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## LINEAR STABILITY ANALYSIS ON A LAMINAR SEPARATION BUBBLE SUBJECTED TO FREESTREAM TURBULENCE

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Boundary layer measurements using hotwire anemometry are employed to study the flow development of a laminar separation bubble (LSB) over the suction side of a NACA0015 aerofoil, at a chord based Reynolds number of 125000 fixed and at an angle of incidence of 2.3 degrees, in a open circuit wind tunnel subjected to a wide range of turbulence intensity ( $0.15\% < Tu < 6.26\%$ ). A Local linear stability analysis (LST) is conducted on experimental boundary layer profiles in the fore position of the LSB (cf. Fig. 1). LST is shown to accurately model incipient disturbance growth, unstable frequencies and eigenfunctions for configurations subjected to levels of  $Tu$  up to 3%, suggesting modal growth of instabilities, even at elevated levels of  $Tu$ . Additionally, the presence of streaks is highly probable for configurations with  $Tu > 1\%$ , with unfiltered wall-normal disturbance profiles agreeing remarkably well with the optimal perturbation profile proposed by Luchini et al. (2000), cf. Fig. 2. This observation leads to the conclusion that the co-existence of both modal and non-modal convective growth of instabilities is present in the LSB, providing experimental confirmation of the numerical simulations by Hosseinverdi and Fasel (2019). Furthermore, increasing the  $Tu$  resulted in the range of unstable frequencies to decrease and the Reynolds number dependence to increase due the inflection point shifting closer towards the wall. This suggests that a viscous, rather than an invicid formulation of the stability equations is appropriate for modeling modal instabilities in the fore portion of the current LSB, especially in the presence of freestream turbulence. It is ascertained that streaks (non-modal instability) modify the mean flow field, resulting in an increased importance of viscosity, which contributes to the the damping of the convective growth of modal instabilities in the LSB.

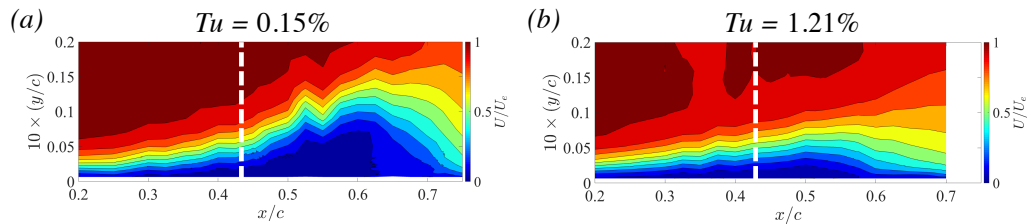


FIGURE 1. Contours (21 chordwise boundary layer profiles) of the mean streamwise velocity for (a) the natural case and (b) the case with freestream turbulence forcing. White line denotes the location of local LST analysis.

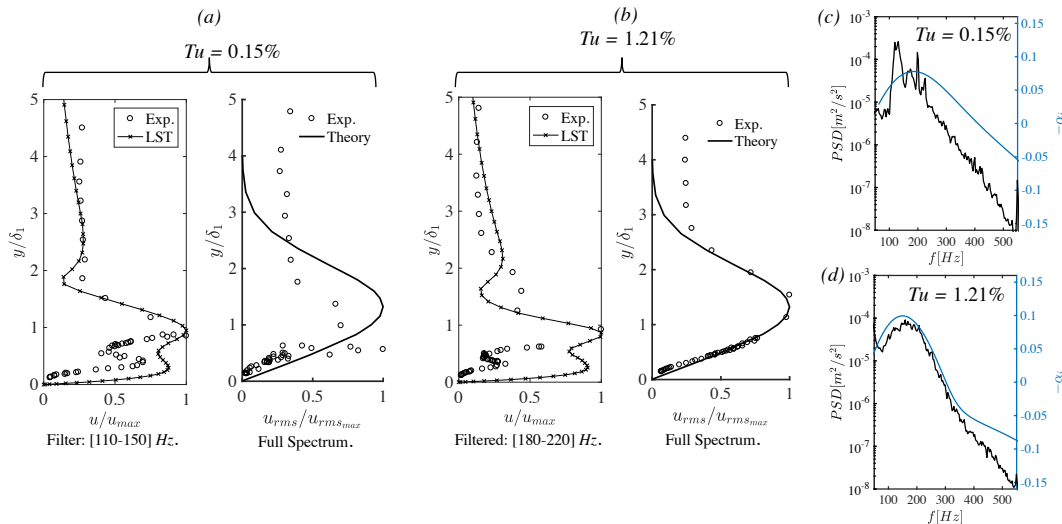


FIGURE 2. Experimental/LST predicted eigenfunctions and unfiltered wall-normal disturbance profiles compared to theoretical predictions by Luchini et. al (2000) for (a) the natural case and (b) the case with freestream turbulence forcing. Comparison between the amplified frequencies predicted by LST and measured in the experiment (c,d)

### References

- [1] Luchini, P. Reynolds-number-independent instability of the boundary layer over a flat surface: optimal perturbations. *Journal of Fluid Mechanics*, 404, 289–309, 2000.
- [2] Hosseinverdi, S., Fasel, H. F. Numerical investigation of laminar–turbulent transition in laminar separation bubbles: the effect of free-stream turbulence. *Journal of Fluid Mechanics*, 867858, 714–759, 2019.