of the diameter of the inlet duct. With having this ratio, all cyclone dimensions were determined (Table 1).Cyclone dimensions given in Table 1 was drawn using Solid works 2010 and with common step suffix entered in Gambit software (Figure 1).

Table 1. Dimensions of the cyclone

D	a/D				b/D	D_e/D	I/D	h/D	H/D	B/D	J/D
	0/5445	0/5	0/25	0/5	0/625		2	4	0/25		0/5

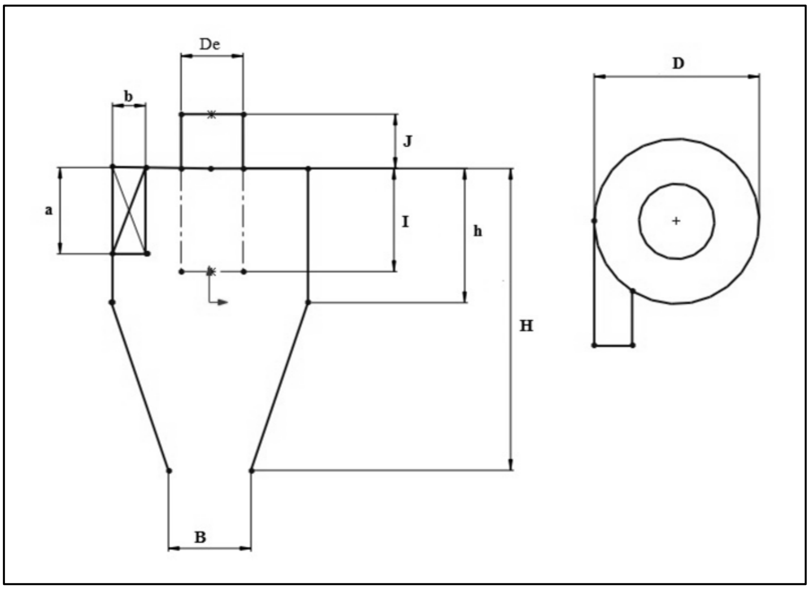

Figure 1:A view of the Stairmand cyclone

A major issue in finite element analysis is to mesh the model properly using appropriate elements such as Hex mesh. Fluent company which is pioneering in software for flow analysis has designed completely professional software for meshing with the name of Gambit. In the present study, cyclone's geometry has been interlaced by a hexagon network in combinational form. Hybrid elements were used in case of failure of hexagonal usage. An example of a meshed cyclone is shown in Figure 2. The overall mesh structure in the outer part of the cyclone is hexagonal cells and in the central part is hybrid. In numerical solution, to ensure that the results of the numerical solution are independent of the network, the network needs to be studied which needs a parameter less dependent to time variable.

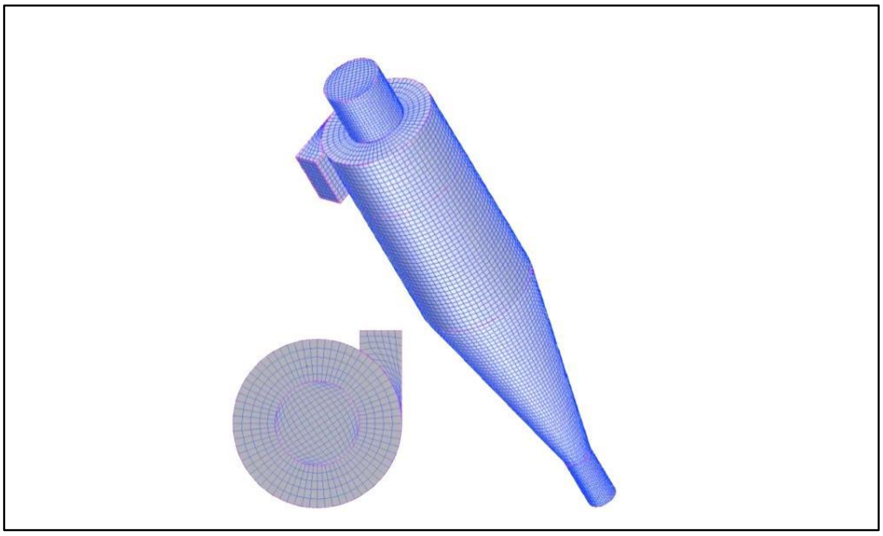

Figure 2. An example of a cyclone grid used in the analysis of primary flow

Tangential velocity shows high differences in network of 48,000 to 120,000 cells (Figure 3), while increasing the number of cells to 230,000 tangential flows didn't show any change in the pattern. This indicates that to study the main flow in the cyclone, a network with 120000 cell number is adequate but to ensure the results, a network with 230,000 grid cells was used, albeit demanding further computing time.

