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Electrohydrodynamic flow in a wire-plate non-thermal plasma reactor measured by 3D PIV method

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Abstract. This work was aimed at measurements of the electrohydrodynamic (EHD) secondary flow in a non-thermal plasma reactor using three-dimensional particle image velocimetry (3D PIV) method. The wide-type non-thermal plasma reactor used in this work was an acrylic box with a wire discharge electrode and two plate collecting electrodes. The positive DC voltage was applied to the wire electrode through a 10 MΩ resistor. The collecting electrodes were grounded. The voltage applied to the wire electrode was 28 kV. Air flow seeded with a cigarette smoke was blown along the reactor duct with an average velocity of 0.6 m/s. The 3D PIV velocity fields measurements were carried out in four parallel planes stretched along the reactor duct, perpendicularly to the wire electrode and plate electrodes. The measured flow velocity fields illustrate complex nature of the EHD induced secondary flow in the non-thermal plasma reactor.

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1 Introduction

Non-thermal plasma techniques have become an important tool for controlling the emission of various gaseous pollutants, such as acid gases (SO_x, NO_x, HCl, etc.), greenhouse gases (CO_x, N_xO_y, perfluorocompounds, etc.), ozone depletion gases (freons, halons, etc.), volatile organic compounds (VOCs, e.g. toluene, xylene, etc.) and toxic gases (Hg, dioxins, etc.). The main advantages of the non-thermal plasma techniques are small space volume, low cost, high pollutant removal and energy efficiencies.

Ohkubo et al. [1] and Kanazawa et al. [2] found that the removal of NO molecules in a needle-to-plate and corona discharge radical shower (CDRS) non-thermal plasma reactors occurred not only in the streamer corona discharge and downstream regions of the reactors but also in the reactor upstream region. The reason of the NO removal in the upstream region of the reactor was not clear. However, the results of the electrohydrodynamic (EHD) secondary flow (ionic wind) measurements in non-thermal plasma reactors [3–6] suggest that the EHD flow is capable of transporting long-living active species, such as ozone, upstream of the discharge region, where they may react with other species. Hence, if the ozone molecules were transported by the EHD flow upstream of the discharge region in the experiment of Ohkubo et al. [1] and Kanazawa et al. [2], they would be long-live and active enough to oxidize NO molecules and efficiently remove them before they reach the discharge region. Results presented in [1–6] show great importance of the EHD secondary flow on non-thermal plasma reactors operation. Collecting data about flow in non-thermal plasma reactors is important for designing reactors of high performance efficiency. Therefore, there are many numerical works for EHD flow [7–9].

This work was aimed at measurements of the EHD flow in a wire-plate non-thermal plasma reactor. Since our previous results [3–6] only suggested 3-dimensional nature of the EHD secondary flow we measured all three flow components using three-dimensional particle image velocimetry (3D PIV) method [10]. Our measurements were carried out in four parallel planes and showed complex 3D nature of the EHD induced secondary flow and a great importance of the side wall effects.

2 Experimental set-up

The apparatus used in this experiment consisted of a wide-type non-thermal plasma reactor, DC high voltage supply and a standard 3D particle image velocimetry (PIV) equipment for the flow velocity field measurement (Fig. 1).

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