Delaying transition to turbulence by a passive mechanism

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Reducing skin friction is important in nature and in many technological applications. This reduction may be achieved by reducing stresses in turbulent boundary layers, for instance tailoring biomimetic rough skins. Here we take a second approach consisting in keeping the boundary layer laminar as long as possible by forcing small optimal perturbations. Due to the highly non-normal nature of the underlying linearized operator, these perturbations are highly amplified and able to modify the mean velocity profiles at leading order. We report results of wind-tunnel experiments in which we implement this concept by using suitably designed roughness elements placed on the skin to enforce nearly-optimal perturbations. The aim of this investigation is to prove that controlled low energy optimal perturbations can, due to their large transient amplification in a non-normal system, effectively *stabilize* that system even in the non-linear regime and can indeed be used for control purposes.

The experiments were performed in a flat plate boundary layer positioned in the MTL wind tunnel at KTH Mechanics. The 3D modulated base flow was generated by placing roughness elements, small standing coin-like cylinders, in an array in the spanwise direction. This array generates a sinusoidal spanwise distribution of alternating high and low speed streaks some distance downstream the array. Smoke visualizations and hot-wire anemometry measurements are used to quantify the transition delay by means of this passive control method. Figure 1 show visualization images (210×168 mm^2), with and without streaks and 2D forced disturbances, located 1434 mm downstream of the leading edge. Flow is from left to right.

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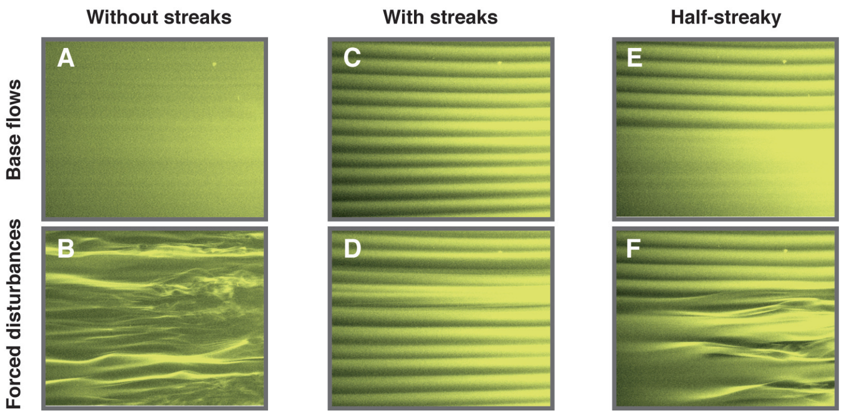

Figure 1: A and B without streaks, without and with excitation ($\mathcal{V}$), respectively. C and D with streaks, without and with excitation ($> 2\mathcal{V}$), respectively. E shows a half-streaky boundary layer without and with excitation ($\simeq 0.8\mathcal{V}$), respectively.