Stall Control on a Hermes 450 V-tail element using DBD Plasma Actuators

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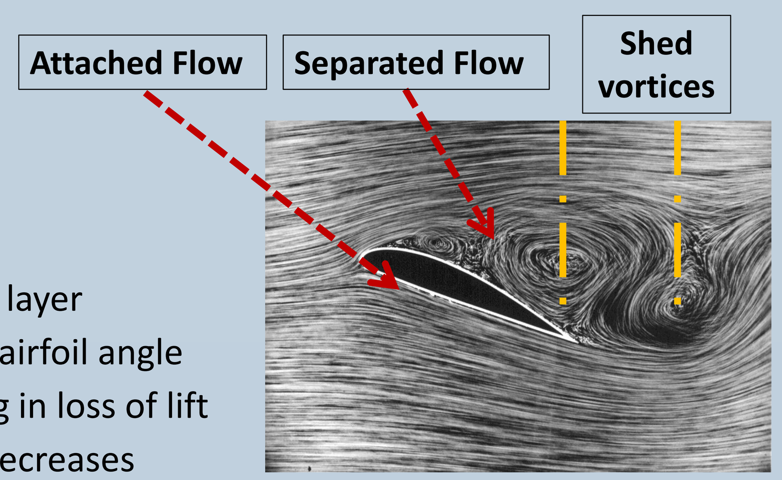
MOTIVATION + BACKGROUND

Motivation

This research implements dielectric barrier discharge (DBD) plasma actuators to control stall on symmetric aerodynamic bodies, such as aircraft V-tails and vertical axis wind turbine blades.

Actuators produce perturbations, corresponding to flow instabilities that increase the total lift generated. This facilitates crosswind take-off and landing and increases wind turbine power.



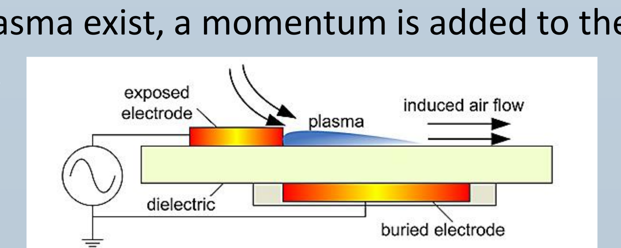
Background

1. <u>What is **Stall**?</u>

Stall is caused by boundary layer separation when a wing or airfoil angle of attack increases resulting in loss of lift and increase in drag. This decreases aerodynamic efficiency of the vehicle or wind turbine.

2. <u>What is DBD (Dielectric barrier discharge) **Plasma** actuator?</u>

The working principle of the **Plasma** consist of two electrodes, one covered, one exposed, a dielectric material between them and a fluctuating high-voltage between them. While the plasma exist, a momentum is added to the flow which acts like a <u>wall-jet</u>, that is analogous to a <u>jet blown from a two-dimensional slot.</u>



3. <u>Active Flow control using DBD Plasma actuator</u>

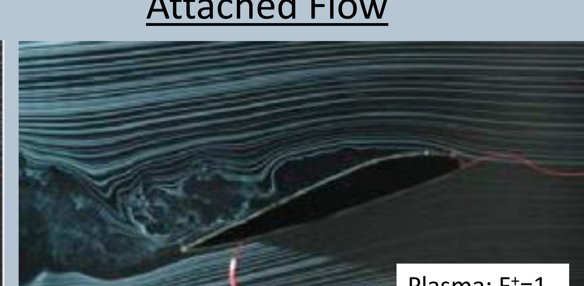
Periodic perturbations amplify, roll-up into vortices and bring high momentum fluid to the surface.