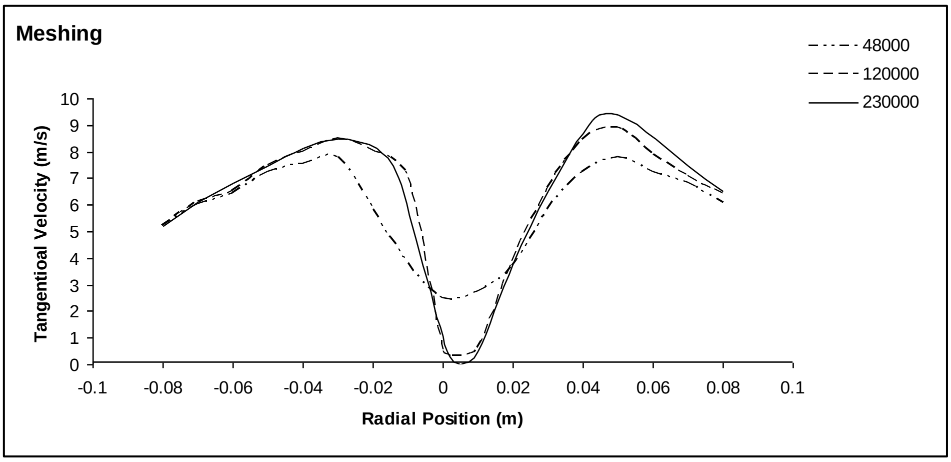

Figure 3.Tangential velocity changes with the number of grid cells

However, in order to increase the accuracy of the solver convergence, multigrain methods are also used in FLUENT. Mmultigrid networks, while the numbers of cells in the network are very high significantly decreases the number of iterations and the CPU time required to access convergence. Two types of multigrain net works are available in the software. Multi-grid method of AMG and FAS. FAS method used only if you use the density-based solver, and if the pressure is elected, this method cannot be used. While AMG method can be used for both. According to the explanation that was given to the state, Solver based on pressure and then separated algorithmic appropriate for the solution of the inner current of the cyclone.

RSM the most widely-used turbulence model was used for modeling the cyclone current, however has some disadvantages, such as the complexity of the calculations (5 and 19). Based on Figure 4 it was found that among the methods presented in this study, the second and third order

Reynolds stress methods predicted flow pattern with appropriate accuracy, due to less calculations of 2nd order model was used in this study. Figure 4 shows that the second and third order models are able in estimation of the tangential velocity than the other models. These models, in addition to estimation the compulsory vertex created in the middle of the cyclone, they estimated semi-free vortex environment in perimeter of the cyclone (distance between the vortex finder and barrel). Of the other points in this figure, the asymmetry in the patterns of the tangential velocity, minimum of tangential velocity has not been on the center of the cyclone (R=0)

This implies that in cases where the experimental reference for comparison is not available, the estimation second level RSM model has been used as a reference for comparison in this essay which is consistent with Gimbun *et al.* (5) and Wang *et al*.(19).

The model selected for tracing wheat particles

To predict the distribution of wheat in the vortex flow, Lagrange and Euler techniques were adopted. The initial works by Chu and Yu (4)and Gosman and Ioannides (6)indicated that the Lagrange method has considerable success at detailing pressure vortex distribution of wheat grains. It was reported that the path of 3×10^5particles should be identified so that statistically a good solution for flow even in the 2 dimensions in the cyclone to be obtained by this method Wang *et. al*.(19).

To increase the use of this knowledge in the industry new changed models have been proposed for explaining the turbulent motion of wheat grains separation path which required lower number of a grains to be routed. According to the results of the recent studies, the discrete phase model was used in this research, after comparing simulation results and

