Study of the oscillating ion wind induced by DBD for various O_2/N_2 concentration ratios

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Plasma actuator based on the dielectric barrier discharge (DBD) is a simple electrical device which can be easily integrated in the aircraft structure. DBD allows to achieve significant improvement of the airflow especially for separated flows. These two factors contributed to a significant popularity of DBD flow control research. One of the main mechanisms of the flow influence by DBD is generation of ionic wind. Many studies were devoted to investigate the effect of DBD on a flow (for example review [1]). Moreover there are already some attempts of DBD using in flight experiment [2, 3]. Unfortunately a significant success was achieved only for low Reynolds numbers. To increase the efficiency of the ionic wind production it is necessary to extend our understanding of the plasma actuator operation.

One of the important questions is the process of oxygen and nitrogen ions formation and their influence on the flow. This kind of information may be obtained basing on the force measurements for various concentration ratios of O_2/N_2. It is well known that DBD generates an oscillating ionic wind therefore the measurement technique has to provide time resolved data. In study [4] the thrust produced by DBD was measured and its great reduction was found for low oxygen concentration. The experimental technique used in paper [4] doesn't allow to understand the unsteady processes occurring in the plasma region. PIV technique [5] allows to obtain the distribution of nonstationary volume force produced by DBD with better precision. The current study is devoted to measurements in unsteady flow field induced by single DBD for various concentration ratios of O_2/N_2.

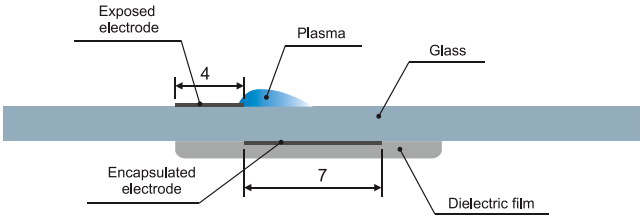


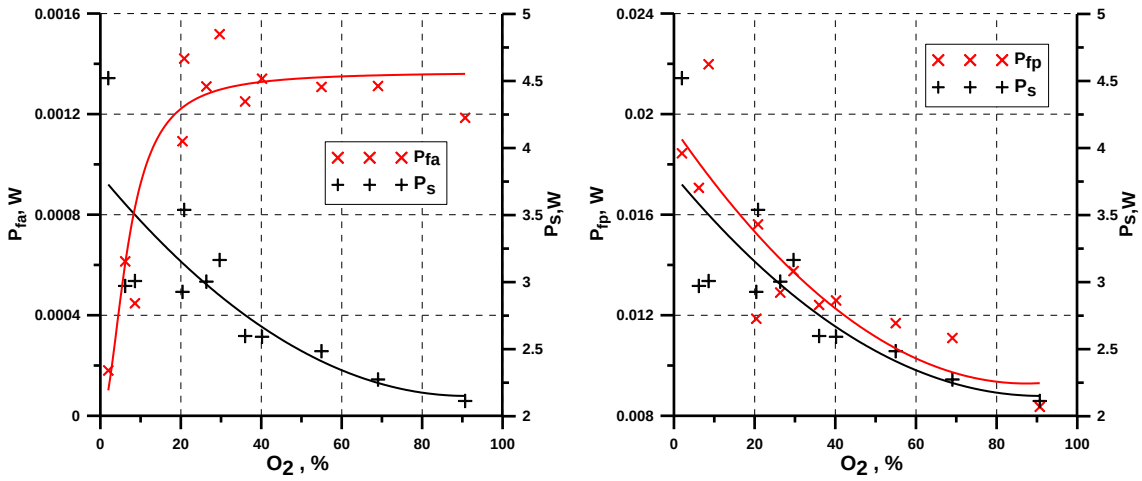
Figure 1 Scheme of DBD

The experiments were done in quiescent environment under atmosphere pressure and room temperature. The DBD scheme can be found in Fig. 1. The distributions of the local acceleration were calculated based on the instantaneous velocity fields obtained by PIV. This technique allowed to estimate the time evolution of the force induced by DBD [5]. The oxygen concentration in the experiments was varied from ≈0% to ≈90%. All measurements were performed for an excitation by sinusoidal voltage with frequency of 13.5 kHz and amplitude ≈7 kV.

Fig. 2 shows dependences of the mean flow power (P_{fa}) and power of the flow pulsations (P_{fp}) (both induced by DBD) as well as the supplied electrical power (P_s) on the oxygen concentration. It is clearly

seen that for all oxygen concentrations $P_{fp} > P_{fa}$. The electric power decreases with increasing of the oxygen content. Molecules of oxygen are electronegative and easily capture the electrons. Reducing of the oxygen concentration leads to creation of more favorable conditions for the plasma formation. This leads to an extension of the plasma region and rise of electrical current (for the constant voltage). The mean flow power (P_{fa}) increases till the oxygen concentration reaches about 20% and then remains approximately constant. But the supplied power decreases with increasing of the of oxygen content therefore the efficiency of the mean ion wind generation increases.

Power of the flow pulsations (P_{fp}) varies in another way. It decreases with increasing of the oxygen content nearly proportional to the reducing of supplied electric power. It means that efficiency of the pulsation generation is almost constant. This is an important and new result which allows to conclude that the oxygen concentration affects the balance of the acceleration and deceleration of the flow produced by EHD forces. The previous studies were focused mainly on the oxygen and nitrogen content on the mean flow, therefore this phenomenon wasn't revealed. These data extend the understanding of the ion wind generation processes occurring in DBD and require the discussion.



a b

Figure 2 Variation of the mean flow (a) and pulsations (b) kinetic power vs. oxygen concentration

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