Energy distribution in a dielectric barrier discharge system at low pressures

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Bochenikov V.M. *, Volodin V.V., Golub V.V.
JIHT RAS, Moscow, Russia
vova.m.bocha@gmail.com

Introduction

The dielectric barrier discharge (DBD) can be used to control the aerodynamic characteristics of the wing of an aircraft. More effective DBD corresponds to more effective control. There are modes in which the DBD actuator operates with maximum efficiency. This work is devoted to the study of the electrical characteristics of the discharge and thrust of synthetic jets, depending on a number of macroscopic parameters. The most important of these is the ambient air pressure. Pressure change has a complex effect on the characteristics of the entire system.

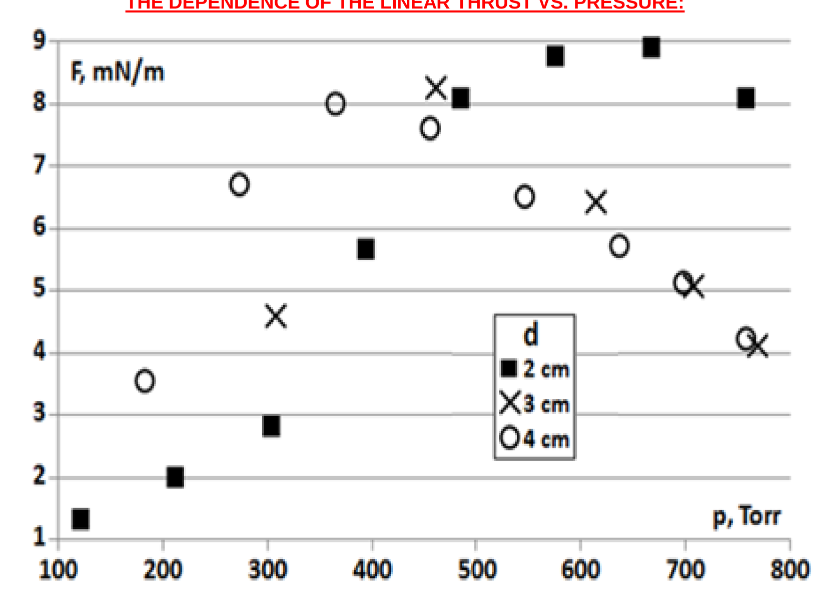
Aims:

- **To obtain dependencies of the linear thrust and specific thrust to power vs. pressure around DBD from 1 bar to 100 torr, that corresponds to the altitude of the flight up to 20 km**
- **To define correlation between power of DBD and quality factor of the system**
- **To determine the dependence of the lift force produced by a symmetric actuator mounted on the lower surface of the wing vs. the velocity of the airflow**

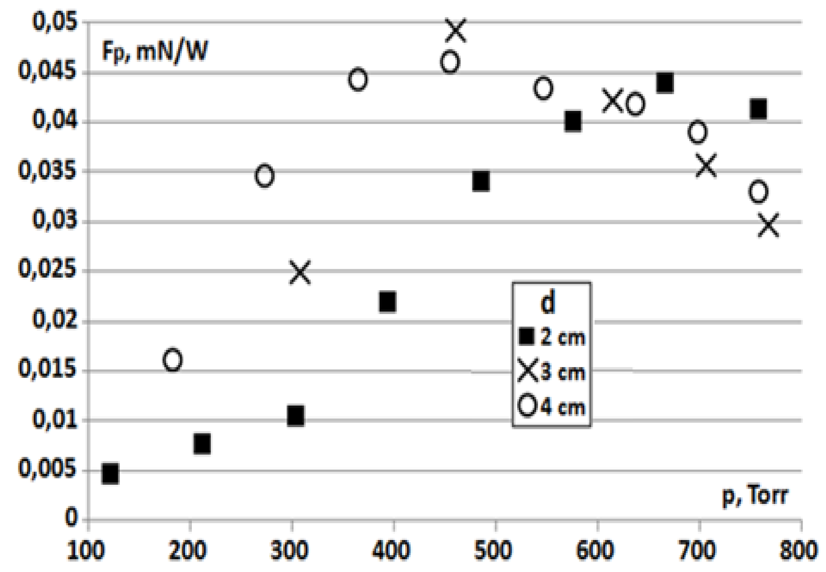
There are modes in which the actuator operates with maximum efficiency

