Nonlinear PSE simulations of the development of TS waves in the presence of optimal streaks

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Almost any cross-flow perturbation introduced into the boundary layer will develop into a streamwise streak trough the so-called lift up effect. The streak then leads to a thickening and thinning of the otherwise uniform boundary layer. From recent experimental and numerical studies it is known that the spanwise modulations of the boundary layer thickness caused by streaks have a stabilizing effect on low amplitude TS waves.

In this talk, we present numerical results of the interaction of exponential disturbances and steady streamwise streaks, using the nonlinear Parabolized Stability Equations. The objective of these simulations is to investigate the possibilities of optimizing the stabilization effect of the streaks on exponential disturbances in Falkner-Skan boundary layers.

The influence of the streak on the stability of exponential disturbances manifests itself through the shape of the modified velocity profile. The excess of the mean flow close to the wall generated by the streak, modifies the velocity profile into a "fuller" shape and is responsible for the stabilizing effect of streak. The mean flow excess increases rapidly with increasing streak amplitude, and disturbances can be completely stabilized if the streak amplitude is sufficiently high. However, the maximum streak amplitude is known to be limited by the occurrence of secondary instabilities on the

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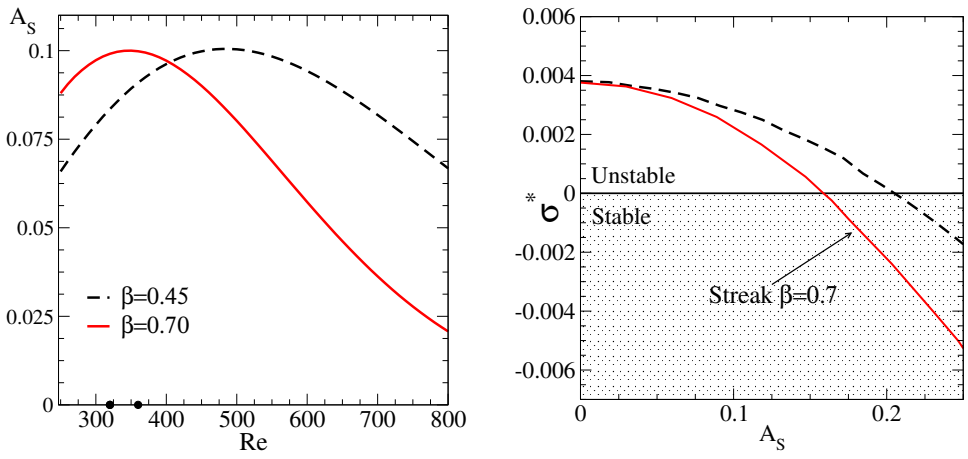

Figure 1: (a) Nonlinear downstream development of streaks with different spanwise wavelengths. (b) The maximum spatial growth rate of TS wave $F = 131E - 6$ in the presence of streaks with varying amplitudes (A_s).

streak. By varying the spanwise wavelength of the streaks with amplitudes below this threshold, it is found that the optimal stabilization effect is obtained in the presence of streaks that attain their maximum amplitude close to Branch I of the TS wave. These streaks generate the largest total mean flow excess in the unstable streamwise region of the TS waves.

Figure 1a shows the nonlinear downstream development of two streaks with the same maximum amplitude but positioned differently in the streamwise direction. The first one attains its maximum amplitude close to Branch II of the TS wave, in contrast to the optimally positioned streak; close to Branch I. Figure 1b the maximum spatial growth rates of a TS wave in the presence of these two streaks with maximum amplitudes between 0–25% of U_∞ are plotted.

The stabilization effect of the mean flow in the presence of streaks, is also observed for oblique disturbances and for boundary layers with favorable and adverse pressure gradients. In Figure 2 the damping of oblique waves in the presence of streaks is observed.

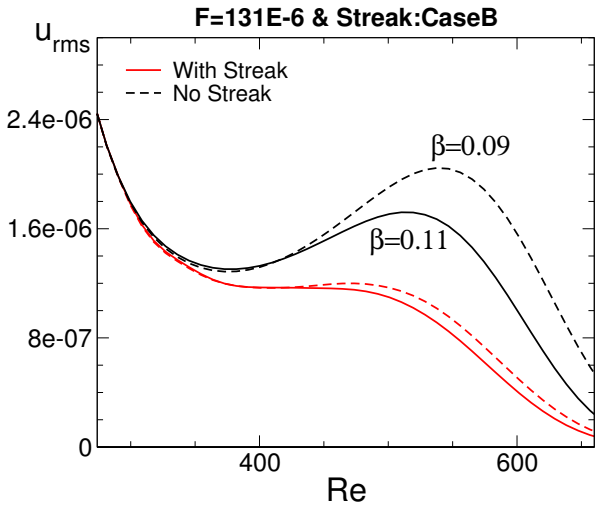

Figure 2: The growth of two different disturbances in the presence and absence of a streak, with a maximum amplitude $A_s \sim 14\%$ of U_∞.