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EFFECT OF VORTEX FINDER DIAMETER ON PRESSURE DROP ACROSS THE MR-DEDUSTER CYCLONE

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ABSTRACT

A study on the effect of different vortex finder diameter towards the operating conditions of the MR-deDuster cyclone system had been carried out in a pilot plant scale unit. Two different vortex finder diameters of 90 and 60 mm of four miniature cyclones with axial inlet entry were evaluated for its pressure drop under various volumetric air flow rates. Results showed that the pressure drop varies inversely proportional to the diameter of the vortex finder. The pressure drop across the MR-deDuster was also simulated by using 3D computational fluid dynamics (CFD) via FLUENT 15.0 which clearly illustrated the pressure profile of MR-deDuster.

Keywords— Multicyclone, MR-deDuster, vortex finder, pressure drop, CFD

1. INTRODUCTION

Cyclone was patented for the first time by John M. Finch back in 1885 and called as dust collector. Due to its simple construction, low manufacturing cost, ease of maintenance, compactness, and lack of moving parts, cyclones continued to grow in popularity and improve in both construction and operation nowadays [1]. To date, cyclone is one of the basic classes of particulate collection equipment commonly applied in many industries [2].

As shown in Figure 1, there are four different types of inlet used in gas cyclones that has its advantages and application each: tangential, axial, helical, and spiral [3]. As example, for the tangential entry, the gas is brought in at the side of cyclone to initiate the swirling action. Meanwhile, for axial entry, the gas is brought in at the top and the swirling action is imparted by stationary vane positioned in path of incoming gases [4].

One of the advantages of axial entry is the high degree of axial symmetry in the flow which gives some operational advantages as it eliminates the region prone to fouling on the back side of the vortex finder [1]. Cyclone units with axial inlet entry are commonly used in multicyclone configuration as these units provide higher efficiencies [5].

The main parameters generally being considered in order to carry out an assessment of the design and performance of a cyclone are pressure drop through the cyclone, volumetric air flowrate, and collection efficiency of particle [3, 6, 7, 8]. The total pressure drop across a cyclone consists of losses at the inlet, outlet, and within the cyclone body [9]. The vortex finder size is a crucial dimension which significantly affects the performance of the cyclone [10].

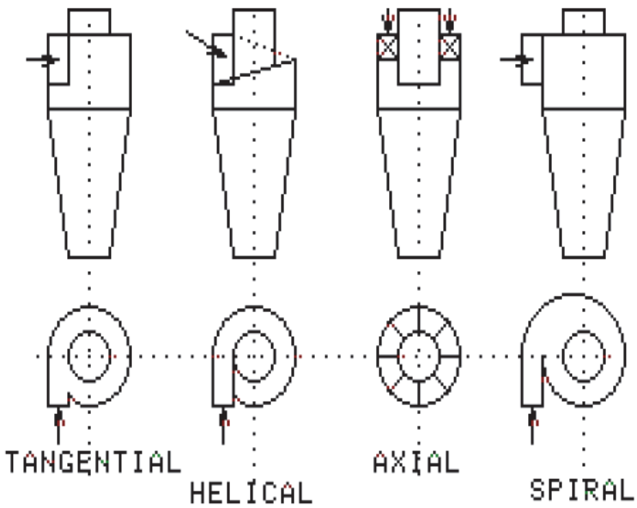

Figure 1. Types of Inlet Entry [3]

A newly developed multicyclone system known as MR-deDuster with axial inlet entry has been tested and reported [4,7,11,12]. However, this paper focused on the effect of changing the vortex finder diameter on the pressure drop across the pilot plant scale of the MR-deDuster unit.

2. METHODOLOGY

2.1. Pressure Drop Across the MR-deDuster

Figure 2 shows the schematic diagram of MR-deDuster arrangement which consists of four miniature cyclones. The unit was designed with axial inlet entry equipped with replaceable vortex finder pipe of any diameter size (designated as D in Figure 3). In this study, a diameter size of 90 and 60 mm vortex finder were used and evaluated.

