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FLOW NEAR PLASMA DISCHARGE WITH LOW-FREQUENCY MODULATION

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Summary: *The flow-field near plasma glue discharge on the wall is studied experimentally using time resolved PIV technique. Effect of low-frequency amplitude modulation of the electric supply of flow is tested.*

1. Introduction

A boundary layer control of laminar-turbulent transition and separation is in the center of researchers' interest for many decades. For this purpose, actuators of various types are used. Recently, plasma actuators seem to be very promising in this context.

There are several types of plasma generators (review in Moreau, 2007), in the presented study we consider only dielectric barrier discharges (DBD) generated by high voltage alternating electric current. The generator is supplied by high frequency AC (order of kHz), while controlled processes are characterized by much lower frequencies. To improve the control capacity of the actuation, amplitude modulation by low frequencies is applied.

2. Experimental setup

The plasma generator with flat copper electrodes has been designed, made from foil 50 μm thick. The 3 mm glass was used as dielectrics. The schematic view is shown in Fig. 1.

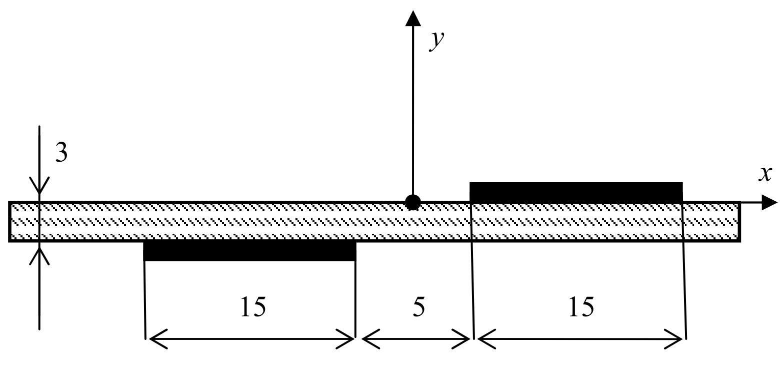

Fig. 1 – The plasma generator

In Fig. 1 there is a coordinate system in the flow area above the generator, below it the other dielectric is placed (8 mm glass). The generator forms bottom of the flow domain, to avoid

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influence of wind in laboratory a Plexiglas chamber 100 mm in width and 1 m in other directions (*x* and *y*) was used. The standard time resolved PIV system was utilized, droplets of glycerol mean size 3 μm as particles.

The high-voltage generator was designed and fabricated in ÚT, details see Procházka et al. (2008).

3. Results

First, parameters of the generator without low-frequency modulation was optimized to obtain the flow with highest velocities possible. Our high-voltage generator provides AC with fixed voltage (approx. 20 kV) and adjustable frequency in range 1 – 60 kHz. The optimal frequency was identified on approx. 7 kHz. The typical flow-field is shown in Fig. 2, mean velocity vector lines are added, coloring shows mean velocity magnitude distribution. Two wall jets are generated in *x* positive and negative directions, fluid is attracted from above.

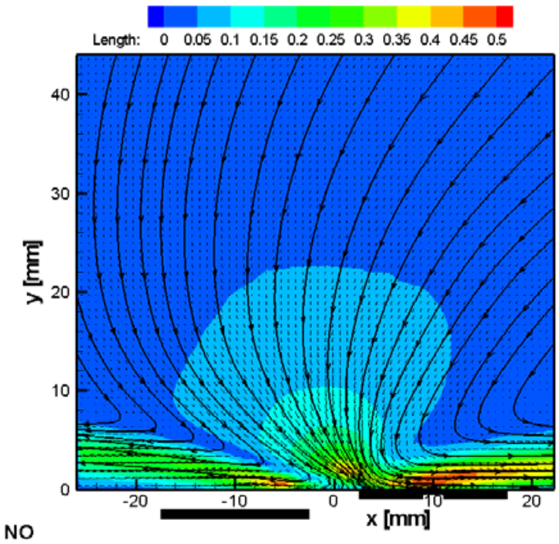
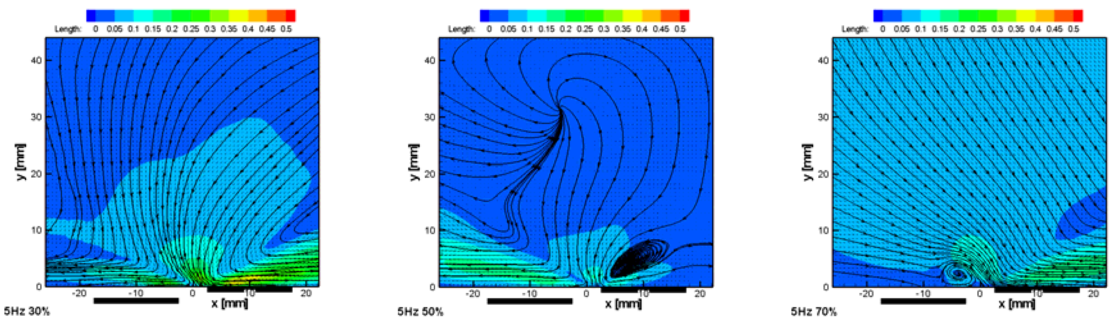


