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NUMERICAL STUDY OF COMPARISON THE EFFECT OF FRICTION AND RESTITUTION COEFFICIENT ON SEPARATION EFFICIENCY OF CYCLONE

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ABSTRACT

Numerical modeling of cyclone on separation process was developed to increase the efficiency of collection. In terms of increasing the accuracy, this researsh was conducted to observe comparison in between the effect of coefficient of friction (COF) and restitution (COR) on the effeciency of colection. This reseacrh was using ANSYS 17 to simulate cyclone in 3D geometry. Where the variation of COR was 0,0.5 and 1 while the COF was 0,10,20 and 120. The result shows COR has not correspondence to the efficiency of collection but COF has inverse correspondence. Hence, the more friction on the cyclone surface, the more resistant sand particle to go down.

Keywords: *friction; restitution; cyclone; numerical; CFD.*

1. INTRODUCTION

Numerical modeling uses CFD over this decade has continued to increase. This is because CFD is a tool to predict an experiment without having to make the set-up first so that it can reduce research costs. In addition, CFD can also be used to understand phenomena that occur where limited tools are difficult to detect.

Several studies have used CFD as dictated method to explain such physical phenomena, including the PCM melting [1,2], flow stream in *cyclone* [3], water turbine in micro-hydro and others.

Prior research has used CFD to investigate such flow stream in cyclone. DEM (*Discrete Element Modelling*) recently has been used to seek sand particle flow stream model [4,5]. This research is used to predict separation efficiency on the cyclone. The same research without using DEM has been used to predict separation efficiency as well. It shows that separation efficiency is directly proportional to diameter of sand particle. But in case of small diameter (1-2 micro) gives unproportionally separation efficiency [6].

From previous research Coefficient of Friction (COF) and Coefficient of Restitution (COR) has not been investigated to find out their effect on cyclone performance. Therefore, this research will investigate the effect of COR and COF on separation of efficiency. This result will engage interaction between wall and sand particle and hopefully it will aid how to find out the appropriate roughness of the cyclone wall.

2. METHODS

In the Figure 1 shows the methodology of this research. At first, using SOLIDWORK 16 as software tool to make geometry of the cyclone and the geometry is shown in the Figure.2.
The configuration of Boundary Condition (BC) used in this research such as inlet, outlet, wall trap and wall are described in the Table 1.
In the Figure 2, the mixture air and sand particle stream are flowed into inlet to outlet where the sand particle is separated into wall trap and the fresh air comes out to outlet.

The modeling of this simulation using Discrete Phase Material (DPM) to engage interaction between sand particle (discrete) and air (continue).

