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PD1) Experimental Study of Small Cyclones as Particle Concentrators

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1.INTRODUCTION

This paper describes the effects of varying the minor flow on particle collection efficiency and particle concentration in small cyclones. A cyclone having a minor flow pumped out from its dust outlet is referred to as a virtual cyclone in this study although the terminology has been used for other types of devices (Torczynski and Rader, 1997). The virtual cyclones tested here have a rectangular inlet and circular outlet similar to the conventional cyclone. The only difference between a conventional cyclone and a virtual cyclone is that the latter has the minor flow pumped out at the bottom. Particles can be concentrated in the minor flow (Galperin and Shapiro, 1999) and thus a virtual cyclone can be used as a particle concentrator.

2.EXPERIMENTAL

Two cyclones, one of aluminum and one of glass, were designed and fabricated for this study. Each has a different cylinder height, body diameter and exit tube length. Figure 1 shows the direction of airflows. The minor flow is pumped out from the cyclones dust outlet at the bottom. In order to study the effects of minor flow on cyclone performance, the two cyclones were evaluated under three different operating conditions. First, the inflow (total flow) was fixed at 80 l/min, while the minor flow, starting from 0 l/min, was increased in 4 l/min step up to 16 l/min. Then, the major flow (conventional exit flow) was fixed at 80 l/min, while the minor flow, starting from 0 l/min, was increased in 4 l/min step up to 20 l/min. Finally, the minor flow was fixed at 4 l/min, while the inflow, starting from 40 l/min, was increased by 10 l/min up to 70 l/min. Monodispersed polystyrene latex (PSL, Duke Scientific Corporation) particles ranged from 0.5 to 4.0 mm were used for cyclone performance evaluation. For each tested PSL particle size, the measured geometric standard deviation ranged from 1.10 to 1.16. PSL particles were generated by an atomizer (TSI Inc., Model 9302). The material density of PSL is 1.05 g/cm^3. The particle-laden air was drawn by a vacuum pump through a diffusion dryer, a dilution chamber, and the test cyclone at a desired flow rate. For each particle size and flow rate combination, five replications of particle concentration were alternately measured by the Aerosizer/Diluter combination (API Inc., Model Mach II-LD). Isokinetic sampling probes were used to sample representative particle concentrations at inflow, major flow and minor flow of the cyclone.

3.RESULTS AND DISCUSSION

The concentration factor of the virtual impactor is expressed as the ratio of particle concentration in the minor flow to that entering the impactor. In this study, the concentration factor for the virtual cyclone was calculated similar to that for virtual impactors. It should be noted that the concentration factor curve for a virtual cyclone, shown in Figure 2, looks different from that for the virtual impactor, which is typically expressed as a general S-shaped curve (Wu *et al.*, 1989). Particles larger than 50% cut-off diameter are collected by wall deposition, while small particles follow the major flow without any collection or removal. Thus, the concentration factor shows the reversed U-shaped curve with a maximum in the region of 50% cut-off diameter. While the virtual impactor can concentrate particles larger than the 50% cut-off diameter, the virtual cyclone has potential for concentrating particles within a narrow range near 50% cut-off diameter. It is also shown in Figure 2 that the higher the inflow rate, the smaller the peak concentration particle size and the narrower the concentration factor characteristic curve. In conventional cyclones the interior flow consists of a double spiral: the outer spiral moving down toward the dust outlet and the inner one moving up along the center axis toward the gas exit. While in virtual cyclones, because of the minor flow, there may be a flow layer going down along cyclone wall toward the dust outlet between the cyclone wall and the outer spiral. Intermediate particles reaching this flow region by their inertia, may follow this uniform flow, go down to the bottom and out with the minor flow and thereby be concentrated in the minor flow.

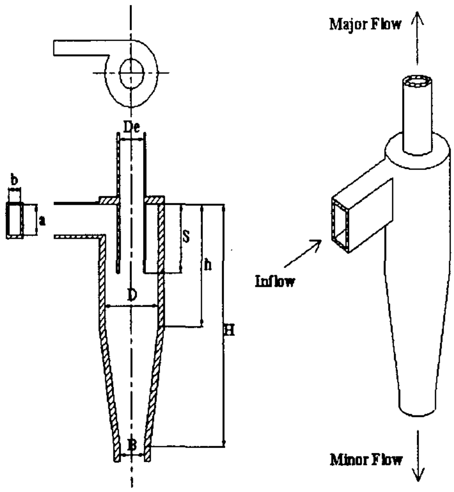

Figure 1. Cyclone flow directions

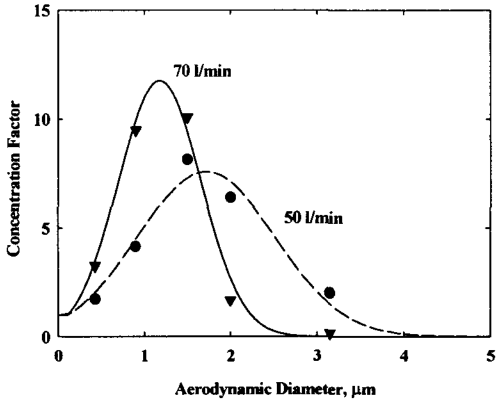

Figure 2. Concentration factor for cyclone

4.CONCLUSION

Particle collection efficiency in a virtual cyclone, which occurs only by the wall deposition, is a little bit lower than that in conventional cyclones. However, compared to conventional cyclones, major flow efficiency for a given particle size in a virtual cyclone is higher and the 50% cut-off diameter is smaller. This is because most of the intermediate particles are concentrated and removed in the minor flow. The cost for gas cleaning using virtual cyclones could be less than that for gas cleaning using conventional cyclones because of the small flow volume of the minor flow containing concentrated particles. The concentration factor of the virtual cyclone had a reversed U-shaped curve with a maximum in the region of 50% cut-off diameter. Thus, the virtual cyclone is able to concentrate particles into its minor flow within a certain size range near the 50% cut-off diameter.

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