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Review

Effect of air flow on corona discharge in wire-to-plate electrostatic precipitator

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ABSTRACT

This paper analyses corona discharge in ambient air with laboratory-scaled wire-to-plate electrostatic precipitator (WPESP). The electric field is behind the electro hydrodynamic (EHD) flow in air. Its measurements provide complementary results for the corona discharge study because the classical theory based on the current and voltage data is unsatisfactory. Taking into account the dynamic air flow velocity is perpendicular to the active wires, measurement method of the positive and negative DC corona current density and electric field, has been introduced. It has been shown also that the dynamic air flow velocity modifies the current density and the electric field distributions on the planes surfaces of the WPESP.

Introduction

Electrostatic precipitators are widely used in technology to collect suspended particles in gases using an electrostatic force and they are one of the ways to control air pollution caused by industrial plants. Considerable research has been carried out during the last decades [1–5]. The configuration mostly used in electrostatic precipitation technique is the wires-to-plates. It consists of high-field parallel active wires located midway between the grounded plates (the collecting electrodes) where the air flows through. The ions produced by the corona near the wire load particles of dust that are in the air which are then driven toward the collecting plates. The particle charges are neutralised and the particle are thus collected. Although the geometry is simple, it is noticed that there is a complex behaviour of the air flow. Due to the collision with neutral molecules in the air, there is a transfer of kinetic energy in the flow by the electric field. This secondary flow is called electro hydrodynamic flow or ionic wind. Both electric field and air flow are present and interacting with each other, which makes the analysis of the body force very complex. Thus EHD flow form arrays of large-scale, span-wise, counter-rotating vertical structures [6].

The collection efficiency of the wire-to-plate electrostatic precipitators (WPESPs) depends on numerous variables like the global drift velocity of charged particles to be removed and their distributions, the magnitude and the polarity of applied voltage, the active electrodes radius, the humidity and temperature of the air, etc….

The basic corona discharge physics is well-known and it can be described as a self-sustaining electrical gas discharge occurring at the vicinity of high-field electrodes. In the WPESPs the high-field wires are surrounded by ionisation region where the free charges are produced and a low-field drift region where charged particles derived to the collecting plates. The corona migration region is governed by the Poisson's equation and the current continuity equation. A complete solution of these equations is not simple. For practical applications, therefore, empirical and semi-empirical formulae have a useful function. When the number of wires is high the geometry can be considered equivalent to a coaxial system as described by Cooperman [7], where the equivalent cylinder radius R_e is given by:

$$R_e = \frac{a}{2\pi} e^{\frac{\pi h}{a}} \tag{1}$$

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and the inception field E_i according to the inception voltage V_i at the wires surface is given by:

$$E_i = \frac{V_i}{R \ln \frac{R_e}{R}} \tag{2}$$

where h is the wires-to-plate spacing, a is the half wire-to-wire spacing and R is the wires radius. The Cooperman's model is widely used in the design and evaluation of precipitators.

In this article a new experimental method has been proposed in order to measure the current density and the electric field at the one grounded plates where the velocity of the inlet air in the WPESP is associated. The experimented air is free of particles and the velocity is perpendicular to the corona wires. The primary air flow and the EHD flow modify the distribution of the space charge density and the applied electric field and make the measurements of this field over the collector electrode very complicated.

The introduced method of electric field measurement uses the Tassicker's biased probes [8–11] which are simple circular or linear sensors, incorporated on a same level of surface in a plane electrode biased at a voltage. They can be miniaturised and suitable for DC corona discharge.

