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An investigation into the effect of electric field on the performance of Dielectric Barrier Discharge plasma actuators

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ABSTRACT

The influence of the inter-electrode electric field of a single Dielectric Barrier Discharge (DBD) actuator on the performance of the device was investigated. The electric field of the actuator was manipulated through the variation of the angle between the electrodes of the actuators. Response forces generated by the plasma actuators were used as performance indicators for these devices. These forces were measured directly utilizing a highly sensitive balance scale. It was verified that depending on the orientation of the variation of the angle between the electrodes, the performance of the actuator may be decreased or increased when compared to a DBD on a flat dielectric plate more commonly investigated in literature. The manner in which the ionic wind flows over the actuators was also explored in the effort to elucidate the influence of the variation of the angle between the electrodes on the response force generated by the device. Results demonstrated that the response forces generated by the actuators may be improved by up to 50% compared to the actuator configuration on a flat dielectric plate commonly investigated. These results indicate the potential available to advance plasma technology by physically manipulating these devices to increase the performances of the actuators.

1. Introduction

Dielectric Barrier Discharge (DBD) plasma actuators are devices commonly utilized to generate non-thermal plasma discharge under atmospheric conditions. The application of active airflow control using plasma actuators has been conventionally investigated for the purposes of boundary layer control [1–3], flow separation control [4,5], and stall control on an airfoil [6–8]. DBD actuators consist of two electrodes separated by a dielectric layer; with one electrode exposed to airflow and the other encapsulated by an insulation material. These electrodes are designated as the exposed electrode and the encapsulated electrode respectively.

Plasma discharge is generated between the electrodes when an electric field of sufficient strength to sustain electron–ion pairs in the gas is established (Fig. 1a). When a high AC voltage is applied to the exposed electrode, a plasma discharge is formed over the surface of the dielectric between the exposed electrode and the encapsulated electrode (Fig. 1b). The generation of the plasma discharge in the vicinity of the electric field causes the charged particles to accelerate towards their respective electrodes. Collisions between these accelerating charged particles and the neutral air particles result in momentum being transferred to the ambient air.

It is well understood that the plasma discharge is distinctly different in the two AC half cycles [9]. The difference in the characteristics of the plasma discharge in each of the half cycles may be elucidated with the source of electrons during the ionization stage. During the negative half cycle, electrons originate from the exposed electrode which easily releases electrons. These electrons are then accelerated towards the encapsulated electrode, impinging on the dielectric surface in the process and subsequently become the source of electrons during the positive half cycle. As these electrons do not readily come off the dielectric layer, an asymmetrical momentum coupling is observed to occur during both half cycles with the neutral air particles. Details concerning the mechanism behind DBD actuators have been widely investigated [10–14] however the actual mechanism behind the physics of the plasma discharge is still under debate.

In quiescent air conditions, activating the DBD actuator induces ambient gas to be drawn in towards the surface of the actuator and accelerated downstream in a direction parallel to the actuator (Fig. 1b). This plasma induced airflow is termed ionic wind in literature. The generation of plasma discharge that accelerates the ambient gas causes a response force to be experienced by the plasma actuator itself (Fig. 2). This net force experienced by the actuator is attributed to the asymmetrical nature of the plasma discharge generated by the device during each of the AC half cycles. These response forces, although small, are readily measurable as a means of determining the performance of the actuators investigated [15,16].

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