2.1. Research Methodology

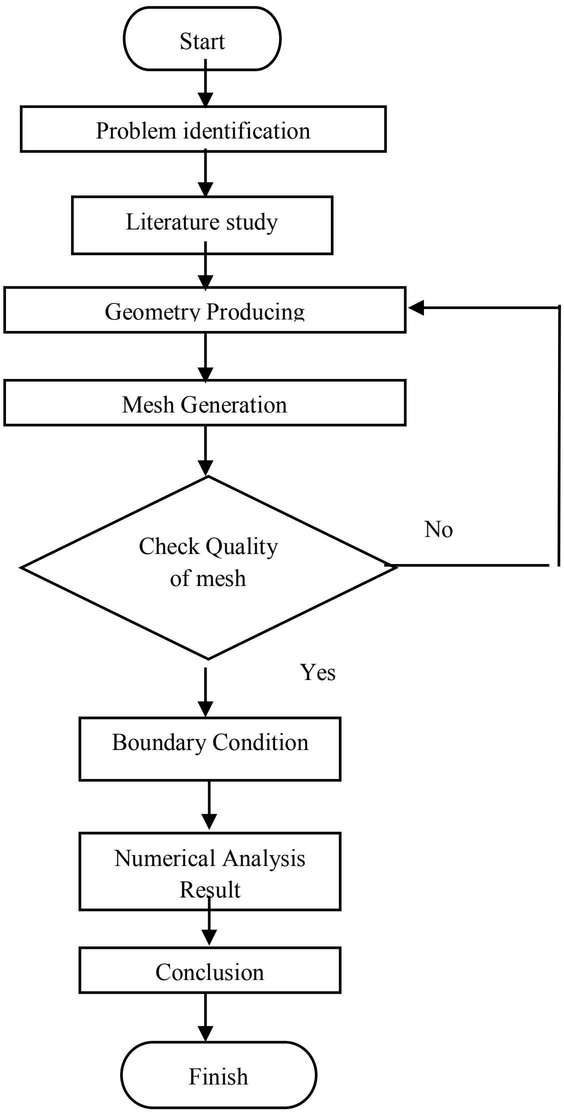

Figure 1. Research Methodology

The assumption of cyclone wall is isolated since the impact of heat from ambient is neglected. Wall trap is special wall that counts the amount of sand particle which is through this wall. this calculation will be used in the separation efficiency of cyclone.
Mesh generation uses ANSYS meshing and it produces tetrahedral mesh with skewness 0.8. this mesh is appropriate since the maximum of skewness is 1. The mesh of geometry is shown in the Figure 3.
Velocity inlet of mixture stream is constant at 2 m/s and turbulency model used in this simulation is k-ε.

Results that are described in this simulation are velocity contour, pressure contour and pressure loss. These results will be elaborated later on after this session.

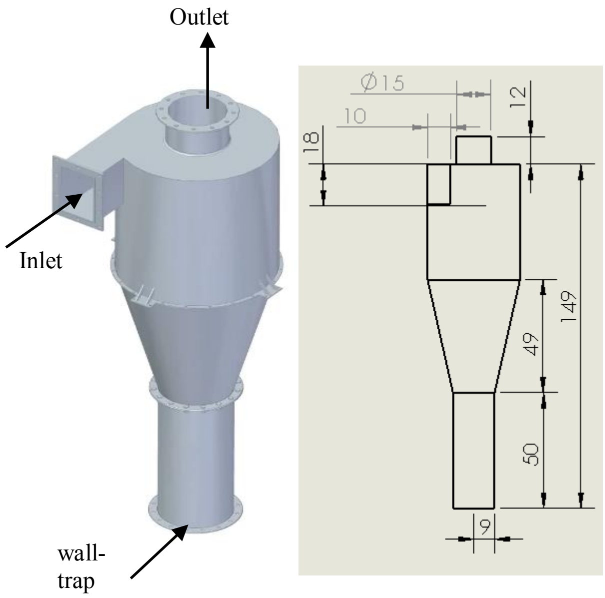

Figure 2. Geometry model and the measurement of the cyclone in mm

2.2. Configuration of Simulation

The governing equation that will be engaged in this simulation are mass and Navier-Stokes only since there is no heat transfer in this phenomenon. The governing equations are described in the following [7].
Mass governing equation:

$$\nabla v_i = 0 \tag{1}$$

v_i is the velocity component in three direction with the assumption of flow stream incompressible and steady state.

Navier-Stokes equation:

$$\frac{\partial \rho v_i}{\partial t} + \frac{\partial \rho v_i v_j}{\partial x_j} = -\frac{\partial \rho}{\partial x_i} + \frac{\partial \rho}{\partial x_j}\left[\mu\left(\frac{\partial v_i}{\partial x_j} + \frac{\partial v_j}{\partial x_i}\right)\right] \quad (2)$$

denoted ρ is density and μ viscosity.

COR equation is described in the following:

$$F_f = kF_n \quad (3)$$

k is COF and the value between 0 and 1 while F_f is friction force and F_n is normal force. The value of k affects the velocity of sand particle when the particle interacts with cyclone wall. COR is the coefficient that affect the resilience of sand particle when they collide to the wall of cyclone.

$$COR = \frac{V_{2n}}{V_{1n}} \quad (4)$$

V_{2n} denotes normal velocity after colliding while V_{1n} normal velocity before colliding. The property of air and sand particle with BC in the simulation are tabulated in table 1.

Table 1. BC properties

BC	value
Inlet	V_{in}= 2 m/s
Wall-trap	*Wall-trap*
Outlet	*Pressure outlet*
Air	ρ=1 kg/m3, Cp=1 kJ / kg.K
Sand Particle	D=1-10 μ m

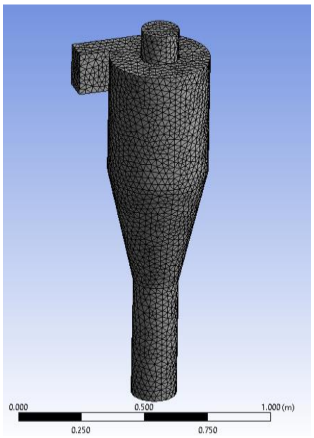

Figure 3. Mesh Generation

3. RESULTS AND DISCUSSION

In this session will be described the results of the simulation such as velocity and pressure contour, separation efficiency, and the last is pressure loss.

