Time-resolved Characterization of An Aerodynamic Dielectric Barrier Discharge Plasma Actuator In Atmospheric Air

R. S. Mangina and C. L. Enloe
U.S. Air Force Academy, Colorado 80840

Aerodynamic dielectric-barrier-discharge (DBD) plasma actuators have been shown to be promising flow-control devices for various external and internal flows [1, 2]. The present configuration of plasma actuator consists of two thin asymmetrically aligned conducting electrodes separated by a dielectric material. The upper electrode is exposed to the airflow and the lower electrode is encapsulated in the dielectric. DBD from the exposed to the buried electrode is created by applying a sinusoidal AC high-voltage (V_{ac}) in the range of 6-22 kV at 200 Hz frequency between the electrodes so that accelerating charged species in plasma transfer momentum en route to the surrounding neutral molecules through collisions, creating an induced flow tangential to the dielectric surface. The influence of using a 50 µm wire exposed-electrode instead of a thin rectangular electrode in air shows significant effects on the plasma structure, particularly in the positive-going (backward discharge) portion of V_{ac} cycle, with corresponding effects on the actuator's ability to impart momentum to the surrounding air. The actuator's performance is assessed using optical interferometer technique by observing the impulse imparted to a freely-moving segment of the actuator as inferred from its motion in time. Consistent with previous measurements [1], we see that the plasma discharge in the negative-going (forward discharge) portion of V_{ac} cycle consists of a relatively diffuse collection of micro-discharges, but during the backward discharge we notice a rapid transition in the nature of the discharge from distinct discharge events observed with thin rectangular exposed electrode to a highly diffuse, glow-like discharge. Also, with increasing V_{ac}, fractures in the discharge plasma current appear in the form of a few (1-10 per cycle, depending on V_{ac}) narrow (10-20µs) high-current bursts in the reverse polarity of the diffuse discharge. With increasing V_{ac}, the integrated plasma current (I_p) in the forward discharge becomes relatively larger compared to the diffuse current in the backward discharge. This trend corresponds to a change in the momentum transfer to the air by the actuator. During each half cycle of V_{ac} waveform, we see positive acceleration of the test sample during the time when the plasma discharge exists. We also see negative acceleration of the plasma actuator body in each half cycle when the plasma discharge quenches, which is attributed to drag induced by the motion of the surrounding air which is still in motion due to its inertia. The plasma behavior during the forward and backward instances as visualized using high speed imaging camera are presented and discussed with respect to the observed temporal characteristics of the plasma current and applied voltage.

[1] T.C. Corke, C.L. Enloe, S.P. Wilkinson, *Annual Review of Fluid Mechanics* **42**, 505 (2010)
[2] Jin-Jun Wang et al, *Progress in Aerospace Sciences* **62,** 52 (2013)