To increase the Lift, the plasma frequency should correspond to a flow instability frequency: shear-layer or shedding frequency. Typically:

$$F^+ = \frac{Freq \times cord}{U_{\inf}} \sim O(1)$$

<u>Separated Flow</u>

<u>Attached Flow</u>



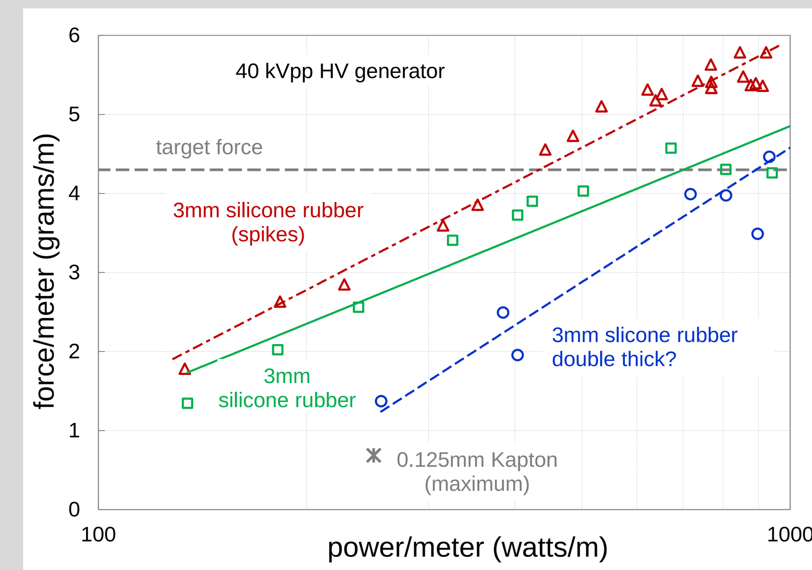
4. <u>The Pros of DBD plasma over other flow control techniques</u>

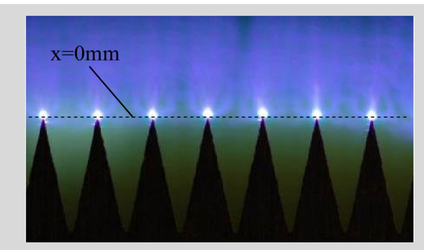
- No moving parts – less prone to failure
- No compresses air, no pipes or slots to add momentum
- Response times are orders of magnitude less than the perturbation time-scale
- Easy and cheap to install

I. INVESTIGATE A NEW DIELECTRIC MATERIAL AND A HIGH VOLTAGE INVERTER

In past experiments the plasma was used in winds up to 12 m/s. For the use of this technology in speeds up to 30 m/s (~110 k/h) we had to increase the force of the plasma by $(30/12)^2 = 6.25$.

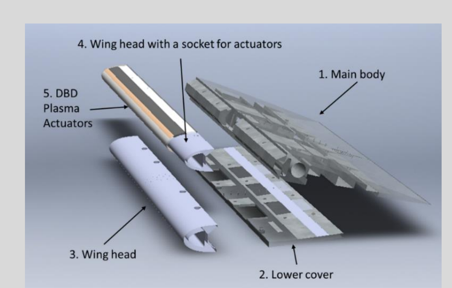
By introducing <u>silicon rubber</u> as a dielectric material, using <u>spiked electrode</u> and a <u>4th generation high voltage inverter</u> we achieved **8.5 the force** in the laboratory