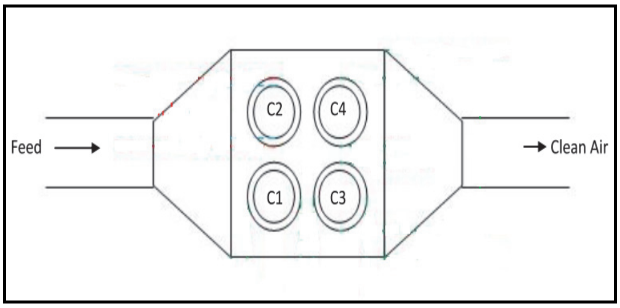

Figure 2. Schematic Diagram of MR-deDuster with Four Miniature Cyclone

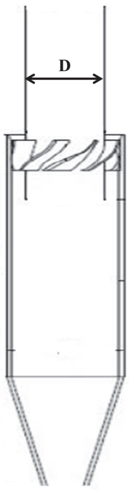

Figure 3. Miniature Cyclone with Axial Entry

The pressure drop across the cyclone was measured by using pressure gauge (Series 2000 Magnehelic® Differential Pressure Gauge) located at the inlet and outlet of the unit. The pilot plant scale of the MR-deDuster is shown in Figure 4.

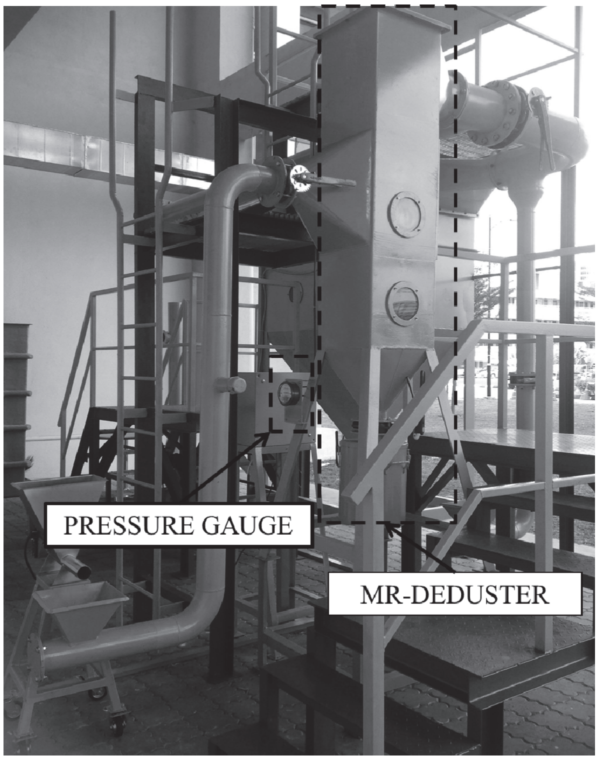

Figure 4. MR-deDuster Unit in Pilot Plant Scale

2.2. CFD Analysis of MR-deDuster

The pressure profile of MR-deDuster was also observed by using three-dimensional computational fluid dynamics (CFD) by using Solidworks and simulated in FLUENT 15.0 to illustrate its pressure contour.

Figure 5 shows the model of MR-deDuster used in CFD simulation with one inlet and four outlet parts.

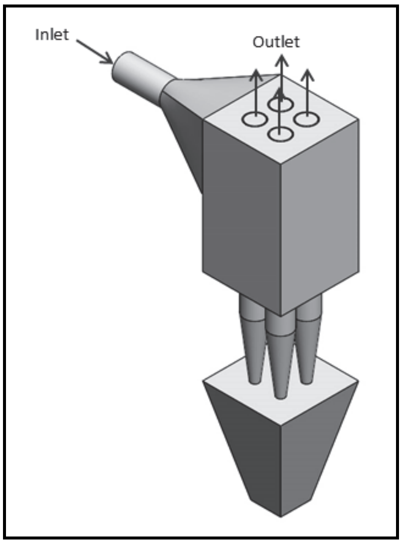

Figure 5. Model of MR-deDuster Unit Used in CFD Simulation

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3. RESULTS AND DISCUSSION

3.1 Pressure Drop Across the MR-deDuster

The pressure drop across the cyclone is directly related to the power of induced draught (ID) fan which is required to operate the cyclone in driving the flue gas through the system [7,8].

Figure 6 shows the relationship between speed of ID fan (frequency) againts the pressure drop across the cyclone.

