Nanosecond Pulse Frequency Effects of Dielectric Barrier Discharge Plasma Actuator for Flow Separation Control over a NACA 0012 Airfoil

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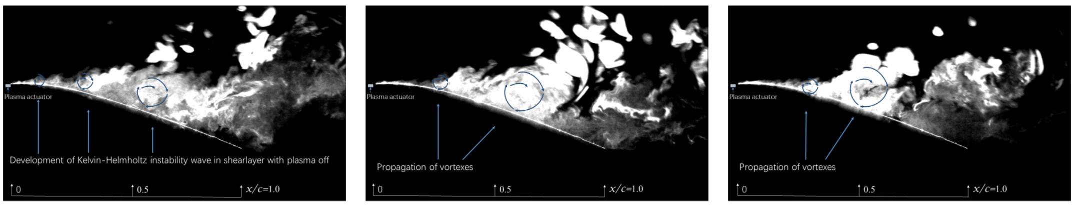
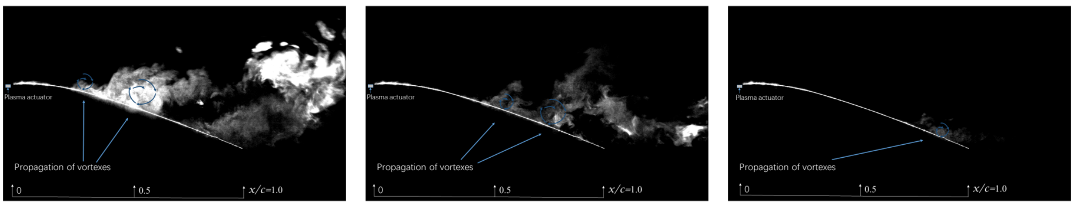
High voltage pulsed nanosecond discharge can be an efficient tool for flow separation control of airfoil[1-9].This work presents results of an experimental investigation of flow control using repetitive, high-voltage nanosecond dielectric barrier discharge(NS-DBD) plasma actuation on a NACA0012 airfoil. The control of separation flow at various Reynolds numbers lying between 5×10^5 and 1×10^6 was investigated using time-averaged pressure measurements,smoke-wire imagery visualizations and time-resolved particle image velocimetry(PIV) results. Here, an actuator was mounted at a distance from leading edge of 1% of the chord length. The measurement results of time-averaged pressure, which was selected as the index of separation control, indicate that the optimal driving frequency varies with the angle of attack. Several flow fields are discussed in detail in this paper. The smoke-wire imagery visualizations results indicate that a series of vortex structures, the produce frequency of which increase with increasing driving frequency in the experimental range, is shed from the shear layer for each drving actuation. The smoke-wire imagery visualizations and PIV measurements reveal that when Reynolds number is above 1×10^6,a driving frequency from $F^+=1$ to $F^+=5$ is able to promote turbulent transition and control the separation over the airfoil , whereas near the stall angle, the promotion of the turbulent transition provides better separation control. For lower Reynolds number for example 5×10^5, only when F^+ is greater than or equal to 15 was the separation eventually controlled.It is also found that the transition from laminar to turbulence can be promoted by plasma actuation,and that flow transition acts as an important factor in the flow-seperation control.At the beginning of the actuation,each actuation can produce a spanwise vortex around the separation point near the leading edge.The spanwise vortices make the separated free-shear unstable and shedding awaw,move downstream along the upper wall,and bring outer flow with high kinetic energy into the near wall region to change the flow structures over the airfoil.At last,the flow on the upper surface of the airfoil become fully attached.



(a)t=0s (b)t=0.056s (c)t=0.139s



(d)t=0.194s (e)t=0.208s (f)t=0.333s

Figure 1: Smoke visualization of interation between flow and nanosecond pulses actuation.

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