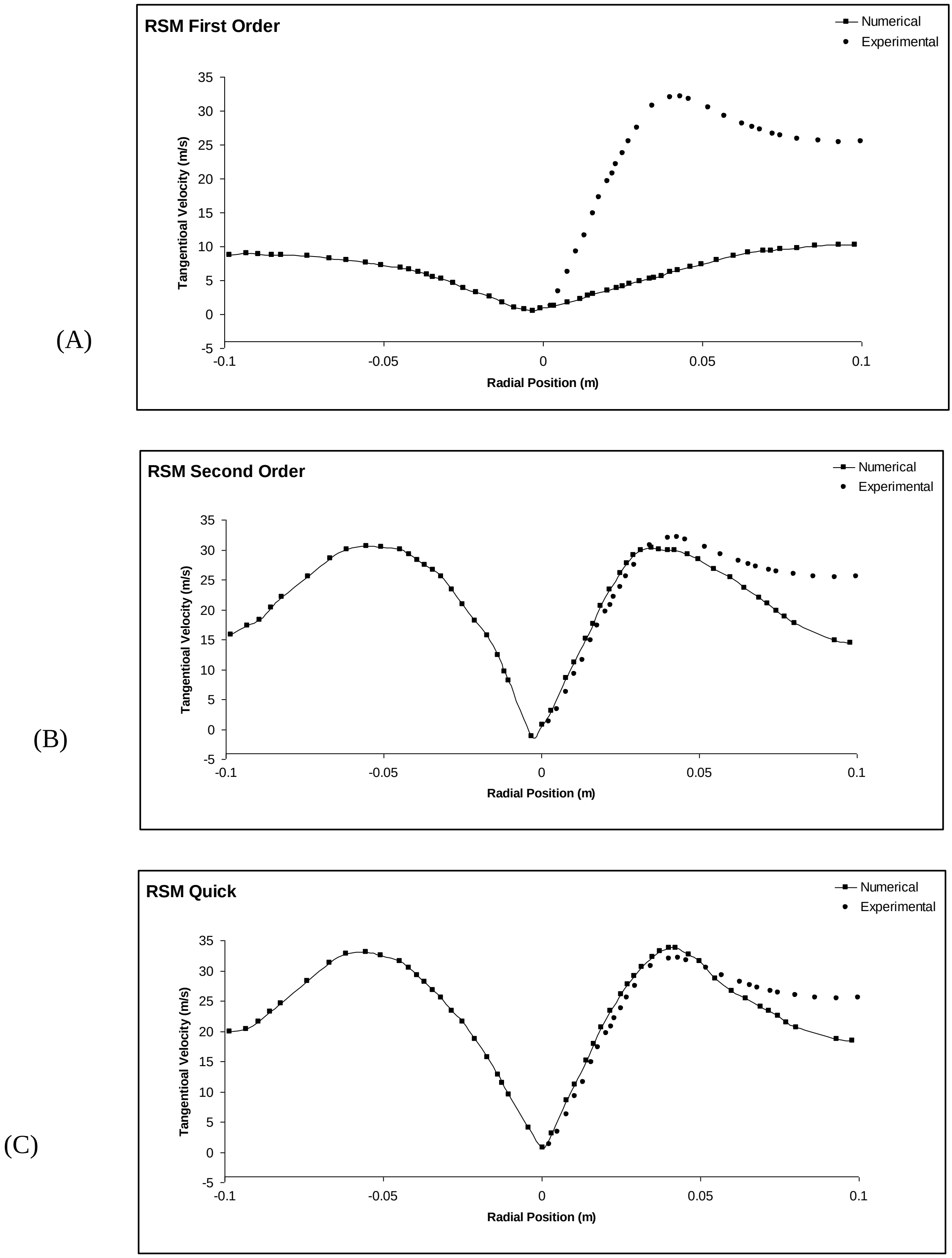

Figure 4:Tangential flow pattern in RSM method

measurements were based on the gas pressure, flow domain and flow pattern confirmed the model in terms of the solid separation efficiency (19).

To model particle distribution, the contrast between the grains of wheat was ignored. Because the dilute phase was considered, hence gravity and the tension of the gas flow in the grain were computed. The tension of the gas was assigned into two parts: one part was computed by the average speed of flow and the other part by gas spreading speed was obtained. Momentum equation of a particle in a two-phase flow at an unspecified temperature was presented as follows (19).

$$\frac{du_p}{dt} = F_k\left(\bar{u} + u' - u_p\right) - g \qquad (1)$$

$$\frac{dv_p}{dt} = F_k\left(\bar{v} + v' - v_k\right) + \frac{w_p^2}{r_p} \qquad (2)$$

$$\frac{dw_p}{dt} = F_k\left(\bar{w} + w' - w_p\right) - \frac{v_p w_p}{r_p} \qquad (3)$$

In which:

F_k = Coefficient of momentum transfer, 1/s

g = Acceleration due to gravity, ms^{-2}

r_p = Radius of the particle, m

t = Time, s

$\bar{u}$ = Average velocity in the direction of the axis, ms^{-1}

u_p = Velocity of the particle in the direction of the axis, m s^{-1}

$\bar{v}$ = Average velocity in the radial direction, m s^{-1}

v_p = Particle velocity in the radial direction, m s^{-1}

$\bar{w}$ = Average velocity in the tangential direction, m s^{-1}

w_p = Velocity of the particle in the direction of the tangent, m s^{-1}

F_k is momentum transfer coefficient between the wheat grains and air flow is calculated as follows:

$$F_k = \frac{18\mu}{d_p^2 \rho_p} C_D \frac{\mathrm{Re}_p}{24} \quad (4)$$

Drag coefficient is given as follow:

$$C_D = \begin{cases} \dfrac{24}{\mathrm{Re}} & \mathrm{Re}_p \le 1 \\ \dfrac{24\left(1 + 0.15\,\mathrm{Re}_p^{0.687}\right)}{\mathrm{Re}_p} & 1 < \mathrm{Re}_p \le 1000 \\ 0.44 & \mathrm{Re}_p > 1000 \end{cases} \quad (5)$$

$$\mathrm{Re}_p = \frac{d_p \rho_g \left| \vec{\varphi}_g - \vec{\varphi}_p \right|}{\mu} \qquad (6)$$

Respite Reynolds number of particles. φ can be u, v and w when the particle in reaction with flow vortex u' ‘v' ‘w' can be obtained with sampling of the distribution anisotropic Gaussian with standard deviation of $\sqrt{2k/3}$. Particle-vortex contrast in term of time and dimensions should not be greater than the durability and size of the random vortex flow by Wang *et. al.*(19).

