# Transition control by dielectric barrier discharge in a swept wing boundary layer at elevated free stream turbulence

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The main purpose of present study was in investigation of possibility of 3D boundary layer control by means of DBD-actuator at elevated turbulence level. Actuator was designed to create a stationary cross-flow vortices near the leading edge, the latter amplified downstream. The experimental set-up and actuator itself are described elsewhere. It was shown that at natural conditions actuator introduced into the flow a significant amount of travelling instability modes, shifting the transition upstream. Thus, the main idea behind the present experiments was to mask these non-stationary contributions of actuator into naturally developing travelling disturbances. To achieve this the turbulizing grid (wire diameter 1.5 mm and mesh size 25 mm) was installed at the tunnel contraction exit upstream the swept flat plate. Resulting free stream turbulence (FST) level was about 0.9%. Overall FST fluctuations level in the 20-2000 Hz band was increased by several orders. The data are presented in the coordinate system with the longitudinal axis $X$ directed along local outer streamline (inclined approximately 10° to the test section axis at all measurements positions), the transversal axis $Z$ is in a normal direction to the local streamline, and $Y$ is wall-normal direction. The reference velocity $U_{fs}$ was measured behind the grid. Single-wire CTA measurements in several $X$-positions within a boundary layer were performed in ($Y$,$Z$)-planes with the actuator on and off, as well as the near-wall intermittency $\gamma$ was measured in a region of laminar flow destruction.

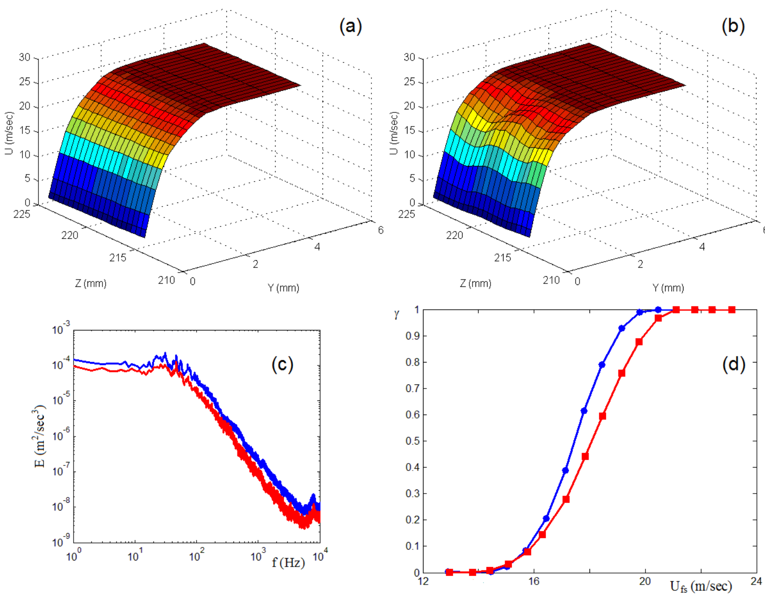


Figure 1: ($a$, $b$) – The mean flow at $X$ = 398 mm without ($a$) and with DBD ($b$); the typical power spectra inside the boundary layer ($c$) and the intermittency distributions over the range of reference velocities $U_{fs}$ at $X$ = 585 mm ($d$). Blue lines is DBD off, red lines is DBD on.

Without control the boundary layer disturbances field has been represented almost exclusively by exponentially growing wave packets of cross-flow instability travelling modes. No significant stationary cross-flow vortices had been observed (Figure 1a). Despite the rather high FST level, two-probe correlations measurements have not revealed any signs of algebraic instability and transient growth associated with it. The results obtained are in line with the findings of [1] in their higher FST level case.

The overall increase of RMS-levels of travelling modes, integrated over the whole (Y,Z)-planes, with DBD turned on was insignificant in comparison to the baseline regime. The growth of these disturbances was still exponential with nearly the same rate. It is important to note that the power spectra has not demonstrating the rise of high frequency fluctuations induced by the actuator in these disturbed flow conditions (Figure 1c). Still the actuator produced the well pronounced spanwise variations of the mean flow (Figure 1b). The spanwise distributions of RMS-levels of non-stationary disturbances also had become modulated. These flow modifications results in the shift of transition end downstream or to higher velocities (Figure 1d). It is worth noting that the transition start occurs at the same position as in the basic regime, while the turbulent spots production rate is significantly lower with the DBD turned on. This fact was also observed visually during the course of measurements. Since the transition zone itself often has significant length in 3D boundary layers subjected to the elevated FST [2], the results obtained shows some potential of DBD actuators in a flow control at these conditions, for example, in problems of internal aerodynamics. In present set-up the downstream shift of transition end location about 50-100 mm was observed at the constant $U_{fs}$ about 15 m/sec.

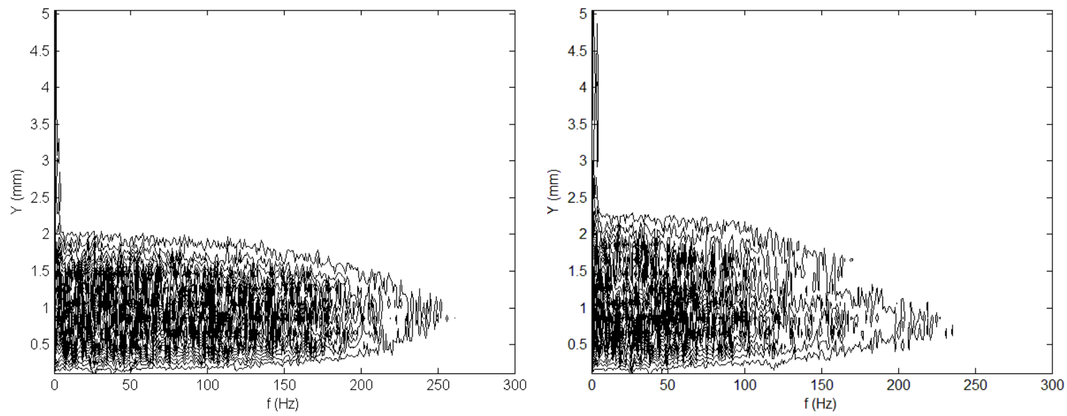


Figure 2: Contour plots of travelling modes power spectra at $X$ = 398 mm, Z = 225.5 mm. Left plot is DBD off, right is DBD on. The contour levels are the same in both plots.

The exact physical mechanism of observed effect has not yet been revealed in full details. Non-linear interactions between the stationary disturbances, introduced in boundary layer by the actuator, and the naturally exited travelling modes could be responsible for it. This suggestion is supported by the data of Figure 2, where the power spectra in the ($Y$,$f$)-plane are shown. These data are typical. Despite the low-frequency pulsations are more protrudes into the outer flow in the "actuator on" regime, the higher frequencies above 100 Hz are substantially dumped.

*References*

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