Dynamics of Airfoil Leading Edge Flow Separation using Pulsed Nanosecond Plasma Actuator

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Nanosecond (ns) dielectric barrier discharge (DBD) actuator is being investigated intensively as an effective actuation technique for aerodynamic bodies at high cruise speed. Nanosecond DBD causes the rapid, localized heating of near surface gas and generation of a micro shock wave. Compared with traditional alternating current (AC) plasma discharge, ns DBD induces much smaller flow velocity in neutral gas and actually functions via Joule heating effect. In this study, a combined numerical and experimental investigation of leading edge flow separation control over a NACA0015 airfoil is conducted to reveal which feature (i.e. the discharge induced shock or residual heat or both in combination) dominates ns DBD control authority. To this end, a well validated and verified self-similar plasma model[1] is loosely coupled with compressible Reynolds averaged Navier-Stokes (RANS) equations solver to model the effect of plasma discharge on external flow and resolve the detailed flow control process. In addition, wind-tunnel experiment is performed for two low Re flows to measure transient flow field with dynamic particle image velocimetry (PIV) system. The simulation and experiment complement each other and information missing from experiment is provided by simulation. The detailed flow actuation process is displayed and Fig. 1 shows the transient flow filed of controlled flow at $Re=5\times10^4$. It is found that the discharge produced residual heat rather than shock wave plays a dominant role in flow control. The mechanism of ns actuation is excitation of inherent flow instability or boundary layer tripping, which depends on both Reynolds number and angle of attack.

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[1] Zheng et al., *Phys. Fluids* **26**, 036102 (2014).

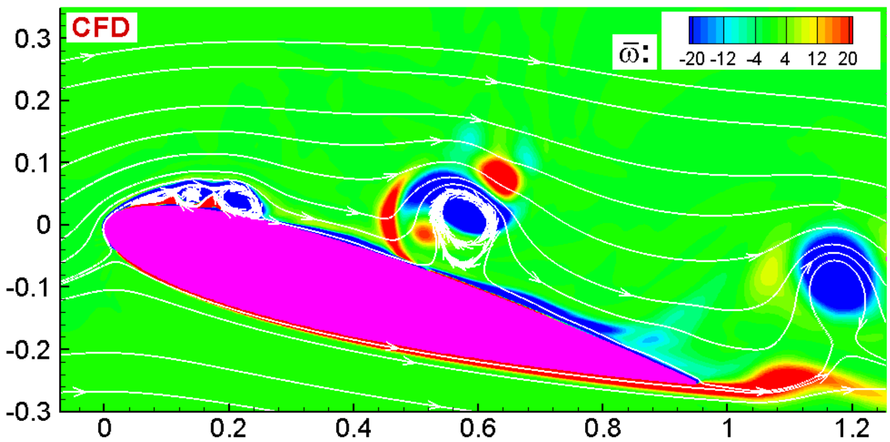

Figure 1: Vorticity field showing the controlled flow over a NACA0015 airfoil, $Re=5\times10^4$ ($U_\infty=10$m/s), AoA=15°.