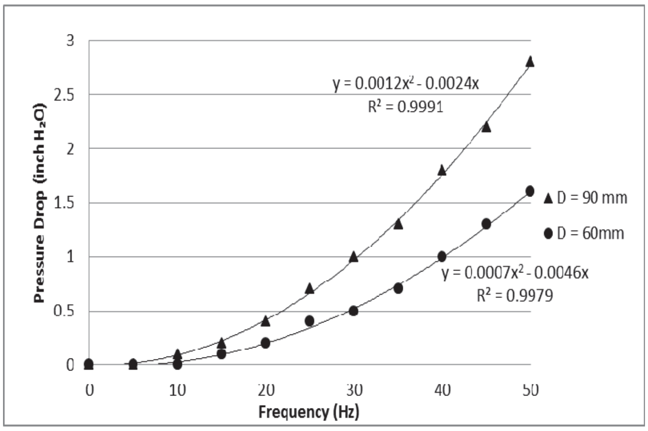

Figure 6. Relationship between Pressure Drop Across the Cyclone of MR-deDuster and Frequency of ID Fan

The highest speed (50 Hz) of ID fan presents the highest pressure drop across the cyclone (2.80 inches of water) as indicated by larger diameter of vortex finder (90 mm). The pressure drop across the cyclone increases directly proportional with speed of ID fan and increasing of diameter of vortex finder. Larger diameter of vortex finder represents smaller area of inlet entry. The speed of the ID fan is basically indicates the air volumteric flow rate passing through the unit, the higher the speed the higher is the air flowing through the unit.

Figure 7 presents the relationship between speed of ID fan (frequency) and air volumetric flowrate passing through the system which showed that there is a similarity in the air volumetric flow rate at a given frequency.

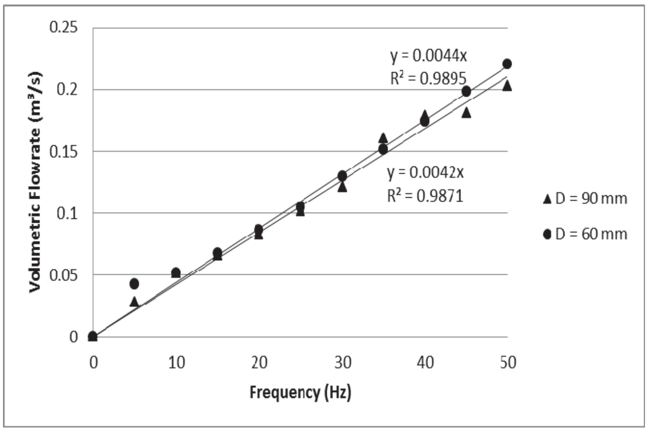

Figure 7. Relationship between Volumetric Flowrate and Frequency of ID Fan

The highest volumetric flowrate obtained from the maximum speed of ID fan for both vortex finder diameter 0.22 m^3/s. The air volumetric flow rate was determined at the stack of the pilot plant using a pitot-tube method.

Figure 8 depicts the relationship between volumetric flowrate in the system and pressure drop across the cyclone. It is expected that the pressure drop across the cyclone increases exponentially with air volumetric flowrate. It is observed and as expected that pressure drop across the cyclone for the bigger vortex finder is higher than the smaller one.

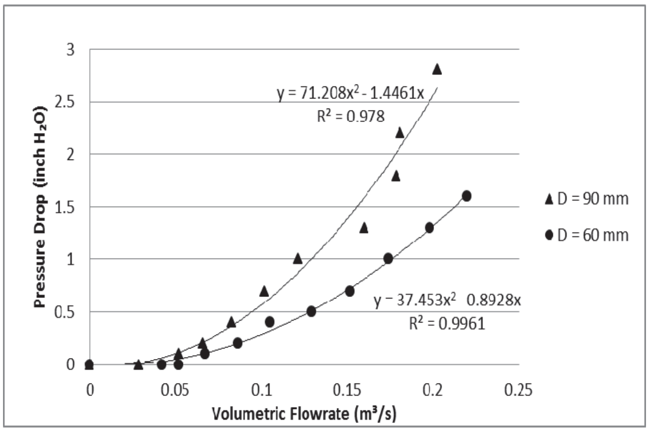

Figure 8. Relationship between Pressure Drop Across the Cyclone of MR-deDuster and Volumetric Flowrate

This is because of the area of inlet entry where the larger diameter of vortex finder presents a smaller area of entry and hence increases the pressure drop of the system significantly especially at the higher air flow rate.

Figure 9 presents the relationship between inlet velocity of the system and pressure drop across the cyclone for two different diameters of the vortex finder which showed that the inlet velocity for larger vortex finder diameter is higher than the inlet velocity for smaller vortex finder due to decreased in the area for inlet entry. In short, the study suggests that the air volumetric flowrate is directly proportional to inlet velocity where higher air volumetric flowrate will increase the inlet velocity, hence increases the pressure drop across the unit.

