Global stability analysis of flows around laminar airfoil

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Experimental[1] and numerical studies[2 3] of transonic flows around airfoil have shown that the shock unsteadiness (also called buffet) is dramatically altered by the laminar or turbulent state of the incoming boundary layer. By performing LES simulations of the transonic flow around an OALT25 airfoil, Zauner et al.[3] showed more specifically the co-existence of a low-frequency buffet mode and an intermediate frequency laminar separation bubble mode. The present work aims at investigating the onset of these two unsteady phenomena by performing a global stability analysis of the transonic steady flow within a RANS framework. To that aim, we consider the Spalart-Allmaras model (SA-neg) as a turbulence model together with the γ transition model proposed by Menter et al.[4]. As shown in Fig. 1, such baseline model (solid) does not well capture the laminar separation bubble (LSB) that forms downstream the shocks, because it underpredicts the turbulence production and associated wall-skin friction downstream the reattachment (dotted). To correct such discrepancy, we have applied the laminar separation correction developed by Bernardos et al.[5], that boosts the turbulent production of the SA model in the vicinity of the reattachment point. That correction, originally calibrated for subsonic LSB's, allows to improve the position of the separation and reattachment points (dashed). By modifying the constants proposed by Bernardos et al., we will further improve the prediction of that laminar separation region. Global stability analysis will be then performed for several angles of attack, in particular to identify the existence of an unstable intermediate frequency global mode associated to the laminar separation bubble, as suggested by Zauner et al.[3]

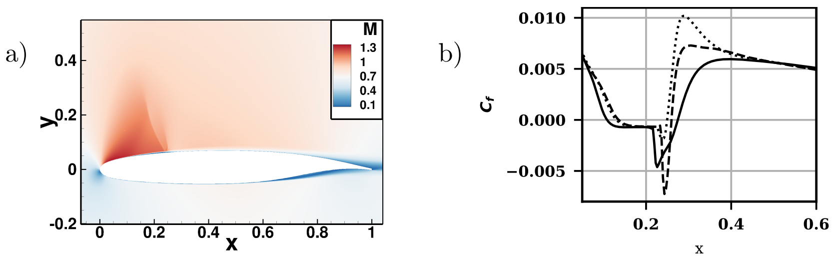

Figure 1: OALT25 airfoil at $M_\infty = 0.67$ and $Re = 500,000$. (a) Mach number field showing shock system and thin LSB below for SA-neg-Log(γ) + LSB corr[5]. (b) C_f distribution for SA-neg-Log(γ) (solid) and SA-neg-Log(γ) + LSB corr. (dashed) in comparison with LES[3] (dotted)

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[2]Zauner and Sandham, *Phys. Rev. Fluids* **5**, 083903 (2020).
[3]Zauner et al., *arXiv:2209.10708 [physics.flu-dyn]* (2022).
[4]Menter et al., *Flow, Turbulence and Combustion* **95**, 583 (2015).
[5]Bernardos et al., *AIAA Journal* **57**, 553 (2019).