Re= Reynolds number

P=Particle index

d_p= Particle diameter, m

This research included two phases of air and solid particles of wheat, the Euler-Lagrange approach has been selected, and since it was dilute phase and particles had no effect on flow turbulence, and according to various sources (Gimbun *et al.*(5) and Wang *et. al.*(19)), discrete phase model was used for routing of particles.

In the present work due to constant temperature, the properties of air flow and solid particles were considered constant. The air was considered as carrier fluid and wheat grains as solid were injected to fluid domain. Both fluid and solid particles properties were presented in Table 2 (7).

Table 2.Properties of the air-solid phases

Phase	Material	$\left(\frac{kg}{m^3}\right)$ ρ	$\left(^0k\right)$T	$\left(\frac{kg}{m.s}\right)$ μ
Fluid	Air	1.225	298	$^{-5}\times101.7894$
Solid	Wheat	1325	298	--

The boundary conditions in this problem are the inlet velocity, outlet pressure and wall conditions. Note that only the velocity component normal to the surface of the control volume is important for the inlet mass flow rate. For the inlet surface, the density is considered to be either constant or in a pressure and temperature-dependent function. The value for the fluid inlet velocity (air) is assumed to be 23 m.s^{-1}, to convey the wheat grains (8).

For the cyclone simulations in this study, the outlet flow from the cyclone was assumed to be discharged to the suction tube with the relative pressure equal to -20 kPa, as the outlet pressure. As the viscous fluid was assumed in this study, there was a no-slip condition at the walls. Therefore, the relative velocity between solid walls and the fluid was zero.

Results and Discussion

In this part, cyclone geometry changes on axial and tangential velocity, and also on separation efficiency were studied. The Table3, based on the geometric parameters of Figure 2, introduces the dimension analysis cyclone in this study.

Effect of the diameter of Vortex Finder

Table (3) shows that the De/D ratios of 0.5 , 0.45 , 0.4and 0.35 were introduced respectively as Case A, Case B, Case C and Case D. Figure 5 shows that maximum separation efficiency of 98% was related to 0.45 ratio. The ratio of De/D=0.45 resulted high collection efficiency for particle size less than 4mm. In general at high of 0.5 the separation efficiency for small seeds (d<4mm) was significantly less in comparison to the other ratios.

Table 3. Introduction to the study of the geometry of cyclones

	D	a/D	b/D	D_e/D	I/D	h/D	H/D	B/D	J/D
Case A	0/5445	0/5	0/25	0/5	0/625	2	4	0/25	0/5
Case B	0/5445	0/5	0/25	0/45	0/625	2	4	0/25	0/5
Case C	0/5445	0/5	0/25	0/4	0/625	2	4	0/25	0/5
Case D	0/5445	0/5	0/25	0/35	0/625	2	4	0/25	0/5
Case E	0/5445	0/5	0/25	0/5	0/75	2	4	0/25	0/5
Case F	0/5445	0/5	0/25	0/5	1	2	4	0/25	0/5
Case G	0/5445	0/5	0/25	0/5	1/5	2	4	0/25	0/5
Case H	0/5445	0/5	0/25	0/5	0/625	0/5	4	0/25	0/5
Case I	0/5445	0/5	0/25	0/5	0/625	0/75	4	0/25	0/5
Case J	0/5445	0/5	0/25	0/5	0/625	1/5	4	0/25	0/5
Case K	0/5445	0/5	0/25	0/5	0/625	2/5	4	0/25	0/5
Case M	0/5445	0/5	0/25	0/5	0/625	2	4	0/374	0/5
Case N	0/5445	0/5	0/25	0/5	0/625	2	4	0/5	0/5
Case P	0/5445	0/5	0/25	0/5	0/625	2	4	0/25	0
Case Q	0/5445	0/5	0/25	0/5	0/625	2	4	0/25	1/5

