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Electrohydrodynamic flow and particle collection efficiency of a spike-plate type electrostatic precipitator

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ABSTRACT

In this work, the results of electrohydrodynamic (EHD) secondary flow and particle collection efficiency measurements in a spike-plate type electrostatic precipitator (ESP) are presented. The EHD secondary flow was measured using 2- and 3-dimensional particle image velocimetry (PIV) method under the negative DC voltage. The PIV measurements were carried out in several cross-sectional planes along and across the ESP duct. The results show a complex and turbulent flow structure in the ESP. The EHD secondary flow significantly depends on applied voltage and measuring cross-sectional plane position in respect to the spike tip. The partial collection efficiency of the ESP was measured for negative and positive DC voltage. The particle concentration with and without discharge was measured at the ESP exit using an optical aerosol spectrometer.

1. Introduction

For several decades electrostatic precipitators (ESPs) have been widely used as dust particle collectors since ESPs have relatively high particle collection efficiency (up to 99.9%) with a relatively low pressure drop. However, the collection efficiency of sub-micron dust particles (of a size typically ranging from 0.1 μm to 1 μm) is relatively lower [1,2] (sometimes less than 50%) due to the mismatching of particle charging and migration velocity.

Sub-micron dust particles which may contain rich toxic trace elements, float for relatively long time in the atmosphere and can easily penetrate into human respiratory system. Therefore, new standards for emission of fine particles are introduced (PM2.5). The existing ESPs have to be modified to meet new standards.

The motion and precipitation of particles in the duct of an ESP depend on the dust particle properties, electrode geometry, electric field, space charge and gas flow field [3]. It has been shown [4–6] that a significant interaction between these factors exists, resulting in considerable turbulent flow structures in the volume between stressed and collecting electrodes. There are evidences which show that the flow turbulences can influence the collection efficiency of fine particles [7,8].

One of the methods to improve the particle collection efficiency in ESPs is to use a spiked discharge electrode [9–11]. However, there were no comprehensive investigations on the electrohydrodynamic (EHD) secondary flow field in ESPs with spike discharge electrode.

This work was aimed at measuring EHD secondary flow in a spike-plate ESP using 2- and 3-dimensional particle image velocimetry (PIV) [12]. Also the particle collection efficiency of the ESP was measured in similar conditions.

2. Experimental set-up

The apparatus used in this experiment to EHD secondary flow measurements consisted of an ESP, a high-voltage supply, and a standard PIV equipment for the measurement of velocity fields (Fig. 1).

The ESP housing used in this work was an acrylic box, 1000 mm long, 200 mm wide and 100 mm high. At the top and bottom of the ESP housing two collecting stainless-steel plate electrodes (200 mm × 600 mm) were placed. In the middle of the ESP the spike electrode (200 mm long, 1 mm thick, and 30 mm tip-to-tip wide) was mounted in the acrylic side walls, parallel to the plate electrodes and perpendicularly to the main flow (Fig. 2). The spike tips were directed upstream on the one side of the electrode, and downstream on the other. The distance from the spike electrode to the plate electrodes was 50 mm.

The negative voltage applied to the spike electrode was up to 27.4 kV, and the time averaged discharge current was up to 260 μA.

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