In the Figure 4 shows the velocity contour in axial direction. This contour will describe the pattern of velocity in cyclone. Generally, from the Figure 4 shows that flow stream has tendency to go up rather than to go down. It is inherently caused by the geometry of the cyclone.

Comparison of velocity contour between diameter of sand 5 and 10 micro meter with the same COR is shown in the Figure 4.

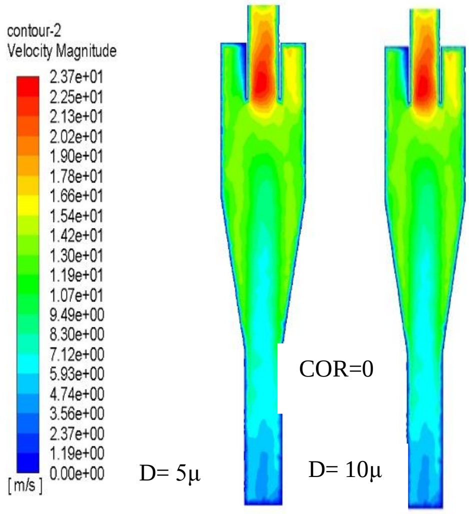

Figure 4. Velocity contour at COR=0

From the Figure 4, the highest velocity gradient is located in outlet while the lowest in region near wall trap. It indicates the resistance flow to go down is bigger rather than to go up. This resistance comes out inherently from the geometry as stated earlier.

The effect of COR on velocity contour is shown in the Figure 5 and Figure 6. The comparison between Figure 5 and 6 shows by increasing COR there is no significant impact to the velocity contour.

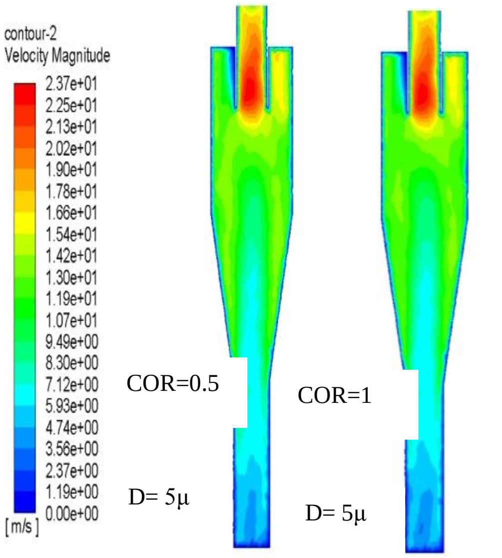

Figure 5. Velocity contour at 5 mikrons

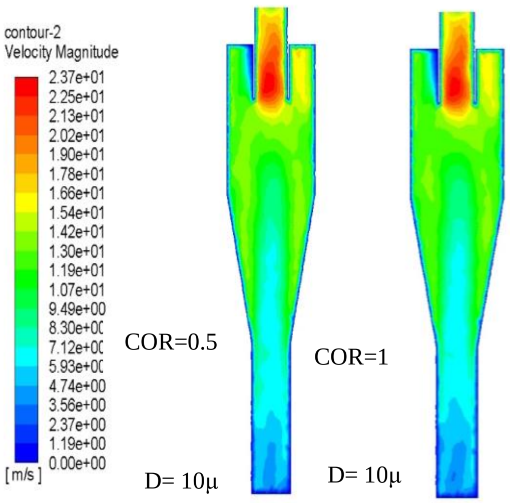

Figure 6. Velocity contour at 10 microns

From Figure 7 shows that the highest COF gives the highest flow resistance since the region of smallest velocity near wall trap is getting bigger. It indicates that COF has directional proportion to flow resistance.

The effect of COF on the pressure loss is tabulated in Table 2. It shows from Table 2 that by increasing of COF will increased the pressure loss. It means that the load of compressor will increase when COF is increased. This correspondence is due to increased friction force will make the major pressure loss is getting bigger.

