Mitteilung

Projektgruppe / Fachkreis: Flow Control, Transition und Laminarhaltung

Experimental control of crossflow-dominated transition using 2-d AC-DBD plasma actuators

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Commercial airliners typically feature backward-swept wings that give rise to a three-dimensional boundary-layer, exhibiting a highly unstable crossflow (CF) component. The CF functions perpendicular to the inviscid-flow streamline and provokes a cross-flow instability (CFI) that dominates laminar-to-turbulent transition. Compared to laminar flow, turbulent flow increases the skin-friction drag of an aircraft significantly, resulting in a lack of fuel efficiency. The CFI is strongly dependent on the level of free-stream turbulence and surface roughness, evolving in either stationary or traveling crossflow vortices (CFVs) (Wassermann & Kloker, 2002, 2003, Downs & White, 2013). The control method of Discrete Roughness Elements (DRE), generalized as Upstream Flow Deformation (UFD) by Wassermann & Kloker, 2002, triggers subcritical stationary CFVs that attenuate the growth of the naturally most unstable stationary CFI mode (Saric *et al.*, 1998). Recently, DNS studies scrutinised the control performance of a body force, instilled into a three-dimensional boundary layer to reduce the CF component through base-flow manipulation, hence delaying transition (Dörr & Kloker, 2015*b*). Alternate-current dielectric-barrier-discharge (AC-DBD) plasma actuators retain the authority to exert such body forces (Yadala *et al.*, 2018).

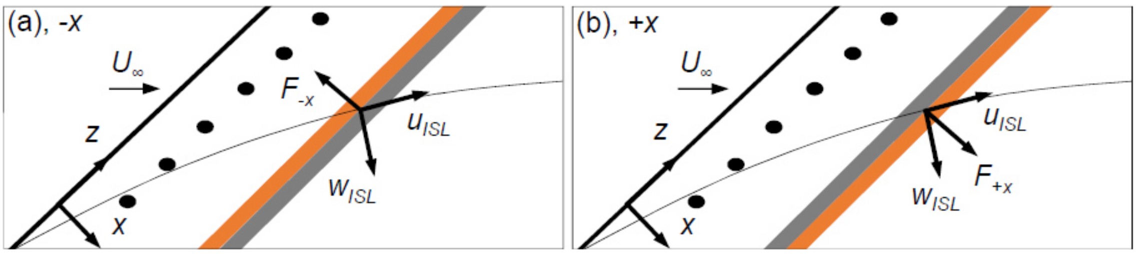

Figure 1: Forcing mechanism of base-flow manipulation with flow from the left (U_∞). (a) Body force F_{-x} along -*x*. (b) Body force F_{+x} along +*x*. The exposed (grey) and encapsulated (orange) electrode and the DREs (black dots) are indicated.

In the current investigation base-flow manipulation with AC-DBD plasma actuators was performed on a 45-degree swept-wing boundary-layer flow for active control of CF-induced transition. The experimental campaign was carried out in the low-turbulence wind tunnel at Delft University of Technology. The wing model is a modified version of the NACA 66018, named 66018M3J, and was extensively validated (Serpieri & Kotsonis, 2015). In the experiments, transition is dominated by stationary

CFI. The AC-DBD plasma actuators were manufactured with a special spray-on technique to secure minimum surface roughness and were operated at 10kHz, inducing a spanwise uniform, two-dimensional body force (Yadala *et al.*, 2018). The force directions, sketched in figure 1, were either partially against (-*x*) or along (+*x*) the local CF component (w_{ISL}). In addition, a row of DREs was spaced at the wavelength of the most unstable CFI mode, artificially promoting transition to turbulence with maximal impact (Yadala *et al.*, 2018). Thus, this testing configuration constitutes the 'worst case scenario' for any given control scheme. Preliminarily, a simplified numerical model estimated a positive effect on the boundary-layer stability when forcing along -*x* and *vice versa* when forcing along +*x*. In the experiments infrared thermography was used to detect and quantify the transition-front locations. The results are shown in figure 2 that demonstrate the typical jagged transition-front pattern, suggesting that traveling CFI modes were of minor importance (Downs & White, 2013). A significant, well-defined transition delay of about 4.5% of chord is observed. The subtraction in figure 2 (c) visualizes the transition delay as a white toothed area. As expected, forcing along +*x* promotes the CF and thus advances the transition (figure 2 (d) to (f)). This study presents the first experimental demonstration of swept-wing transition delay via base-flow manipulation with AC-DBD plasma actuators.

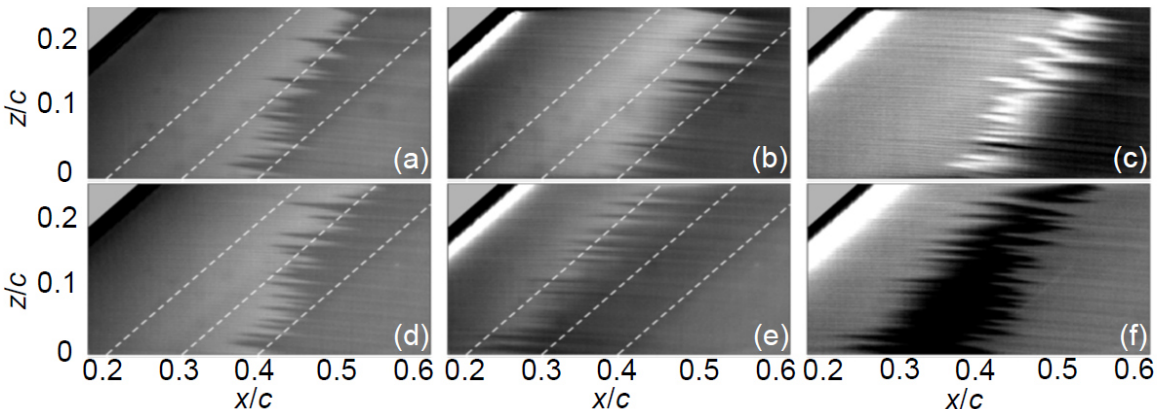

Figure 2: IR thermography time-averaged fields for U_∞=25ms^{-1} (Re_∞=2.08·10^6). The flow comes from the left. The x-scale of the deskewed images is projected on *z*/*c*=0. (a) to (c) from left to right: No forcing, -*x* forcing, subtraction of (a) from (b). (d) to (f) from left to right: No forcing, +*x* forcing, subtraction of (d) from (e).

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