Experimental apparatus and design of the probe system

The experimental method aims to obtain new measurements of current density and electric field for positive and negative DC corona in laboratory-scaled WPESP, Fig. 1, and in which the inlet air velocity of the ambient air, free of all particles, is controlled. 13 parallel wires (1) are fixed with two insulating supports (2) and

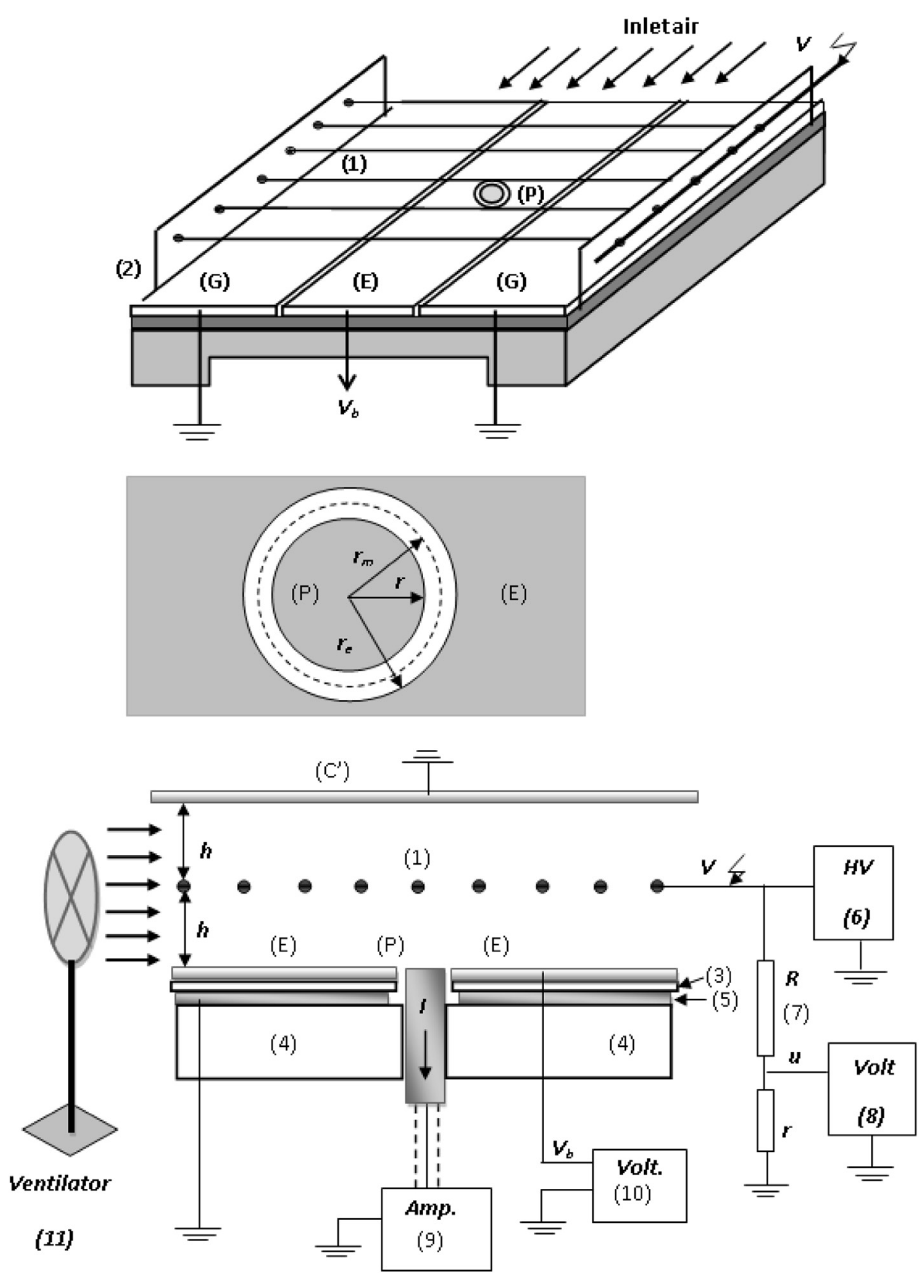

Fig. 1. Experimental assembly with the circular field probe (not in scale). 1: corona wires. 2, 3, 4:Insulating props. 5: screen. 6: d.c. high voltage source. 7: high voltage divider. 8: voltmeter. 9: picoammeter. 10: d.c. low voltage source. *P* probe collector; *E* biased electrode; *G* guard planes; *C′* collector plane.