

Performance of MR-De`Duster in Capturing Low Density Particulate

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Abstract. A newly multi-cyclones named MR-deDuster is developed to capture particulate emission from potential industries. This study aims to assess the performance of MR-deDuster in capturing low density particulate. The tested particulate used in the study is PreKotTM (proprietary of AMR Sdn. Bhd), which is a low density particulate available in the market and commonly used as a pre-coating material with particulate density of $747 \pm 2.2 \text{ kg/m}^3$. Fractional collection efficiency, overall collection efficiency, cut diameter (d_{pc}) and stack concentration were used to determine the performance of unit. The study indicates the unit able to capture about 88% of low density particulate at volumetric gas flow rate of $0.19 \text{ m}^3/\text{s}$. The study has shown that collection efficiency of MR-deDuster increased as the volumetric gas flow rate increased. However, as the volumetric flow rate of gas was further increased to $0.21 \text{ m}^3/\text{s}$, the collection efficiency of the unit was reduced. The optimum collection efficiency was observed to occur at volumetric gas flow rate of $0.19 \text{ m}^3/\text{s}$.

1. Introduction

Cyclone is a commonly used technology especially as an air pollution control separator [1-3]. The technology already evolved more than 50 years and there are numbers of empirical and semi-empirical simulation introduced to simulate the cyclone performance. However, most cyclone theories disable to accurately simulate the cyclone performance [4-6]. Most of the background theories of cyclone only applicable for certain cyclone operating conditions [7]. Therefore, experimental validation is still the most reliable method to assess the performance of a cyclone [7-9]. The theoretical background of a particular cyclone commonly identified based on the actual performance of the unit.

Multi-cyclone is the most widely used in capturing particulate matter due to its advantages such as simplicity of design, lower operating and maintenance cost as well as the ability to work in harsh operating conditions. However, most of current multi-cyclones used are not effective enough to reduce the emission level within the legislative limit at all time. Thus, a study on the development a fine particulate emission control system was carried out to provide a better performance multi-cyclones to meet more stringent emission limits. In this study, the performance of MR-deDuster (a newly



developed multi-cyclone) in capturing low density particulate (PreKot™) was validated and verified via assessment collection efficiency of pilot plant scale of the unit. Four identical prototype cyclones were installed in the pilot plant and the design of these prototype cyclones were based on the optimum configurations. The actual effect of flow velocity on the performance of MR-deDuster also observed via different operation of volumetric gas flow rates. The actual performance test of MR-deDuster pilot plant scale consists of fractional collection efficiency, overall collection efficiency, and cut diameter (d_{pc}).

2. Methodology

The actual performance test of MR-deDuster unit was evaluated based on the performance of the prototype MR-deDuster in a pilot plant scale. The pilot plant was set up by assembled four identical optimum configurations prototype cyclones. The operating conditions of MR-deDuster pilot plant (i.e. volumetric gas flow rate and inlet velocity) was evaluated based on US EPA Method 2 - Determination of stack gas velocity and volumetric gas flow rate (Type S pitot tube).

PreKot™ were used to represent low density particulate. Particulate density, size distribution and morphology of PreKot™ was measured prior to the performance test. Particulate density and morphology were determined using MicromeriticsAccuPyc II 1340 Gas Pycnometer and scanning electron microscopy (Hitachi, Model S-3400N) respectively. While, the size distribution of the particulate was measured using sieving technique (Endocotts Octagon 2000 Digital Sieve Shaker).

The actual performance test of MR-deDuster pilot plant scale consists of fractional collection efficiency, overall collection efficiency and cut diameter (d_{pc}). Several methods were used in determine the cut diameter, fractional efficiency and overall collection efficiency of MR-deDuster as shown in table 1. The performance of MR-deDuster was studied under four different volumetric rates of 0.13, 0.16, 0.19 and 0.21 m³/s at the ambient temperature.