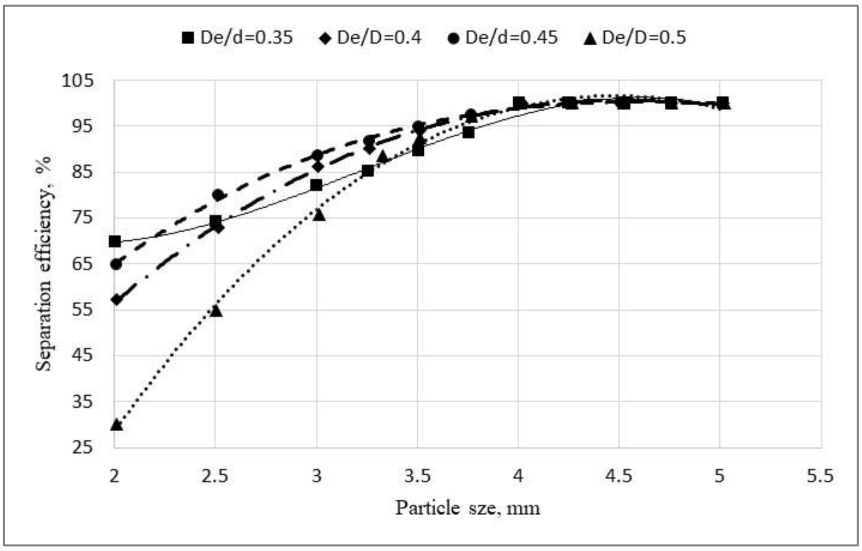

Figure 5. Comparison of the cyclone separation efficiency at different ratios of De/D

To analyze the spectrum of this increments and decrements of separation efficiency, tangential velocity (Figure 6) and the axial velocity (Figure 7) patterns were presented at mentioned ratios. Due to maximum value of tangential velocity was related to the ratio of 0.45, hence this higher separation efficiency was dedicated to that. Although tangential velocity at the ratio of 0.4 was less than that of 0.45, however its tangential velocity was more than the ratio of 0.5. Therefore separation efficiency at 0.4 ratio was between 0.45 and 0.5 ratios separation efficiencies. The variation of separation efficiency at the ratio of 0.35 cannot be justified based on tangential velocity pattern change. Because tangential velocity at the ratio of 0.35 is equal or more than that of 0.5 ratio. The reason for this event can be justified by axial velocity pattern change (Figure 7).

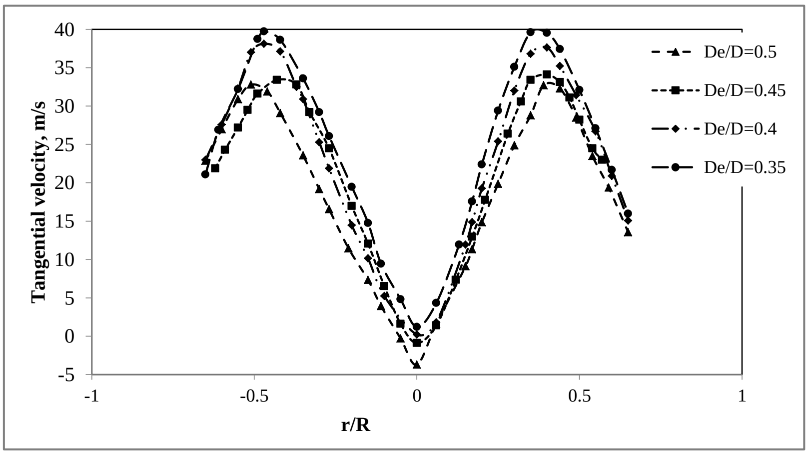

Figure 6. The effects of the reduction of outflow tube diameter on the tangential velocity (Z=0.66 m)

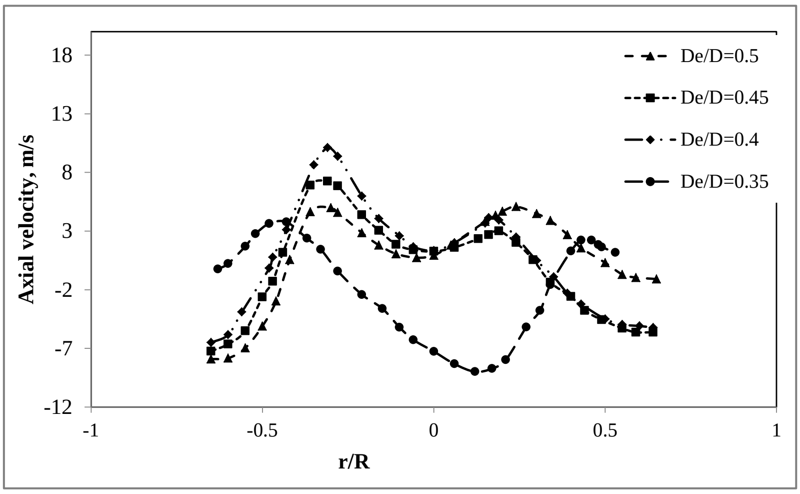

Figure 7. The effects of the reduction of outflow tube diameter on the axial velocity (Z=0.66 m)