For multiparametric system, finding the optimum is reduced to consecutive search of linear thrust and specific thrust to power for each of the system's parameters. For example: frequency, amplitude, distance between the exposed electrodes et al.
Pressure is one of these parameters:

THE DEPENDENCE OF THE LINEAR THRUST VS. PRESSURE:

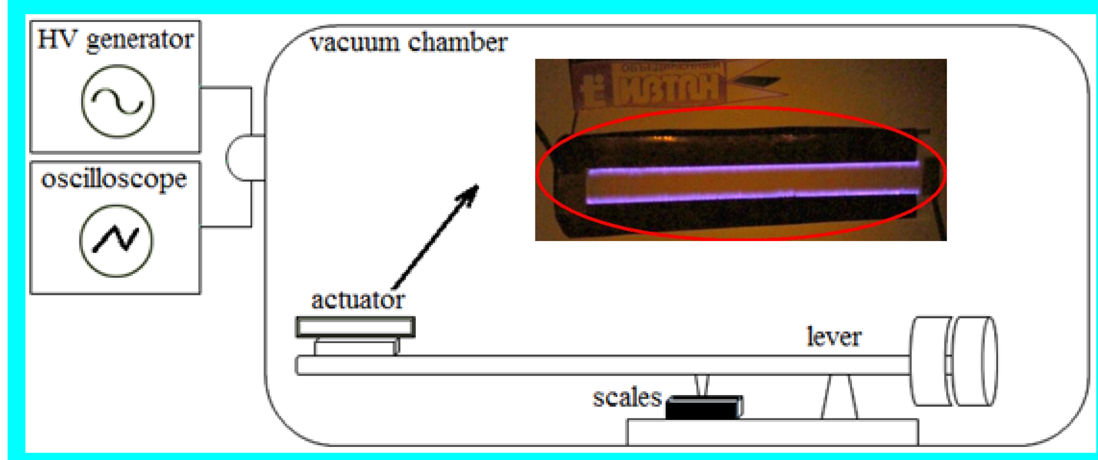


THE DEPENDENCE OF THE SPECIFIC THRUST TO POWER VS. PRESSURE:



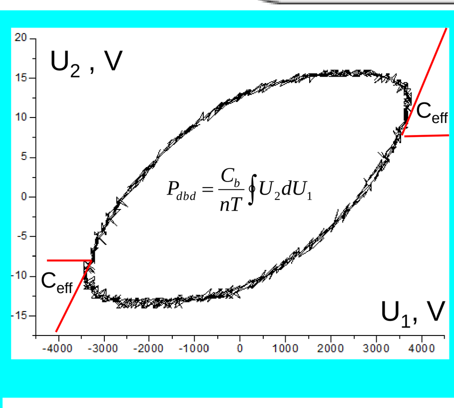
***d –** distance between exposed electrodes*
***υ** = 3 kHz*

DBD & synthetic jet



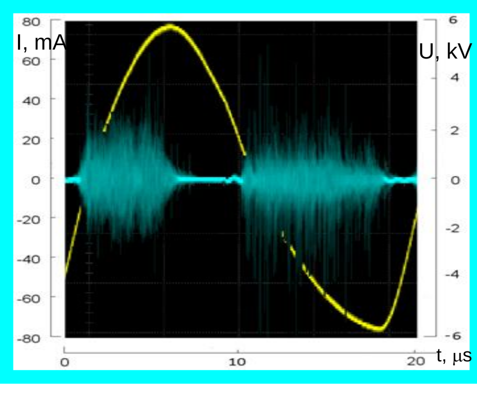
Wall jets from each half of the symmetric actuator forming synthetic jet

Steady state flow at continuously supplying of the alternating voltage on the exposed electrodes

