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Selective Dielectric Barrier Discharge Actuation for Flow Control of Delta Wings

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Project Summary: The goal of the proposed project is to control the vortex formation over a delta wing surface, using selective Dielectric Barrier Discharge (DBD) actuation to improve the aircraft’s performance. The flow over a delta wing at high angles of attack is characterized by the presence of two large-scale primary vortices that contribute substantially to lift generation (Fig.1). However, at low speeds vortex breakdown, which can be induced by unfavorable pressure gradients or freestream disturbances, can lead to lift decrease and to an oscillating motion about the roll-axis, affecting stability, commonly described as wing rock. Thus, the ability to manipulate and control vortex flow over a delta wing is of vital importance, because these vortices mainly determine the aerodynamic performance and control of the aircraft.

Plasma actuators are electrical devices that generate a wall bounded jet without the use of any moving parts. The standard plasma actuator consists of a single encapsulated (ground) electrode. Despite DBD’s operational power requirements, and relatively high operational temperatures that might prohibit their use over long periods of time, these actuators can be used to strengthen the vortices and provoke early vortex bursting that can result in not only wing stabilization but also in stall delay and lift enhancement. In contrast to conventional DBD actuators driven by sinusoidal voltages, a voltage profile consisting of nanosecond pulses superimposed on dc bias voltage is proposed. The advantage of this nonself-sustained discharge is that the parameters of ionizing pulses and the driving bias voltage can be varied independently, which adds flexibility to control and optimization of the actuators performance. Selective actuation also curtails the amount of power draw as well as the total thermal output in comparison to a conventional DBD actuator.

The proposed work will investigate the possibility of selectively manipulating vortex formation using nanosecond DBD’s over a delta wing to improve aircraft’s performance. Wind tunnel testing and flow visualization will be used for evaluating the DBD’s efficiency. This project provides a good synergy between theory and computational analysis to hands-on and experimental

Fig. 1: Vortex formation on a delta wing at a high angle of attack. [A.A. Sidorenko et al. “Plasma control of vortex flow on a delta wing at high angles of attack”].
testing. The student, under the mentor’s guidance, will gain significant experience in how to conduct an experiment, collect data, analyze data and write a report, necessary skills for the student’s future career. Also, results from this proposed research will provide critical preliminary data for external funding and potential internal/external collaboration for the Mentors.

The RCEU student’s tasks in the project include:
i.) Develop and test nanosecond DBD actuators.
ii.) Design and 3D print a delta wing wind tunnel model.
iii.) Integrate the DBD’s on the delta wing model and conduct wind tunnel testing experiments.

Student Prerequisites
The student will be required to have the following skills: i) Strong background in Aerodynamics and electronics; ii) Good knowledge of MATLAB, Solid Edge/ SolidWorks and LaTeX; iii) experience with wind tunnel testing and 3D printing; iv) Experience with writing technical reports; v) A minimum GPA of 3.2 is required.

Student Duties & Deliverable
The project will require an extensive laboratory effort but also the archiving of results in a formal manner. During these experiments the student will require to use analytical and observational skills. The experimental results must be routinely logged (e.g., log-book) and quality controlled. Repetition of wind tunnel experiments is required to assure repeatability but also determine the inaccuracies of the observations. The student will present current results and report progress on a weekly basis. A final report will be submitted during the ~12th week and evaluated by the mentors. The student can also have the opportunity to present the findings in UAH seminars for undergraduate research or national symposiums/conferences. A tentative timeline for 12 weeks is as follows:

Week 1: Introduction to both labs, equipment, and background.
Weeks 2-3: Review literature on DBD’s and present a design and a design alternative.
Weeks 4-5: Finalize designs and purchase required parts.
Weeks 6-7: Design build and test DBD’s.
Weeks 8-10: Integrate DBD’s on the wind tunnel model and conduct wind tunnel testing.
Weeks 11-12: Analysis and documentation of the results including a poster.

Mentor Supervision and Interaction
During the summer semester, both mentors spend the majority of their time working in the lab and assist students during experiments. Thus, the mentors will have regular interactions with the RCEU student. The student will also have daily interactions with the graduate students who work and conduct research in the labs. Direct supervision, mentoring, and evaluation of the project by both mentors will occur weekly at regularly scheduled project meetings. In the weekly meetings the current status of the project, recent results, difficulties encountered, next steps, and address any other issues that may come up will be discussed.