It is obvious that the axial velocity patterns show that all patterns had the same trend except the proportion to 0.4. But in the ratio of 0.35 this trend is suddenly transformed and the predicted axial patterns are changed. In this ratio, in comparison with the previous scenarios, the axial velocity patterns show a positive axial velocity near the wall. This indicates that current flows upward near the Cyclone wall. Also, in the middle of the cyclone, the flow accelerates towards the lower sections and together with a high axial speed approaching to wheat grain collector. Such a high-speed stream will never be seen in previous structures. Small wheat grains are affected by drag forces and centrifugal force has a little impact on them. High central velocity (Figure 7) by dragging small wheat grains to the grain collecting outlet can be a factor in increasing small seed separation efficiency.

In the case of coarse wheat grains, the mechanism is very interesting. Centrifugal force was more effective on these wheat seeds, hence wheat grains are pulled out of the center of the cyclone to the walls as they come down. In this area wheat grains meet a rising upward stream and instead of moving to the collecting outlet they move to the outflow pipe, this decreases the separation efficiency. This mechanism should lead to a sharp decline in the separation efficiency of wheat grains, but the rising stream in the outflow tube is blocked and re-moves into the cyclone center and some of these wheat grains are redirected to the wheat grain collection outlet.

To prove this physical analysis, the path of a sample particle has been shown in two ratio of 0.35 and 0.5, respectively. Figure 8 shows the path of a single seed inside cyclone during separation process at the ratio of 035. In this ratio, the large grain of wheat goes out from the center to the cyclone wall due to centrifugal force and rising upward along the wall. In top section, the flow is blocked and goes down again and goes to the middle of the cyclone and repeatedly this operation happens until the particle has finally been able to discharge to the dust outlet pipe. This reduces the seed separation efficiency of coarse wheat grains and also increases the corrosion rate in the upper areas of the cyclone.

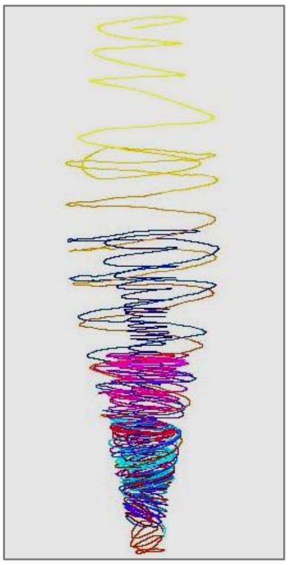

Figure 8. The path of a single wheat grain inside cyclone during separation process (De/D=0.35)

Figure 9 shows at the ratio of 0.5, the sample particle goes down to the lower part of the cyclone, and in this part it trapped in the central vertex is released from the outflow pipe by central stream.

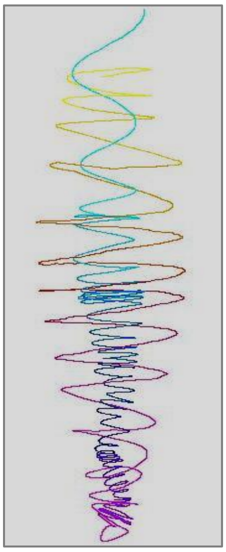

Figure 9. The path of a single particle during separation process at the ratio of 0.5

The effect of vortex finder length (I)on the separation efficiency

By changing the length of the vortex finder, the reviewed cyclones in this section, in Table 3, are introduced as Case A, Case E, Case F and Case G.As it is obvious, in ratios of 0.5 and 0.75 which axial and tangential flow patterns are almost inconsistent and the separation efficiency showed similar trend(Figure 10). But in ratio of 1, efficiency has increased as a result of increasing tangential velocity. In the ratio of 1.5, although the tangential velocity at different intervals did not differ much from the previous states, the cyclone efficiency showed a significant decrease, such a decrement occurs in real situations. In examining the tangential velocity patterns (Figure 11), the tangential velocity decrease in higher sections in the ratio of 1.5 is apparent.

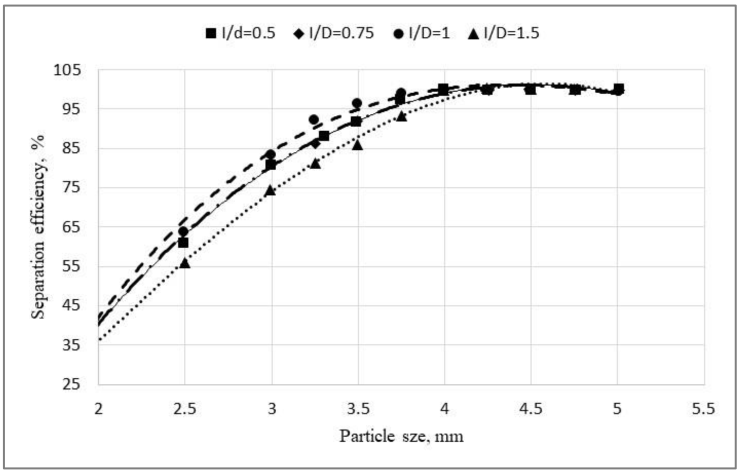

Figure 10: Comparison of separation efficiency cyclone at different ratios of vortex finder length to barrel diameter

