Journal of Electrostatics 71 (2013) 1117–1123

Contents lists available at ScienceDirect

Journal of Electrostatics

journal homepage: www.elsevier.com/locate/elstat

Performance characteristics between horizontally and vertically oriented electrodes EHD ESP for collection of low-resistive diesel particulates

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ARTICLE INFO

Article history:
Received 7 November 2012
Received in revised form
10 September 2013
Accepted 3 October 2013
Available online 12 October 2013

Index terms:
Diesel engine
Diesel emission control
Particulates
Marine emission
Electrostatic precipitator
Electrohydrodynamics
Reentrainment
Air pollution control

ABSTRACT

The novel electrohydrodynamically-assisted electrostatic precipitator (EHD ESP) was developed to suppress particle reentrainment for collection of low resistive diesel particulates. The collection efficiency was compared between vertically and horizontally oriented electrodes of the EHD ESP using 400 cc diesel engine. The particle size dependent collection efficiency was evaluated for the particle size ranging in 20 to 5000 nm using a scanning mobility particle sizer (SMPS) and a particle counter (PC). Both horizontally and vertically oriented EHD ESP showed an excellent suppression of particle reentrainment. However, the horizontally oriented electrode EHD ESP showed significantly improved for the particle size of 300–500 nm in comparison with vertically oriented electrode EHD ESP, resulting in more than 90% collection efficiency for all particle size range. The EHD ESP has high potential especially for highly concentrated marine diesel engine emission control.

1. Introduction

The particles emitted from diesel engine exhaust are low resistive in nature and extremely small in the range of 70–120 nm. These particles are penetrated into an alveolus and extremely harmful to human health. These particles are generated from various emission sources such as diesel automobiles, marine engines, power generation engines, and construction machines. The collection of low resistive particles (PM) has been known to be extremely difficult. The low resistive diesel engine particles are detached from the collection plate where the electrostatic repulsion force due to induction charge exceeds particle adhesion force on the collection electrode. This phenomenon has been known as particle reentrainment or resuspension, resulting in poor collection efficiency. The use of diesel particulate filter (DPF) was widely used for the collection of automobile diesel PM but was not economical and cost effective, especially for marine engine emission where PM concentration is often exceed 100 mg/m^3.

The regulation for 3.5 tons automobile diesel particulate matter (PM) emission was 0.7 g/kW h in year 2009. On the other hand, the marine engine PM regulation was not strictly set by MARPOL treaty in 2005. However, PM emission from the ship damaged the exporting new cars during shipment. More stringent regulations are forced by TEER-3 by 2011 and TEER-4 by 2016 (80% of NO_x reduction at the present level).

There are few literature describing the control of particle reentrainment [1–3]. Recently, two-stage ESP i.e., charging field using DC field, followed by the collection field using low frequency AC field including the trapezoidal waveforms in the range of 1–20 Hz has been investigated for the collection of diesel particles in tunnel [4–7], while the conventional ESP utilizes DC high voltage. Several particle trapping design collection plates were reported but

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http://dx.doi.org/10.1016/j.elstat.2013.10.004

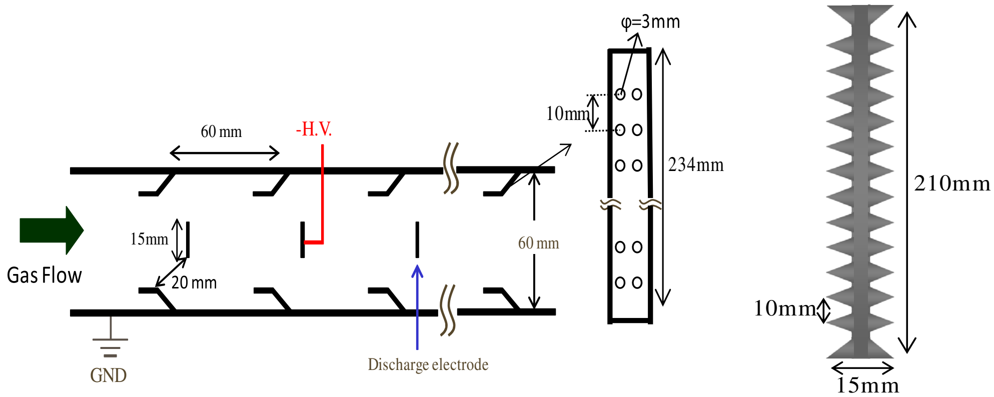

Fig. 1. The vertically oriented electrode EHD ESP configuration.