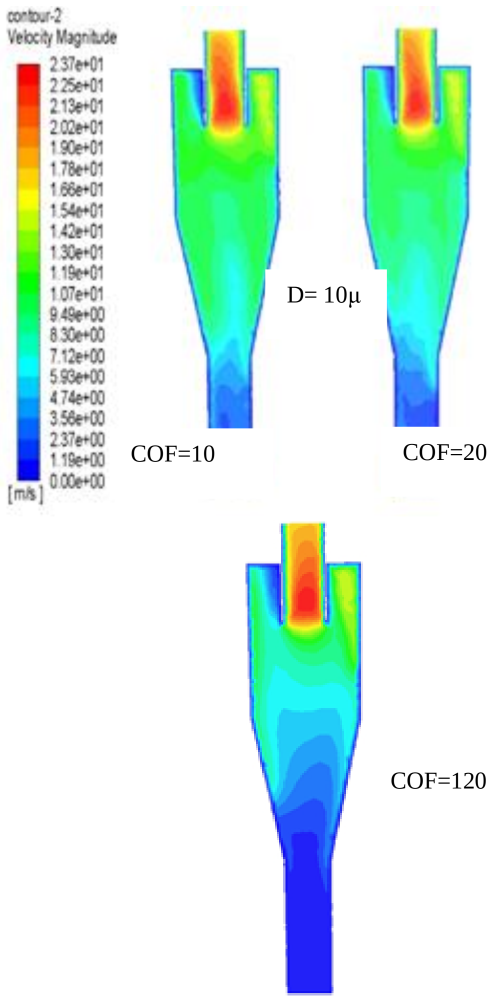

Figure 7. Velocity contour at 10 microns diameter of sand particle

Table 2. Corresponding of COF to the pressure loss at 10 micro meter diameter of particle

COF	ΔP (Pascal)
0	258.27
10	272.63
20	280.88
120	354.63

Table 3 shows the effect of COR to the pressure loss. The increased COR has no significant effect to pressure loss since COR has no correspondence to the velocity as well.

The effect of COF to the separation of sand particle at 10 microns in cyclone is shown in the Figure 8. In the Figure 8 shows that increased COF will decrease the performance of cyclone.

Table 3. Corresponding of COR to the pressure loss at 10 micro meter diameter of particle

COR	ΔP (Pascal)
0	261.81
0.5	261.81
1	261.81

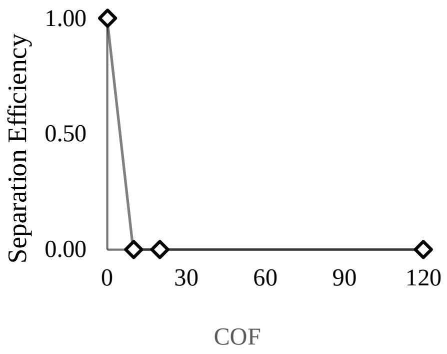

Figure 8. The effect of COF to separation efficiency

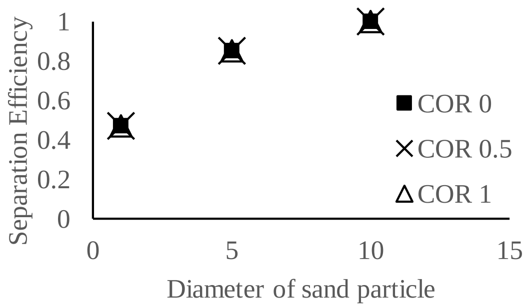

Figure 9. The effect of COR to separation efficiency

It is caused by increasing of COF will increase the flow resistance of sand as well. As the result the sand tends to go up rather than to go down. Hence, the performance of cyclone decreases.

Figure 9 shows that the effect of COR is not significant to separation efficiency. It depicts as increased diameter of sand will increase the efficiency of separation only.

4. CONCLUSION

Generally, the flow has tendency to go up rather than to go down. It is due to the characteristic of the cyclone geometry. The flow resistance has significant impact on pressure loss and the performance of cyclone. It is shown as increased COF, pressure loss and the separation of efficiency are increased as well.

The effect of COR has no significant impact on velocity contour and separation efficiency. Since the resilience of sand particle is only effect on the direction of collision.

This simulation shows prominent result that indicate the important of selection of wall in term of roughness to cyclone performance.

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