This is due to the increase in friction in the ratio of 1.5 and consequently the reduction in the effects of centrifugal force effect of on wheat grains. Another noteworthy point is that the maximum tangential velocity occurs in the radius of the outflow pipe. Therefore, in general, the tangential velocity in the ratio of 1.5 is less effective and because it’s maximum value is within the internal radius of the outflow pipe. The internal whirlwind is not effective in trapping wheat grains at this distance. For example, in Figure 11, at a level of 0.38, the maximum effective tangential velocity in the ratio of 1.5 is about 23 m/s.

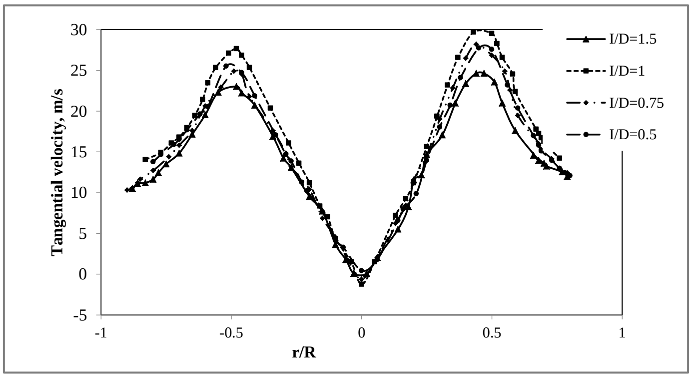

Figure 11. The tangential flow patterns by changing the penetration length of the vortex finder at Z=0.38m

The axial flow patterns induce reduced efficiency in both structures, because there is a high negative velocity near the outflow pipe wall(Figure 12).The downward flow in the bottom of the tube is driven by a uprising stream and this collision can be an important factor for reducing the pressure in these structure and, consequently, reducing the cyclone efficiency (This flow behavior is observed at a ratio of 1.5). Also, this downstream can drain small wheat grains toward bottom outlet, however they are gravitated by the uprising flow which can take wheat away from the outflow pipe of the cyclone. This can be a factor in reducing the separation efficiency of wheat grain in a ratio of 1.5.

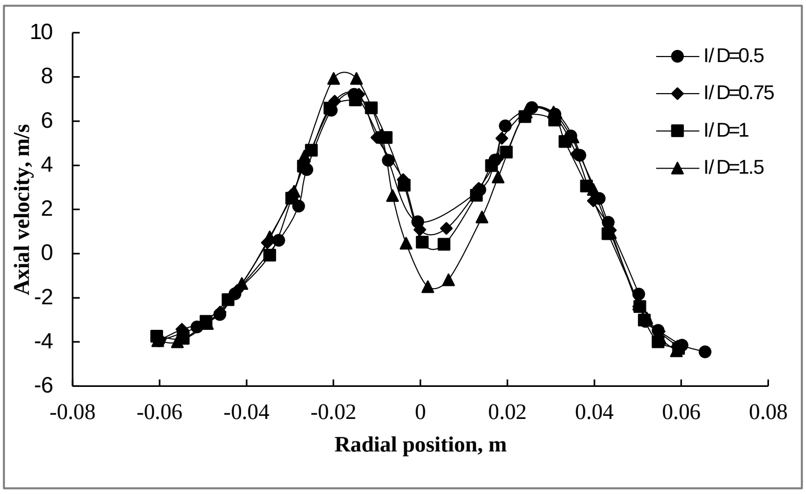

Figure 12. The axial flow patterns by changing the penetration length of vortex finder at Z==0.38 m

The effect of barrel height (h) on the separation efficiency

In this section, by changing the height of the barrel, an attempt is made to obtain an optimal ratio for the efficiency of the cyclone collection (Figure 13).Geometric conditions in these cyclones are presented in Table 3, respectively Case A, Case H, Case I, Case J and Case K, respectively. As shown in this figure, for wheat grains with approximate size of 3 mm and more, the ratio of h/d= 0.75 was the most appropriate option, has been studied among all ratios. However, for seeds size less than 3 mm h/d=0.5 was more appropriate.