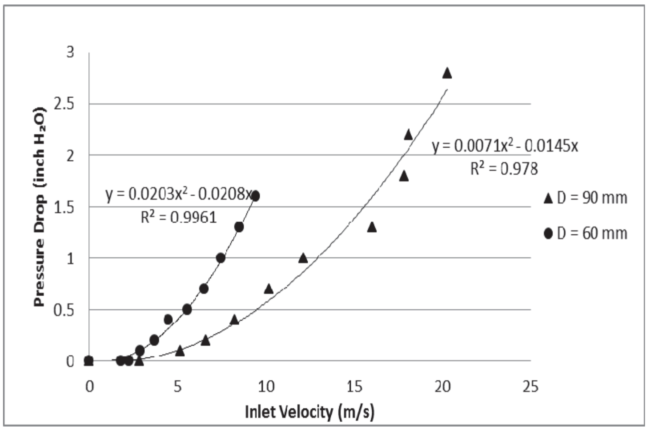

Figure 9. Relationship between Pressure Drop Across the Cyclone of MR-deDuster and Inlet Velocity

As the inlet velocity increases, the pressure drop of the cyclone also increases and a higher inlet velocity not only presents a higher collection efficiency but also increases the pressure drop of the cyclone [7, 9]. Pressure drop and inlet velocity for the system with 60 mm vortex finder diameter seems to be much lower than the system with 90 mm diameter for a given air volumteric flow rates. The maximum pressure drop across the cyclone with 60 mm vortex finder diameter was 1.60 compared to 2.80 inches of water for the maximum pressure drop across the cyclone with 90 mm vortex finder diameter.

Reduction in inlet velocity resulted in reduction of pressure drop across the cyclone hence lowered the energy required. It is important to note that the pressure drop is closely connected to inlet velocity which is a measured of the operating cost of the system [8]. All of the discussed parameters were in agreement with the Equation 1;

$$Q = A*V \qquad \text{Equation 1}$$

Where Q is the air volumetric flowrate of the entire system (m^3/s), A is the inlet entry area of the MR-deDuster (m^2) and V is the inlet velocity of the system (m/s).

3.2 CFD Analysis of MR-deDuster

Figure 10 presents the results of the simulated pressure contour of MR-deDuster with diameter of vortes finder of 90 mm with air volumetric flow rate of 0.19 m^3/s which showed that

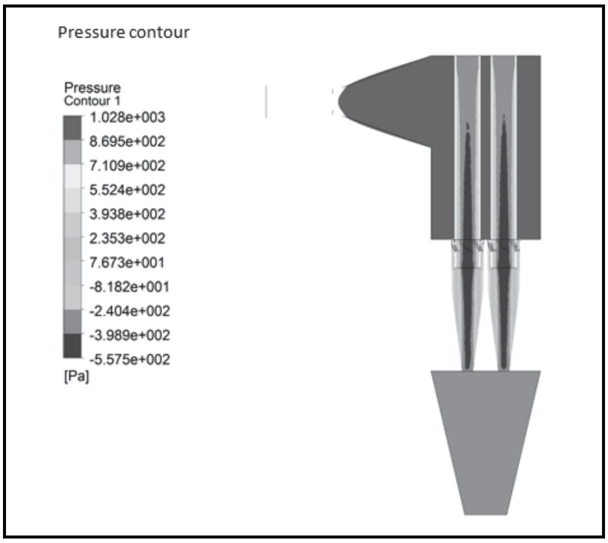

Figure 10. Pressure Contour of MR-deDuster

the pressure decreases radially from wall to the centre and formed a low pressure area at the centre of each unit. While, a higher pressure is at the entry area surrounding the vortex finder outer wall of each cyclone. The CFD analysis simulates the pressure drop of MR-deDuster approximately 1.37 inches of water which indicated low pressure drop measured in the cyclone.

4. CONCLUSION

A study on the effect of different diameter size of vortex finder on the pressure drop across the MR-deDuster cyclone had been presented in this study. A higher pressure drop across the system having a larger diameter vortex finder is due to the reduced in the effective area of inlet entry in each of the unit cyclone. The predicted pressure drop across the system by CFD modeling was able to be measured with clearly profiled of pressure contour.

ACKNOWLEDGEMENT

Both N. Hasyimah and H. Norelyza are post-graduates students of Malaysia-Japan International Institute of Technology (MJIIT) Universiti Teknologi Malaysia. The post-graduates research fellowship from the institution is acknowledged.

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