Table 1.Methods in determining the MR-deDuster collection efficiency

Parameter measured	Method/Instrument
Fractional collection efficiency	Sieving method (Endecotts, Octagon 2000 Digital Sieve Shaker)
Overall collection efficiency	US EPA Method 17 – Determination of particulates matter emission from stationary source
Cut diameter	Fractional collection efficiency graph

3. Result and Discussion

Figure 1 shows the experimental fractional collection efficiency of PreKot™ for volumetric gas flow rates of 0.13, 0.16, 0.19 and 0.21 m³/s. PreKot™ was used as particulate tested in this study to represent the low density particulate. As expected, the fractional collection efficiency of PreKot™ increases as the volumetric gas flow rate increases. However, the fractional collection efficiency of the unit seemed to reduce as the volumetric gas flow rate of gas was increased to 0.21 m³/s. This phenomenon was described by Kalen and Zenz [10] as saltation velocity (v_s) where the collection efficiency of cyclone decreases as the flow velocity increases. The reduction in the collection efficiency at the higher flow velocity is due to re-entrainment of particulate. The re-entrainment of the particulate may be due to secondary gas flow as described by various literature [11-13]. The increase of flow velocity may increase the secondary gas flow, which results in acceleration of the velocity at the edge of vortex finder. The gas flow acceleration will force some gases and particulate to move

radially inward toward the vortex finder which the particulate completely escaping the centrifugal action [11].

Besides, figure 1 also illustrates the differences between fractional collection efficiency of PreKot™ is obvious for particulate smaller or equal to 50 μm . Though, the differences of fractional collection efficiency were not clearly seen for coarser particulates of PreKot™. In general, the fractional collection efficiency of PreKot™ for all volumetric gas flow rates tested was much lower than theoretical prediction [1-3]. This may due to physical properties of PreKot™ which consists of porous particulates which have a high tendency of the particulate to break-up during the experiment. This assumption is further support by the SEM image of emitted PreKot™ at stack as shown in figure 2.

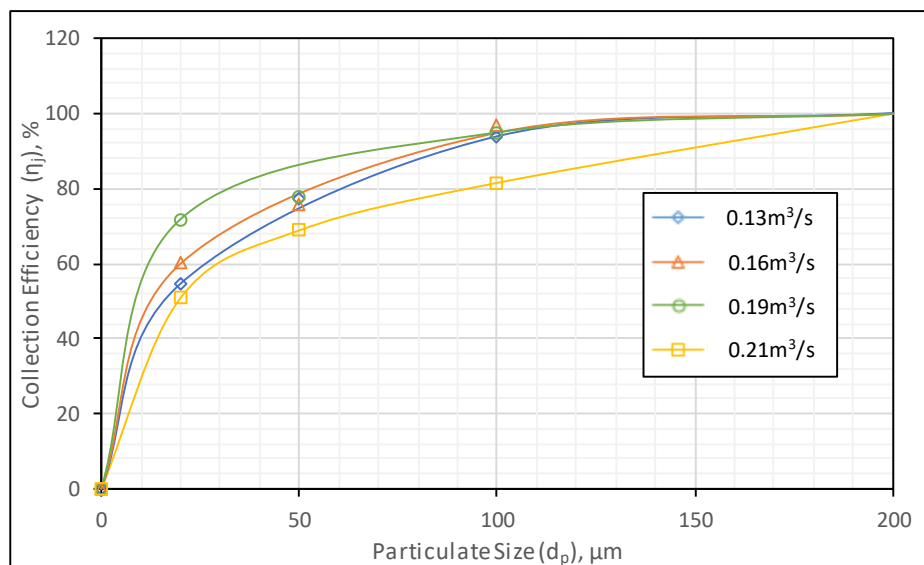


Figure 1. The fractional collection efficiency of MR-deDuster using PreKot™ for volumetric gas flow rates of 0.13, 0.16, 0.19 and 0.21 m^3/s