Effect of dust outlet diameter on separation efficiency

In this section, by changing the diameter of the dust outlet diameter, its effects on the grain separation efficiency of wheat have been investigated. The cyclones examined in this section are Case A, Case M and Case N in Table 3.Considering the numerical results of this study, it was found that the smaller outlet diameter cyclone has a high collecting efficiency in comparison with large diameter cyclones (Figure 14). These results were consistent with Gimbun et al. (2005) results. The high efficiency is due to the large amount of speed and Reynolds number in the smaller outlet diameters. So the value of this ratio is determined according to the available facilities, but the ideal value of B/D was 0.374 in according of separation efficiency.

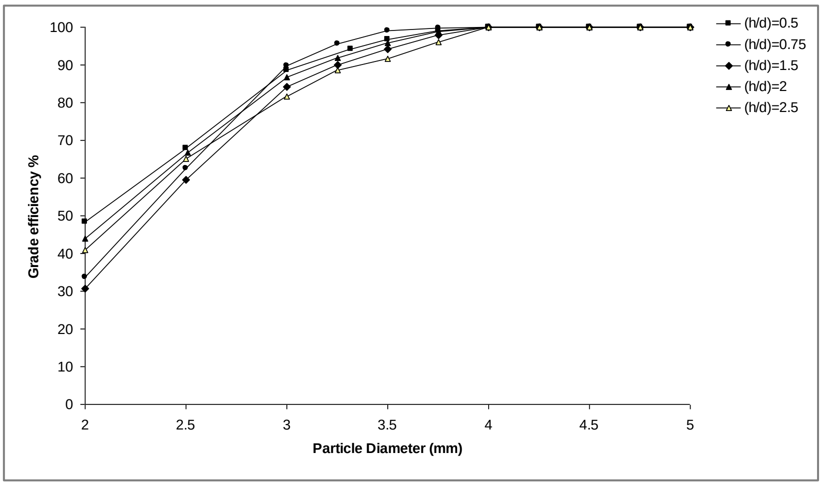

Figure 13. Comparison of effect of changing the height of barrel on separation efficiency

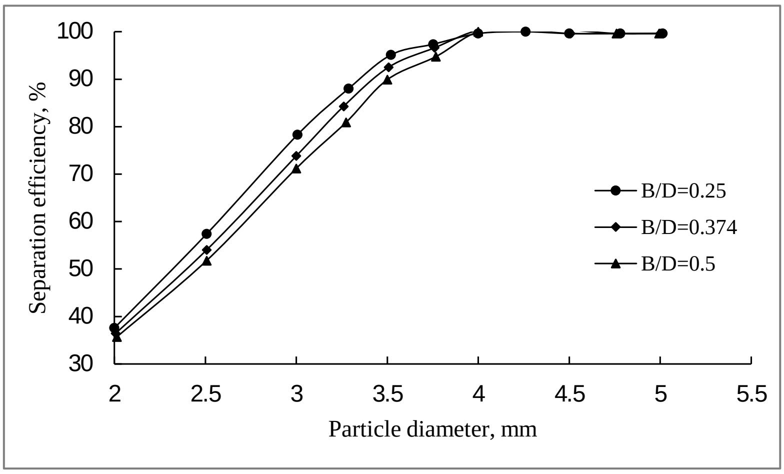

Figure 14. Comparison of the dust outlet pipe diameters on the separation efficiency

Conclusions

The axial velocity patterns showed a reasonable trend by decreasing the ratio of outlet flow diameter to the barrel diameter to 0.4. But in the ratio of 0.35 this trend is suddenly transformed and the predicted axial patterns are changed. In this ratio, in comparison with the previous scenarios, the axial velocity patterns show a positive axial velocity near the wall. This indicates that current flows upward near the Cyclone wall. Also, in the middle of the cyclone, the flow accelerates towards the lower sections and together with a high axial speed approaching to wheat grain collector. Small wheat grains are affected by drag forces and centrifugal force has a little impact on them. High central velocity by dragging small wheat grains to the grain collecting outlet can be a factor in increasing small seed separation efficiency.

In the case of coarse wheat grains, the mechanism is very interesting. Centrifugal force was more effective on these wheat seeds, hence wheat grains are pulled out of the center of the cyclone to the walls as they come down. In this area wheat grains face a rising upward stream and instead of moving to the dust outlet they go to the gas outlet pipe. This decreases the separation efficiency. This mechanism should lead to a sharp decline in the separation efficiency of wheat grains, but the rising stream in the flow outlet is blocked and re-moves into the cyclone center and some of these wheat grains are redirected to the wheat grain collection outlet.

By changing the diameter of the dust outlet diameter, its effects on the grain separation efficiency of wheat have been investigated. Considering the numerical results of this study, it was found that the smaller outlet diameter cyclone has a high collecting efficiency in comparison with large diameter cyclone. The high efficiency is due to the large amount of speed and Reynolds number in the smaller outlet diameters. So the value of this ratio is determined according to the available facilities, but the ideal value of B/D was 0.374 in according of separation efficiency.

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