This study is motivated by understanding the physics and controlling transient growth, and subsequent bypass transition of the laminar boundary layer to turbulence. Toward this end, an active isolated roughness element placed at the wall in a Blasius boundary layer is used to introduce steady and unsteady streak disturbances (known to be the precursor to the formation of turbulent spots in bypass transition) in a controlled way; enabling systematic investigation of the evolution of the disturbances and of potential methods to control them in real time. In the first part of this work, a parametric investigation using hot-wire measurements throughout discrete y-z planes (normal to the freestream velocity) provides insight into the influence of the streamwise development of the streak disturbance; namely, the freestream velocity, U, as well as the cylindrical roughness element height, k, and diameter, D. The hot-wire data are complimented with flow visualizations; correlations are drawn between these data, distinguishing non-transitioning, intermittent, and continuously transitioning flows. An increase in U, k, or D causes the total disturbance energy, E to increase; surprisingly, the total energy is not observed to exhibit transient growth for non-transitioning cases. However, examination of the energy of individual features of the disturbance shows that the high-speed "vortex-induced" disturbance experiences growth for all cases, and that the eventual decay or continued growth of this disturbance correlates well with the onset of transition. The Disturbance Energy Density, e, is introduced to provide a more appropriate measure (than E) of isolated disturbance amplitude growth or decay. The normalized disturbance energy density is found to scale with k^6 and U^6 leading to a collective scaling term represented by (Re_k_U)^6, when the streamwise coordinate is normalized as (x*-x_k*) = (x-x_k)(U/v)(k/D) (where x_k is the streamwise location of the roughness element and v is the kinematic viscosity). The scaling is successful over a large streamwise domain, downstream of approximately (x*-x_k*)=5.

In the second part of this study, a series of control experiments is carried out with the goal of cancelling, or reducing the strength of the roughness element induced streaks in real time, and hence prevent, or delay, the onset of bypass transition. The control strategy utilizes two wall-mounted hot-wire shear sensors, one upstream and one downstream of a plasma actuator to provide inputs to a feedforward-feedback control model. The control model is constructed by collecting disturbance-input to shear-stress-output (I/O) data to empirically determine the parameters of first-order boundary layer response models, which capture the boundary layer dynamics. The model parameters are subsequently used to tune the feedforward and PI-feedback controllers. The control is examined over a range of k, U, control strategies, feedback sensor locations, and unsteady disturbance frequencies; and is found to practically completely cancel the steady state disturbance at the downstream sensor location. However, due to a mismatch in the spatial distribution of the disturbances generated by the roughness element and the actuator, the control is not as effective over a y-z plane, reducing the planar disturbance energy by up to 75.5%. Near-complete cancellation is expected with proper actuator design to match the spatial characteristics of the roughness element and plasma actuator induced disturbances. The control of unsteady disturbances demonstrates a limited frequency response, with a maximum controllable frequency approximately f_k=2.0 hz; although substantially higher frequencies can be controlled by moving the feedback sensor closer to the actuator, to reduce the convective time delay in the control loop.

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