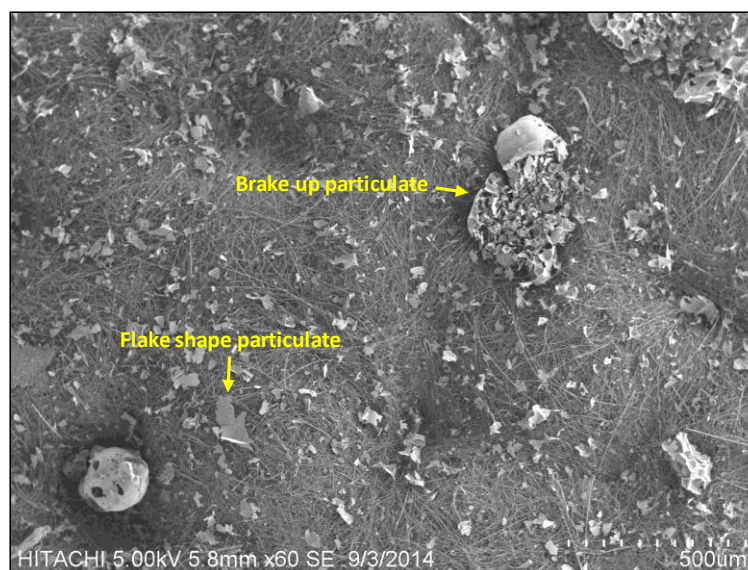


Figure 2. SEM image of emitted PreKot™ at stack

Figure 2 shows the break-up particulate of PreKot™ as compared to its initial morphology of porous eccentric shapes of a loosely pack material (as shown in figure 3) but became flake type shape after the experiment. The break-up of PreKot™ particulate may happen during collision of particulate with the cyclone wall, or collision among particulates during experiment. The turbulent dispersion caused by higher flow rate may also increase the break-up tendency among PreKot™ particulates. This break-up phenomenon changes the particulate size distribution of PreKot™, which is increasing its fine size fraction compared to the initial size distribution before the experimental run. Thus, increasing fraction of finer particulate was assumed to reduce the collection efficiency of PreKot™.



Figure 3. SEM image of PreKot™

Figure 4 and table 2 show the cut diameter of MR-deDuster using PreKot™ for volumetric gas flow rates of 0.13, 0.16, 0.19 and 0.21 m³/s that was obtained from the fractional collection efficiency plotted in figure 1. Indeed, the cut diameter decreases as the volumetric gas flow rate increases. However, the cut diameter starts to increase when the unit operates at 0.21 m³/s. Whereas, the overall collection efficiency of PreKot™ (as shown in figure 5) increases as the volumetric gas flow rate increases and decreases again at volumetric gas flow rate of 0.21 m³/s. The optimum cut diameter and overall collection efficiency was observed to occur at volumetric gas flow rate of 0.19m³/s. The reduction of collection efficiency and the increase of cut diameter of PreKot™ at volumetric gas flow rate of 0.21 m³/s are in agreement with the finding illustrate in figure 1. Thus, it can be concluded that the saltation velocity phenomenon of MR-deDuster unit happens at volumetric gas flow rate of 0.21m³/s.

Meanwhile, table 3 and figure 6 presents the concentration of PreKot™ at the outlet stack of the MR-deDuster pilot plant. The emission of PreKot™ decreases as the volumetric gas flow rate increases from 0.13 m³/s to 0.19m³/s and the emission was increased when the volumetric gas flow rate went up to 0.21m³/s. The lowest concentration of PreKot™ was obtained at volumetric gas flow rate of 0.19 m³/s and the highest concentration obtained at volumetric gas flow rate of 0.21 m³/s with values of 0.42 g/m³ and 0.80 g/m³ respectively.

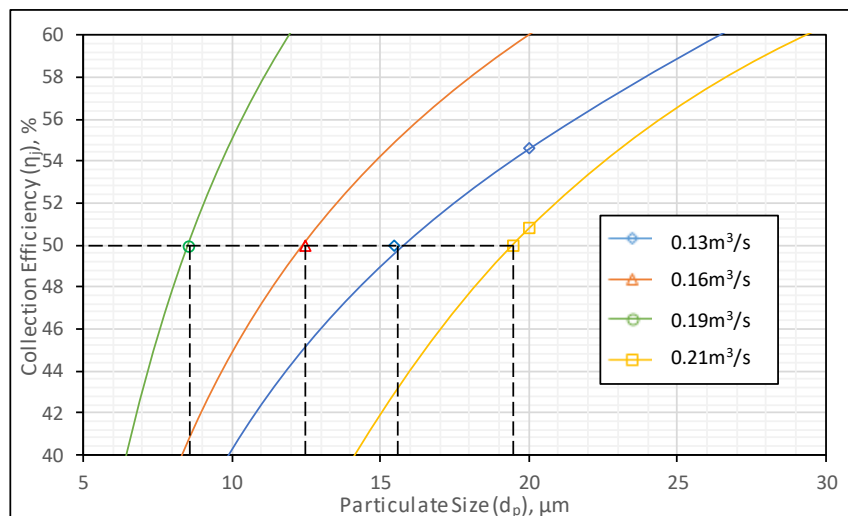


Figure 4. Cut diameter of MR-deDuster using PreKot™ for volumetric gas flow rates of 0.13, 0.16, 0.19 and 0.21 m³/s

Table 2: Cut diameter of MR-deDuster using PreKot™ for different volumetric gas flow rates

Volumetric gas flowrate (Q), m ³ /s	Cutdiameter (d _{pc}), μm
0.13	15.5
0.16	12.5
0.19	8.5
0.21	19.5