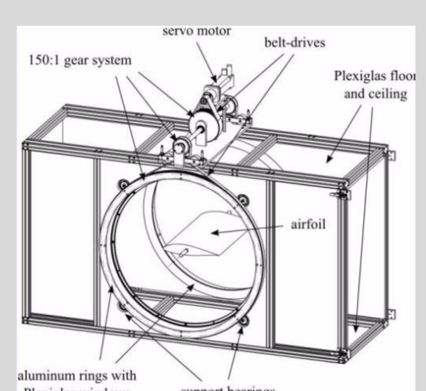




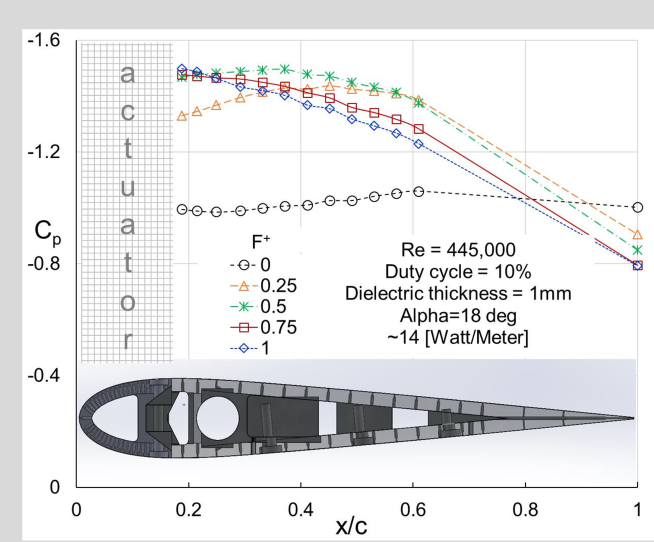
II. EXPERIMENTAL SETUP

An airfoil (2D wing), with a 35cm chord, was designed, based on the Hermes tail-element geometry. Wind tunnel testing was performed in the Flow Control Laboratory at **takeoff Reynolds numbers.**





The model enabled us to get the pressure distribution on the wing. Integrating the pressure yields the lift, form-drag and pitching moments.



OBJECTIVES

I. Investigate a new dielectric material and a high voltage inverter for the DBD plasma actuators.

II. Construct "full-scale" 2D model and experimental setup.

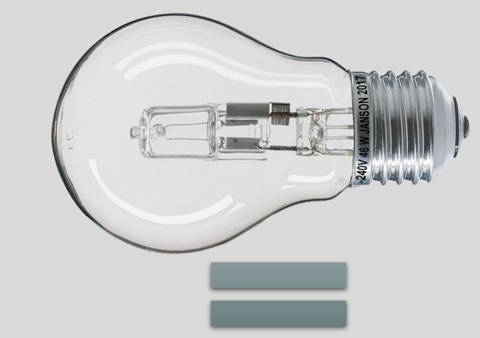
III. Conduct a full series of flow control experiments using DBD Plasma technology.

IV. Implement plasma actuators on the full-scale tail element and conduct full-scale tests and flow visualization in the IAI low speed wind tunnel.

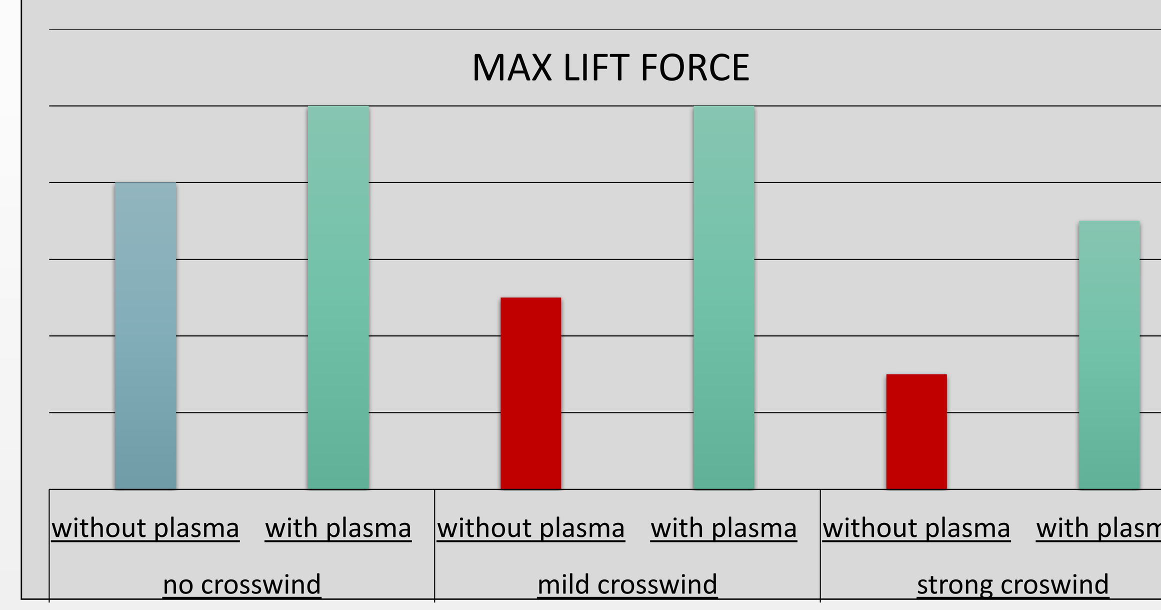
V. <u>Future research - Implement the technology on "Vertical Axis Wind Turbine"</u>