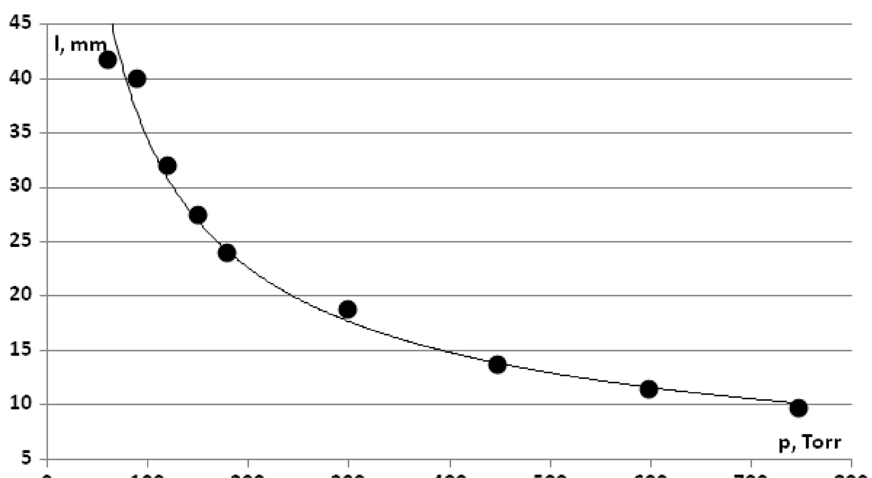


Lissajou figure for determining the discharge power and effective capacitance of the system

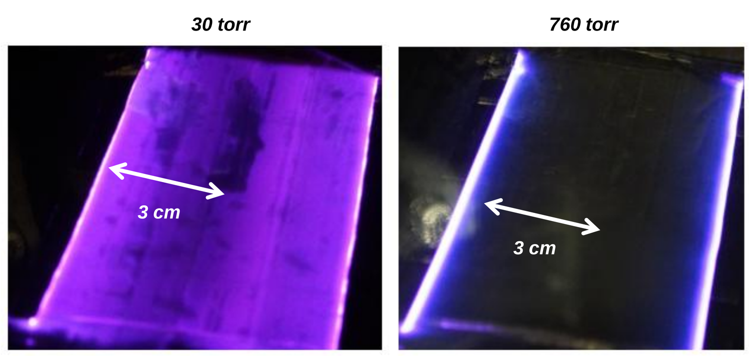
Voltage (yellow) and current (blue) of DBD



THE DEPENDENCE OF THE PLASMA LAYER'S LENGHT VS. PRESSURE:



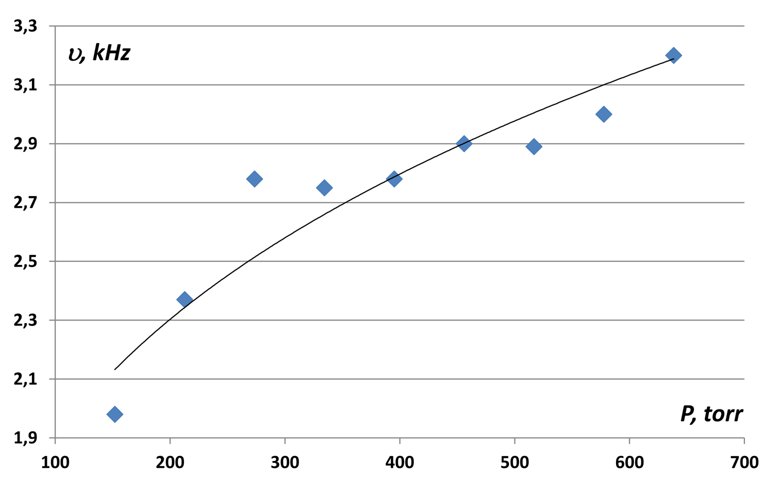
DBD at different pressures



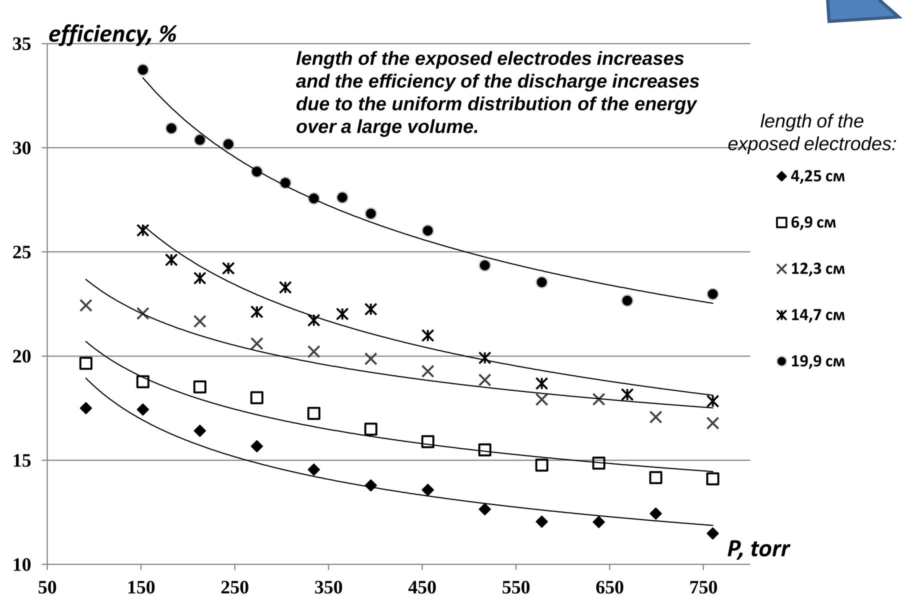
The length of the plasma layer substantially depends on the pressure. With decreasing pressure, the discharge becomes more homogeneous.

