An Integrated Approach to Understanding and Enhancing the State-of-the-art for Dielectric Barrier Discharge Plasma Actuators

- A Workshop –
24-25 February 2010

WORKSHOP MOTIVATION:

Despite significant advances in DBD plasma actuator technology and the recent popularity of these devices in aerodynamic flow control, there remain enduring questions regarding the operation, performance, and design of DBD plasma actuators; questions that impinge significantly on the future applicability of these actuators in aerodynamic applications. In addition, it is becoming increasingly clear that further advancements in actuator technology, driven by actuator scaling demands in the face of increasing Mach and Reynolds numbers, are of paramount importance to the flow control community. To confront these actuator challenges, we are required to understand what improvements are needed in the actuator and its design. The path to these actuator improvements lies with addressing the necessary advancements in plasma physics theory, plasma modeling, flow simulations, and ultimately actuator design. It is these challenges that motivate the current workshop.

Even in the absence of the aforementioned influences from the flow control community, there are outstanding basic research questions regarding the underlying physics of DBD actuators. Questions regarding an understanding of the air chemistry of the actuator during operation including the influence of the operational environment, the coupling of the plasma to the air, the level of fidelity required when undertaking plasma-air simulations, how to do rational reduced order modeling of the air chemistry, what developments are required in experiments to give insight into the underlying plasma air chemistry, and what experiments are required to validate modeling and simulation efforts.

To this end, the goals of the workshop are to identify the current state-of-the-art and best practices for plasma actuator science and development, to identify paths forward in the actuator technology development, and to propose a clear set of recommendations for future research in the area.

WORKSHOP THEMES:

The workshop will encompass:

1. Opportunities for control authority, parameter optimization
    a. GOAL: What are the actuator requirements to use DBDs in aerodynamic applications of interest?
    b. Want to use aerodynamic flow control applications to inform the development of plasma actuators
    c. How do aerodynamic control demands influence and drive actuator design and application? Impact on thrust, power, velocity, bandwidth
2. Novel experiments w/ DBD actuators, reveal new opportunities
    a. GOAL: What novel experiments are needed to support actuator development? How do we do those experiments?
    b. There is a fundamental deficiency in that numerical results need validation against experimental data that are spatially and temporally resolved
    c. It has been suggested that what is required are spectroscopic measurements to probe the chemistry, species, and electron density. What other experiments are required?
3. Theoretical developments in DBD modeling and thermo-chemistry
    a. GOAL: What is the state-of-the-art in air chemistry modeling? How can finely resolved time simulations inform modeling? How does the environment affect the air chemistry?

What are the relevant influences in the air chemistry? What experiments are required to support theoretical development and validate simulations? (See above theme)

b. Motivated by a lack of fundamental understanding of plasma flow coupling for real gas
c. Related topics include comprehensive air chemistry models, non-equilibrium gas modeling, multi-scale modeling for actuator and flow-field

4. State-of-the-art modeling for high-fidelity simulations
    a. GOAL: What are the essential features of the plasma physics that must be retained as the order of the modeling is reduced? How do we capture the ion and electron dynamics efficiently in modeling? How do we get to a reduced order model incorporating the relevant plasma physics into the boundary layer and bulk fluid dynamics and in a way that is viable for flow simulations?
    b. Reduced order modeling: phenomenological or first principles?
    c. What are the essential parameters and modeling fidelity required for engineering trade studies that allow the exploration of large parameter space for aerodynamic, stability, and control applications? How much uncertainty/accuracy can be tolerated for decreases in simulation time?
    d. Establish metrics for objectively assessing the performance of models
    e. What is high-fidelity modeling in the case of DBD actuators and flow simulations? What level of fidelity is required and why?
5. Actuator developments
    a. GOAL: Which direction(s) should be pursued in actuator development to improve thrust production/power consumption, power reduction?
    b. In actuator development is the greatest priority an increase in thrust? Thrust over delivered power? Induced momentum? Or is it novel arrangements of actuator electrodes?
    c. Of the different types of plasma actuators, which actuator is best suited, if one exists, for a particular application? How do we objectively assess actuator technologies?
    d. Is it possible to tailor actuators to achieve a desired flow response to specific/varying flow control conditions?
    e. How can DBD actuators be designed to give a tailored flow control response? The unique body force nature of the actuator means that we can create actuator flow fields that have never previously been possible using conventional actuators, i.e. surface-issuing jets. How can we take advantage of this capability to advance the state-of-the-art in flow control?
    f. There is a wide variety of parameters that have an important influence on the actuator performance, including:
        i. The material choice of both the dielectric and the electrodes; to date these are based on trial and error and not thoroughly investigated from electro-chemistry side.
        ii. Novel electrode arrangements? Electrode geometry/shape effects?
        iii. Fully-3-D actuator configurations; Spanwise variation in actuator electrodes for quasi-3-D control: how does the modeling change in these cases? What are the relevant spatial and temporal scales? Do current models retain fidelity (at what level?) in these cases?
        iv. (Nano) pulsed actuation
        v. Multi-barrier plasma actuators
        vi. Micro-scale actuators: higher thrust density at micro-scale
        vii. Driving waveform modifications

WORKSHOP ORGANIZATION:

The workshop will be organized around the five themes listed above. The first day of the workshop will be comprised of short presentations in these themes. The intent is to establish the context for which to engage in discussions on the second day. Each presentation will conclude with a list of challenges that, in the view of the presenter, are important to the theme. At the end of the first day, these theme challenges will be collated for distribution and will form the focus for breakout sessions on the second day. Participants in each theme will discuss and debate the challenges in each theme ultimately working towards a set of recommendations and conclusions regarding the best path forward. Each theme will then present their findings to the group as a whole with additional time allotted for further discussion from other theme groups. At the conclusion of these presentations and discussion, the overall recommendations will be listed and prioritized by the group to form a consensus of the workshop conclusions and recommendations.

PRESENTATIONS:

The intent of the presentations is to speak to the challenges in the theme area and how either the community at large is addressing these challenges, or how the specific work of the presenter is working to advance the area. **The focus of the presentations should be on the overall community needs, not on promoting the presenters specific research per se.** Presentations will be limited to fifteen (15) minutes or ten (10) slides (including title slide) total whichever comes first and with limited slide builds. The final slide, i.e. slide 10, **must** be a list of challenges which, in the opinion of the presenter, are important to the advancement of the current state-of-the-art in the theme area.

WORKSHOP OUTCOMES:

As an outcome of the workshop, we would like to see clear guidance on the actuator developments required to see plasma DBDs become a viable flow control tool in flight-scale aerodynamic flow control applications. This guidance could be in the form of a roadmap for future DBD research, or where the research and development gaps are, and may result in a summary article on the workshop outcomes and advocacy for future work.