III. MODEL RESULTS – ALLOWING TAKEOFF OF THE AIRCRAFT WITH A POWER COST OF LESS THAN A LIGHT BULB

We conduct different experiments to scan the optimum and sensitivity of F^+ for this system and the sensitivity of duty cycle and power on the performance of the wing. Data processing revealed the following:



- Enabling take-off and landing in a <u>mild</u> crosswind consumes only <u>5-10 watts</u> (equal to a small LED lamp).
- Enabling take-off and landing in a <u>strong</u> crosswind consumes only <u>50-70 watts</u> (equal to a regular Halogen lamp).
- Without a crosswind, the takeoff length is shortened by more than 50 meters.
- **On the basis of results obtained in the laboratory, we can achieve significant increases in the net aerodynamic efficiency and endurance, resulting in longer range and flight times.**



IV. IAI WIND TUNNEL EXPERIMENTS

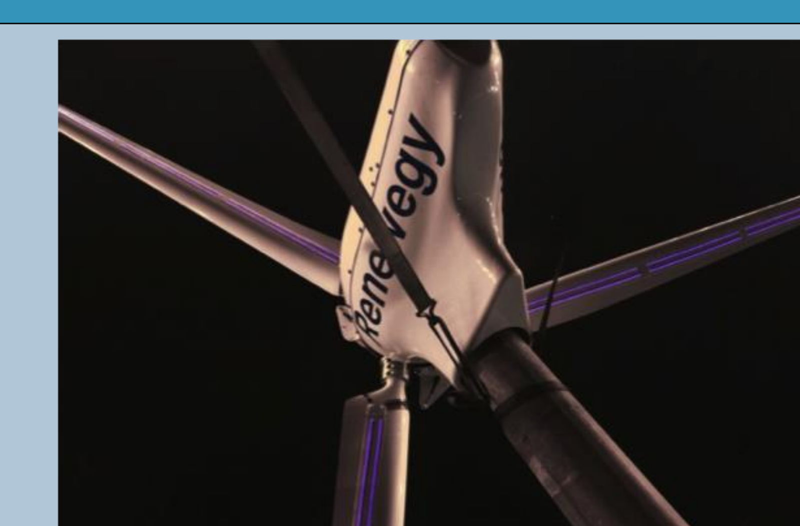
On the basis of 2D experiments performed at the Technion, full-scale tail element will be performed in the IAI low-speed wind.

V. FUTURE RESEARCH

Our main energy-related goal is to implement this technology on wind turbines. **This renders it dual-use technology, namely wind-energy and aviation.**

Prof. Greenblatt had a success on implementing this technology on a small-scale vertical wind turbid with a feed forward control system with a net gain of more than 10%. An additional challenge on horizontal axis wind turbines is load control.

We want to implement the new dielectric material, 4th generation high power inverters, close-loop control system and special wing design to a full scale model. Laboratory evaluation will be followed by field testing.



Supported by The Nancy and Stephen Grand Technion Energy Program (GTEP)