When the length of the discharge changes, the electrical characteristics of the system also change.

THE DEPENDENCE OF THE SYSTEM'S RESONANCE FREQUENSY VS. PRESSURE:

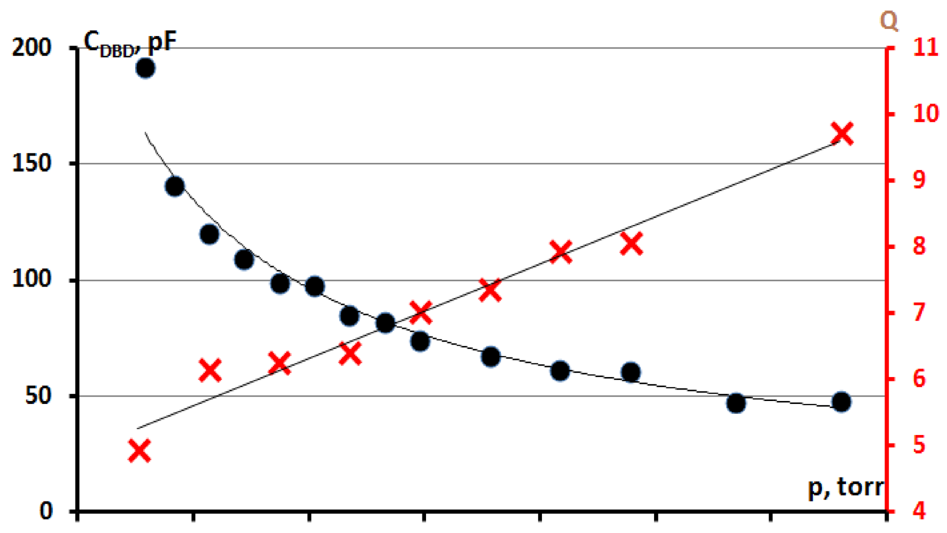


THE DEPENDENCE OF THE DBD'S EFFICIENCY VS. PRESSURE:

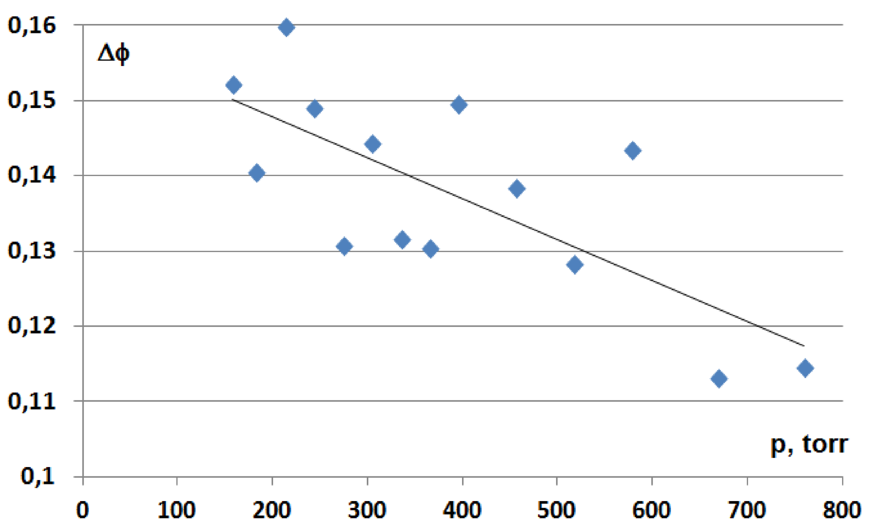


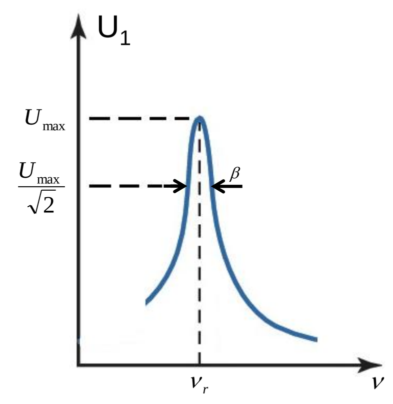
As the pressure decreases, the resonance frequency decreases, and the discharge efficiency increases significantly.

