Development of Single-Stage, Small-Size Electrostatic Precipitator for High Gas-Velocity with Slit-type Collecting Electrode

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Abstract

In this study, we had developed single-stage, small-size Electrostatic Precipitator(ESP) for high velocity(6~12 m/s) with slit-type collection electorde(CE). Slit-type CE is the SUS plate holed long slit, perpendicular direction of airflow. Through experiments of 4 cases, slit-width CE(0, 5, 10, 20 mm), we had confirmed that slit-type ESP efficiency is higher than original ESP(0 mm slit) in the condition of high velocity conditions(over 6 m/s). Developed slit-type ESP could be utilized for air cleaning system in the subway-tunnel or road-tunnel.

Introduction

Electrostatic Precipitation is usually utilized for cleaning dust at flue gas treatment system in industry, since low pressure loss and low maintenance fee. But ESP should be operated under low gas-velocity conditions (under 2 m/s) because of low efficiency under high gas-velocity conditions. For application of ESP on ventilation system in the subway-tunnel or road-tunnel, ESP size should be small and ESP efficiency should be high under high gas-velocity conditions. In small-size ESP, the collection efficiency is decreasing with increasing gas velocity because turbulent flow is easily growing.

For development of small-size ESP, it had been studied that discharge electrode (DE) is changed from wire-type to plate-type. In this study, we had changed collection electrode (CE) from plate-type to slit-type.

Basic concept

In ESP mechanism, the main force of precipitation is electric force between DE and CE. In the matter of collection efficiency, the flow type is another main factor. In order to capture dust on CE plate, the dust should be in viscous region.

In Fig. 1 uniform stream U moves parallel to a sharp flat plate. In the case of laminar flow, which means low gas velocity condition, the viscous region is very broad and far ahead. But in the case of turbulent flow, which means high gas velocity condition, the boundary layer is very thin and separated between turbulent region and viscous region (Frank M. White). Turbulent region is getting broad, and viscous region keeps thin layer. Therefore the collection efficiency in laminar flow is higher than in turbulent flow.

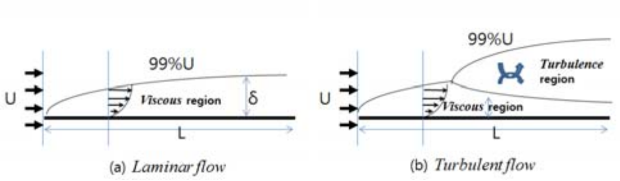

Figure 1. Comparison of flow past a sharp flat plate at low and high Reynolds number

In Fig. 2, contaminated gas moves parallel to ESP. The DE is plate-type and CE is classified into flat-plate type and slit-type. If the gas velocity is high, the turbulent flow is easily growing between CE and DE. But in the case of slit-type CE, the flow would be reunited at the end of broken CE and new boundary layer would be started at the end of slit. It could make less turbulence in ESP, therefore collection efficiency could be raised by slit-type CE.

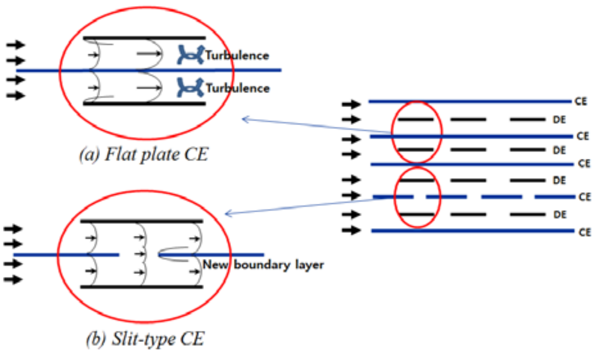

Figure 2. Comparison of flow past a flat plate CE and slit-type CE in ESP

Experimental Setup

After dust is mixed with air at the entrance of test duct, air flow is induced into ESP via perforated plate by induced draft fan (fig. 3). Air velocity (3, 6, 9, 12 m/s) is controlled by induced draft fan power. The particle counters (Grimm model 1.109) measure particles at front and rear part of ESP, simultaneously.