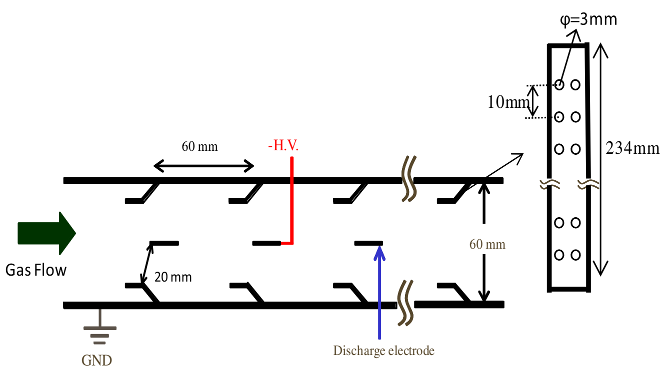

Fig. 2. Horizontally oriented electrode EHD ESP configuration.

were not taken into account the electrohydrodynamics (EHD) to transport the charged particles into the pocket zone [8]. Some ESP manufactures use the corrugated collection plates. However, the primary reason was to increase the strength of large and long ESP collection plates. This design may help preventing trapping loss in the corrugated section but both concepts have limited success for minimizing the reentrainment. Recently, electrostatic flocking filter on the collection electrode was developed to capture fine diesel particles [9]. The wet ESP was another strong candidate for this application but it creates water treatment as opposed to dry process.

Based on fundamentals of reentrainment theory, the new electrohydrodynamically-assisted ESP (EHD ESP) was developed to overcome the reentrainment in the ESP [10–13]. The EHD ESP, which utilizes the ionic wind to transport the charged particles effectively into the zero or low electrostatic field zone (or pocket zone) attached to the collection plate. The captured particles are trapped in the pocket and the particle captured in the pocket zone was exposed to zero electric field, so that no electrostatic repulsion force by induction charge takes place, which is the major contribution for the reduction of particle reentrainment. Obviously, the particle exposed to electrostatic filed experiences the electrostatic repulsion force. The effectiveness of the EHD ESP was demonstrated to show the significant suppression of particle reentrainment [8,10]. Furthermore, the integrated diesel engine emission control to removal PM and NO_x was developed. EHD ESP and nitrogen plasma were used as for PM control and NO_x reduction system, respectively [12]. As an extension of the EHD ESP, the EHD plasma ESP was developed. The PM is effectively captured and at the same time, collected particulates are incinerated by the surface discharge plasma [13].

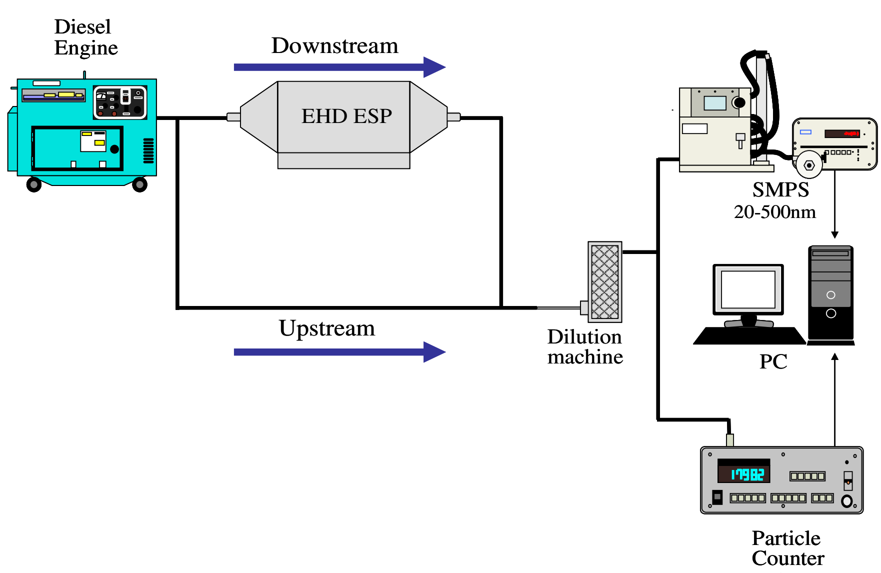

Fig. 3. Schematic diagram of the experimental setup for the conventional and EHD ESP performance evaluation.