DNS OF THE INTERACTION OF CROSSFLOW INSTABILITIES WITH FORWARD-FACING STEPS

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Previous studies on the interaction between stationary crossflow (CF) vortices and a forward-facing step (FFS) have shown a significant influence on the laminar-turbulent transition (e.g. [1, 2]). In a recent experimental investigation, Rius-Vidales & Kotsonis [3] found that the effect of the step height on the transition location is non-monotonic. An unprecedented transition delay (w.r.t to the case without FFS) occurs when the incoming stationary CF vortices interact with a shallow FFS. Instead, the interaction with a higher FFS leads to an upstream advancement of the transition front location. The present work aims to numerically reproduce the experimental setup in [3] through direct numerical simulation (DNS). The current investigation's final goal is to understand further the flow physics behind the observed behaviour in the experiments.

The 3D DNS simulations are run on a relatively small domain to reduce the computational cost. The required boundary conditions for the latter are obtained with a complementary 2.5D RANS simulation followed by 2.5D DNS simulations for the base flow fields. The effect of discrete roughness elements used to condition the instability modes in the experiments is accurately reproduced via perturbations computed through nonlinear parabolised stability equations. Those are imposed at the inflow boundary of the 3D DNS domains. Unsteady noise is also added as a random forcing in the boundary layer such that the laminar-turbulent transition in the simulations approximates that in the experiments for the clean case without step.

The results show that the experimental setup can be numerically reproduced with sufficient accuracy as far as the steady flows are concerned, with a good agreement between the experimental and numerical velocity profiles upstream and downstream of the step. The transition delay effect due to a small FFS is also found in the DNS (Figure 1) and a detailed analysis of the unsteady disturbances will be presented to shed light on this behaviour.

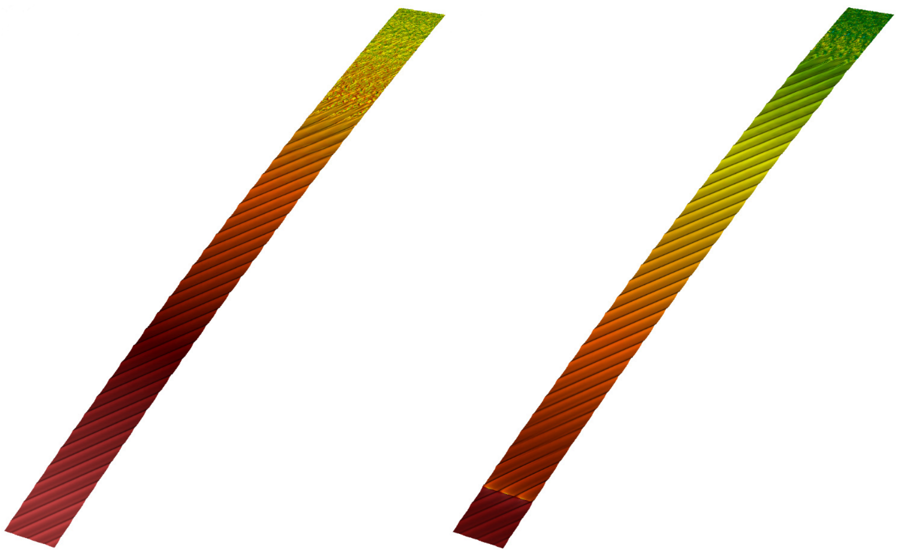

Figure 1: Isosurfaces of instantaneous magnitude velocity field colored by pressure in the clean case (left) and FFS case (right).

References

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