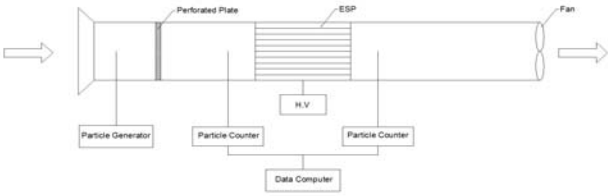

Figure 3. Schematic diagram of the experimental setup

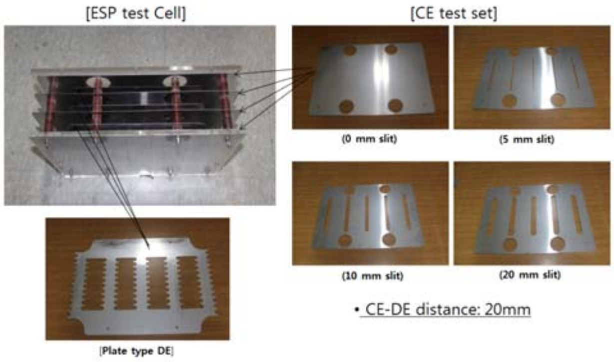

Figure 4. Test ESP cell and components (DE, CE)

ESP is made of saw-plate type DE (3ea) and CE (4ea). The type of CE is 4 cases (0, 5, 10, 20 mm slit width). The size of CE is 120(W) x 295(H) x 410(L). The distance between DE and CE is 20 mm. The voltage on DE is 15 kV.

Result

ESP performance is calculated by collection efficiency as follow.

- Collection efficiency = 1- C_{out}/C_{in}

In fig. 5 (a), the collection efficiency of slit-type ESP is lower than plate-type (0 mm slit) ESP. But the efficiency gap is under 3% at PM1.0. As flow velocity is getting fast, which is over 6 m/s, the collection efficiency of slit-type ESP is always higher than plate-type ESP. Especially, collection efficiency of 5 mm slit-type ESP is the highest under 6, 9, 12 m/s flow. And the efficiency gap is growing according to increasing velocity and smaller particle size.

This result means that slit-type ESP is more efficient for high flow velocity condition. And slit-type ESP is more suitable for cleaning PM 2.5.

Conclusion

This study is for development of single-stage, small-size ESP under high gas-velocity condition with slit-type CE. The conclusion of this study is as follow.

(1) The efficiency of slit-type ESP is higher than plate-type ESP under high gas-velocity conditions.

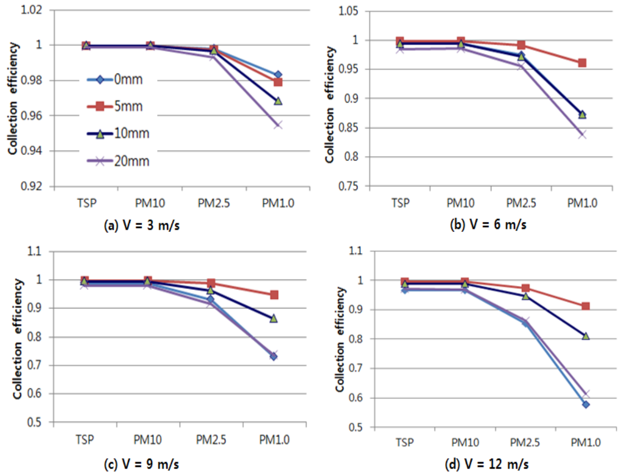

Figure 5. Collection efficiency according to slit width and flow velocity

(1) The efficiency gap between slit-type ESP and plate-type ESP is increasing with gas-velocity and from PM10 to PM1.0.

(2) The best slit width is 5 mm in this study.

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Frank M. White, Fluid Mechanics, MC Grow Hill