Fig. 2 – Mean flow-field generated by plasma discharge

Then a series of experiments with rectangular modulations with frequencies 5, 10, 20, 50 and 80 Hz and duty cycles 30%, 50% and 70% were performed. The flow with modulation generates train of vortices within the wall jets, frequency and size of which are determined by modulation frequency. Furthermore, in the mean flow the distinct quasi-stationary vortex is generated above the bottom electrode. The flow-field is generally less symmetrical (*y*-axis) then in the reference case, left jet is sometimes missing.

In Fig. 3 there are mean velocity fields of the above mentioned cases, frequency and duty cycle is specified in left bottom corner of each figure. Each line (3 pictures) corresponds to one frequency, duty cycles are different. Please note, that the duty cycle 30% means, that the discharge is 70% of the period on and the rest 30% off. The position of electrodes is indicated schematically on the *x*-axis as well.



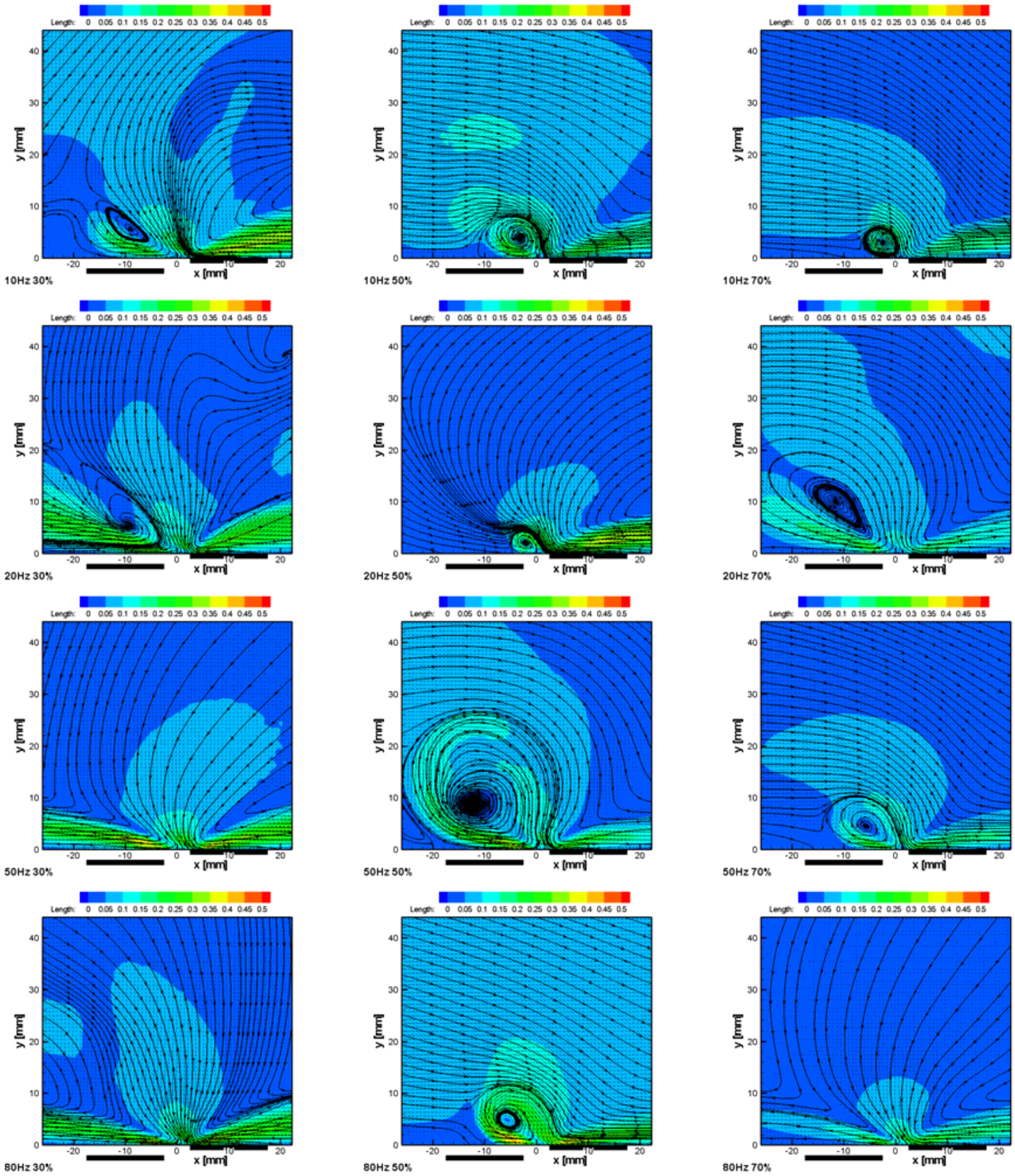


Fig. 3 – Mean flow velocity patterns as fiction of modulation frequency and duty cycle

The wall jets is either oriented along the wall, or it forms the quasi-stationary vortex. This vortex is distinct mostly on the left-hand part of the velocity field close to the wall, but this structure does not necessarily appear in instantaneous pictures. Flow-fields for duty cycle 30% are close to this without modulation (compare Fig. 2).

Note, that the velocities are relatively small in magnitudes (up to 0,5 m/s), so measured result is very sensitive to boundary conditions.