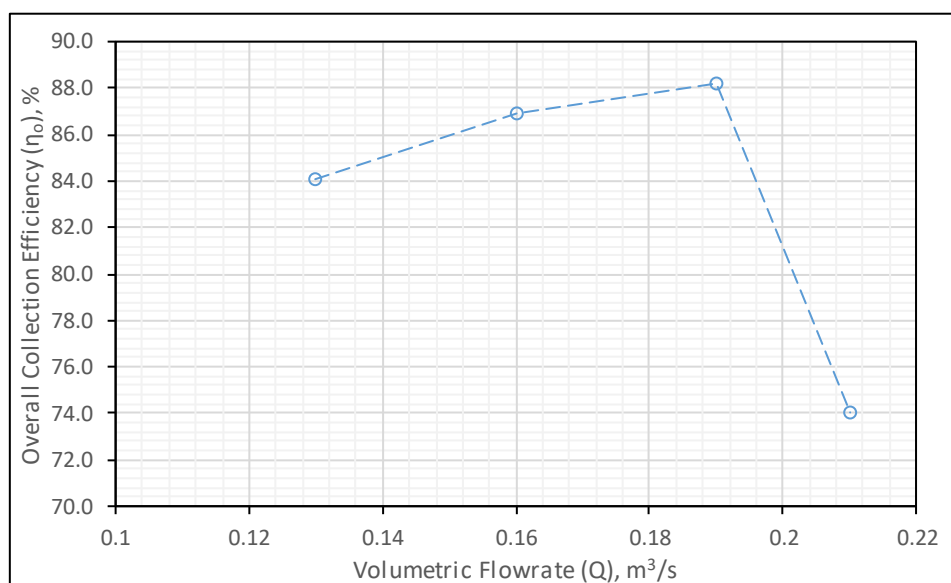
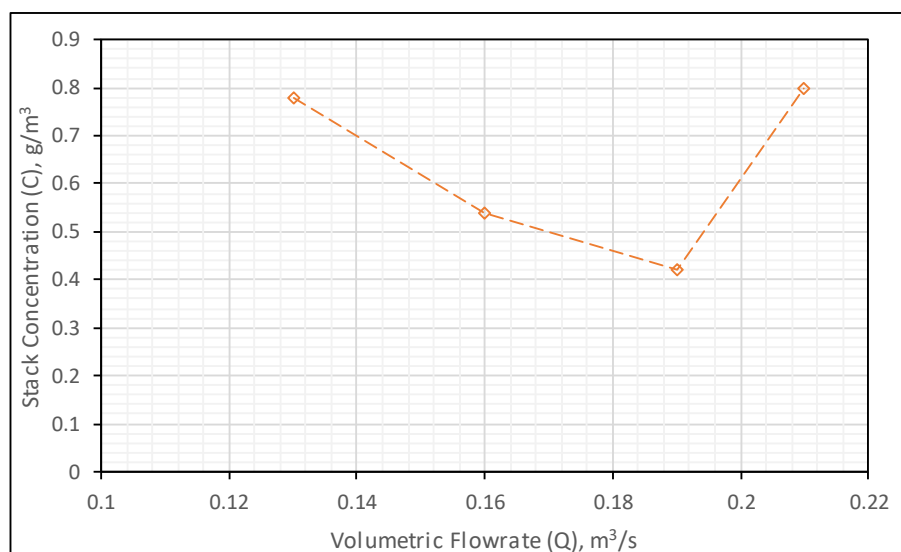


Figure 5. Overall collection efficiency MR-deDuster using PreKot™ for different volumetric gas flow rate

Table 3. Stack concentration of PreKot™ for different volumetric gas flow rates after underwent treatment using MR-deDuster

Volumetric gas flowrate (Q), m ³ /s	Stackconcentration (C), g/m ³
0.13	0.78 ± 0.05
0.16	0.54 ± 0.19
0.19	0.42 ± 0.04
0.21	0.80 ± 0.27

**Figure 6.** Stack concentration of PreKot™ for different volumetric gas flow rates after underwent treatment using MR-deDuster

4. Conclusion

The study has shown that the collection efficiency of PreKot™ increases as the volumetric gas flow rate increase. However, as the volumetric gas flow rate of gas was further increased to 0.21 m³/s, the collection efficiency of the unit seem to be reduced. The optimum collection efficiency was observed to occur at volumetric gas flow rate of 0.19m³/s. The decrease of the collection efficiency at volumetric gas flow rate of 0.21m³/s was attributed to saltation velocity phenomenon where the collection efficiency of cyclone decreases as the flow velocity increases.

Acknowledgments

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