THE DEPENDENCE OF THE SYSTEM'S CAPACITY & QUALITY FACTOR VS. PRESSURE:



With decreasing pressure, the phase difference between voltage and current increases:





Using the resonance curve, the attenuation coefficients of the system were determined and the values of the logarithmic damping decrement were calculated.

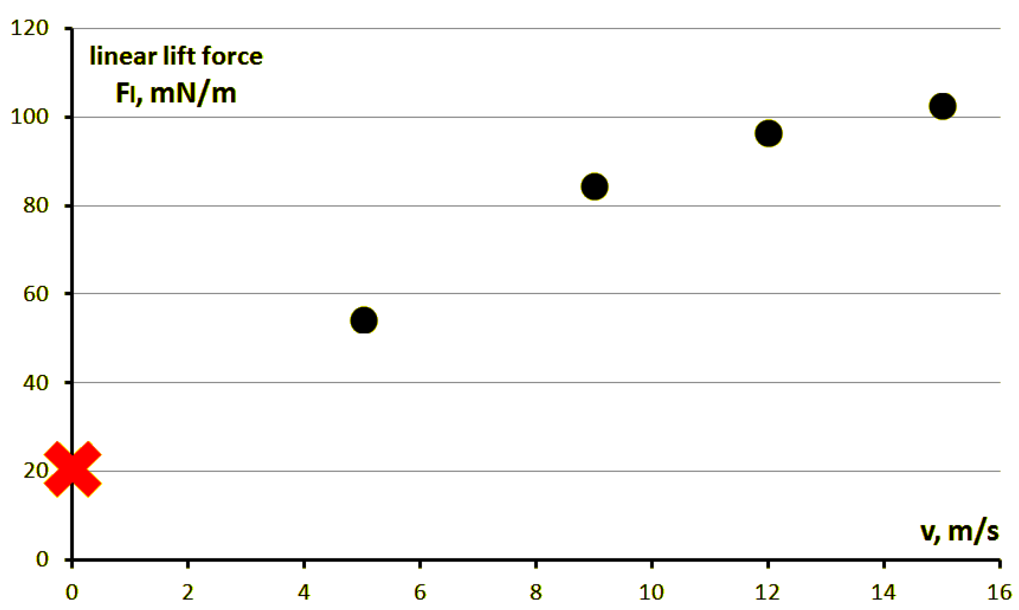
The increase in logarithmic damping decrement with decreasing pressure is consistent with the efficiency measurements. That is, the more energy goes to the DBD, the stronger the attenuation of the system

An increase in the discharge power is accompanied by a simultaneous increase in the system attenuation coefficient. DBD is a significant, though not the only factor of energy loss in the system.

It can be concluded that to control the flow with the help of the DBD, reducing the quality factor of the system is a necessary condition for increasing its efficiency.

Interaction of DBD with an airflow

THE DEPENDENCE OF THE LIFT FORCE VS. VELOCITY OF THE AIRFLOW:



- **With increasing flow velocity increases lift force**
- **Value and sign of lift force depends on angle of attack and location of actuator on the wing**

Actuator mounted on the lower surface of the NACA – 0015 profile near the back edge
and performs the function of the jet flap

Conclusions:

- ***There are pressures when linear thrust and specific thrust to power have maximum value. Those pressures depend on the geometry of the actuator.***
- ***As the pressure decreases discharge efficiency increases significantly.***
- ***It can be considered that "power-actuator-DBD" system is an oscillating circuit.***
- ***With decreasing pressure, the attenuation coefficient increases, and the quality factor of the system decreases.***
- ***The more energy goes to the DBD, the stronger the attenuation of the system.***

- **The reaction on the interaction of synthetic jet and airflow arises lift force that significantly superior that the thrust of the synthetic jet**
- **With increasing flow velocity increases efficiency of interaction between DBD actuator and airflow**

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