Study on transient and steady-state processes of corona discharge ionic wind

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Abstract

When a high voltage is applied to the electrode with a higher curvature, an ionic wind is generated between the two electrodes. This study visualizes the ionic wind using tracer particles and uses Particle Image Velocimetry (PIV) techniques to obtain the flow field of the ionic wind, investigating both transient and steady-state processes. The results indicate that during the transient phase of negative corona ionic wind, multiple jets are generated at the needle electrode and move towards the mesh electrode, with subsequent jets exhibiting higher velocities compared to earlier jets. In contrast to the transient ionic wind, the steady-state ionic wind exhibits greater maximum velocities and an extended effective jet range.

Introduction

In the corona discharge space can be divided into two areas. The very small area near the tip of the corona electrode is the ionization zone, where the electric field is extremely strong, reaching up to 10^8 V/m. Another area is the drift region, located between the ionization zone and the grounded electrode. In the drift region, large scale particle collisions induce a macroscopic airflow directly between the electrodes, called ionic wind. Compared to traditional wind generating devices, ionic wind offers advantages such as non-rotating structure, no noise, and long service life. Due to these benefits, ionic wind is widely used in various fields, such as electric propulsion, cooling, and drying.

For the study of ionic wind, most researchers focus on ionic wind velocity [1], efficiency [2, 3], and the electrode structure of ionic wind devices [4], but there is less research on the development process of ionic wind. The development process of ionic wind is divided into transient and steady-state processes [5]. In the process of ionic wind generated by corona discharge, the first generating ionic wind channel between electrodes is called transient process, which usually lasts only a few to hundreds of milliseconds. When the ionic wind develops continuously and stably between the electrodes, it is called the steady-state of ionic wind. Both the study of the transient and steady-state processes of ionic wind are significant for revealing the potential mechanisms of ionic wind.

Hence, this paper investigates the development process of ionic wind using needle to mesh discharge electrode. Ionic wind is visualized with water droplets, and its flow field during the development process is studied by PIV. The mechanism of ionic wind is discussed based on the experimental results.

Experimental Setup

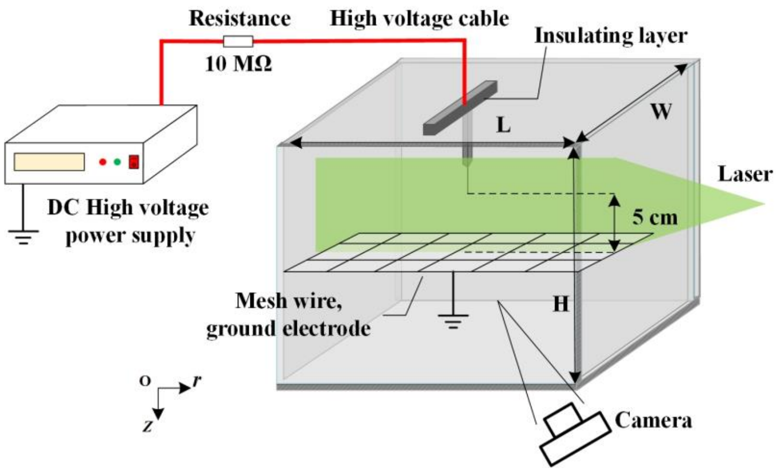

Fig.1 Schematic diagram of the experimental setup. The inner size of box is 20 cm × 20 cm × 20 cm (L × W × H).

The schematic diagram of the experimental setup is illustrated in Figure 1. The experimental apparatus consists of an acrylic box containing needle-to-mesh electrodes filled with air. Tracer water droplets are uniformly dispersed within the box, and these droplets are illuminated using a laser generator (HN-532) with a wavelength of 532 nm. A direct current (DC) high voltage is applied to the stainless steel needle electrode through a 10 MΩ ceramic resistor. The tip of the needle electrode features a curvature radius of 1 mm, while the mesh wire electrode is grounded. The gap between the electrodes measures 5 cm. Throughout the experiment, the temperature is controlled at 25 ℃ and the relative humidity is maintained at 99%.

Images are captured using a high-speed camera (CAMCUBE4) with a maximum resolution of 1960 × 1080 pixels and a maximum frame rate of 1000 frames per second, positioned perpendicular to the laser beam. Particle Image Velocimetry (PIV) technology is employed to obtain the velocity field of the ionic wind during the transient process. For the initial transient process, smoke is used as the tracer particle. The particle size is less than 1 μm, and its effect on the ionic wind evolution is considered negligible. The images are taken at a frequency of 500 Hz using the high-speed camera.

The PIVlab toolbox in MATLAB is utilized to process the raw images. The velocity vectors are computed using auto-correlation and cross-correlation algorithms in PIVlab. The interrogation window is set from 256 × 256 pixels to 64 × 64 pixels, with an overlap of 50%.