EXPERIMENTAL INVESTIGATION OF THE EFFECTS OF A PULSED ACTUATION ON THE FLOW TOPOLOGY INDUCED BY A DBD ACTUATOR

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For active flow control (AFC) purposes in aerodynamic applications, one important key feature is the momentum transferred to the natural flow, but strategies based on periodic excitation in relation with natural flow instabilities are also largely explored to optimize the AFC efficiency. If dielectric barrier discharge (DBD) actuators are indeed characterized by quite low momentum coefficients, one of their main advantageous features is their fast time response and their potentialities to induce small flow perturbations simultaneously at different frequency scales by adjusting the waveform of the voltage applied to the DBD actuator [1]. That makes them attractive for various aerodynamic applications in which they could be operated in pulsed actuation. They have been indeed used in AFC purposes in wind tunnel environment to modify natural instabilities in flow configurations such as transition or separation of boundary layers. In order to deeper analyze the flow induced by a DBD actuator operated in pulsed actuation, this study addresses the characterization of the flow field topology around a DBD actuator in quiescent air using PIV measurements and in presence of turbulent boundary layer evolving along a plane plate. Even though the body force produced by the actuator in quiescent air is modified in presence of an external surrounding flow [2], such information provides insights about the actuator working principles and are interesting for data comparison or body force model validation.

The DBD setup chosen for the experimental tests is based on a common geometry used in our research group. It consists of two copper tape electrodes separated by a thin dielectric composed of 250 μm-thick Mylar and 45 μm-thick Kapton tape layers. The actuator is tested mainly in pulsed actuation, i.e. in a burst modulation which consists of switching on and off the DBD according a square wave modulation of the carried sinusoidal signal (1kHz, 10 kV) at a low frequency (a few tens of Hertz) and a variable duty-cycle (25% to 75%).

The effects of the pulse frequency and the duty cycle on time-averaged velocity fields and phase-averaged velocity fields measured by PIV around the DBD actuator are important. Typical results indicate different flow topologies induced by the actuator in pulsed actuation according to low (5 Hz) and high (100 Hz) pulse frequencies and different duty cycles as well. The induced flow is dependent on time scales related to the plasma actuation forcing and to the ambiant air flow. From time-averaged velocity fields, the wall jet topology can be extracted from velocity profiles plotted along the actuator. More limited momentum are obviously observed for the lowest pulse frequency and duty cycle. Time-averaged velocity fluctuation fields show the signature of a vortex activity more especially for the lowest burst frequencies. Phase-averaged velocity fields permit to highlight the presence of cyclic starting vortices created in the phase ON and then convected in the phase OFF of one pulse. By applying specific non-dimensional variables [3] to analyze such starting vortices, it is possible to study some of their self-similarity properties during their time life. On the contrary, for the highest burst frequencies, time scales are too short for the flow field to roll up to generate a vortical structure and consequently the resulting flow field tends to be similar to the one resulting from a continuous actuation. Finally, in presence of a surrounding flow of 5 m/s evolving along a flat plate leading to a 20 mm-thick turbulent boundary layer, the influence of the DBD actuator on the main coherent motions or structures is studied by Quadrant-Hole technique.

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[3] R Whalley et K S Choi, 703:192–203, June 2012.