To show the instantaneous structure and periodicity of the flow-field with periodic input signal modulation, one period of modulation cycle is shown for the case of 10 Hz modulation 30% duty cycle. To visualize the vortical structures, distribution of the vertical velocity com-

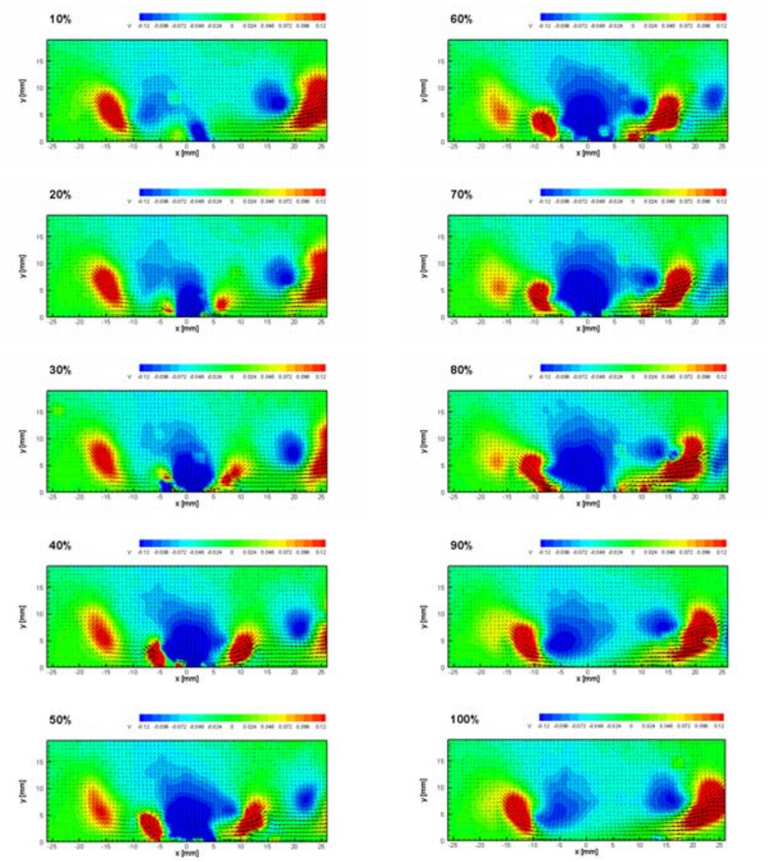


Fig. 4 – Phases of flow excited by plasma discharge modulated by frequency 10 Hz, duty cycle 30 %

ponents are shown in Fig. 4 (blue-negative, red-positive, green-zero). Ten phases of the pseudo-periodical process are shown. The phase in percent of modulation period is shown in left-top corner of each picture. The sequence starts in upper-left corner, continues downwards.

When the plasma generation is applied, two vortices arise close to the electrodes; they are entrained by the wall jets. The flow pattern could be more or less symmetrical with respect to *y* axis, or non-symmetrical, with one wall jet much stronger then the other. The case depends on boundary conditions and possible disturbances, the process of jets re-distribution is very sensitive and of stability nature.

4. Conclusion

The presented results show flow-field generated by plasma discharge. Two wall jets are generated in symmetrical way or not. Influence of low frequency modulation of the signal is shown qualitatively. Periodic modulation generates train of vortices within the wall jets.

To obtain higher velocities either higher voltage or thinner dielectric layer has to be applied in future.

5. Acknowledgement

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6. References

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