

Detached-Eddy Simulations for active flow control

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Until 2020, the aviation industry expects to reach the goal of 50 percent in emission reduction, which has motivated extensive development on the active flow control (AFC) methods. AFC is especially appealing in case of separated flows, for which natural instability phenomena can be efficiently exploited to manipulate flow characteristics. For the numerical investigations focused on a variation of several parameter values for evaluating the AFC effectiveness, it is not affordable regarding computing resources and time to adapt DNS or LES methods. Due to the well-known limitations of RANS models in the context of unsteady separated flows, the parametric study of AFC presents an ideal application for the hybrid RANS-LES methods (HRLM).

In this study, we aim to assess the ability of HRLM application in an optimization frame work for AFC. Two specified test cases, the backward-facing step (BFS) flow and the NACA0015 airfoil flow, are of fundamental type. This work includes a comparison of different choices of underlying RANS models as well as subgrid-scale stress models in LES mode. The results show that the BFS case is not sensitive to the different near-wall treatments in HRLM; while for the NACA0015 aerofoil case, with the same mesh resolution, only IDDES predicts flow separation and turbulent structures as demonstrated experimentally.

Spectra analyses based on the IDDES results are thus carried out by using Dynamic Mode Decomposition to identify spatial structures to the different Strouhal frequencies. The characteristic physical modes of the unexcited flows are extracted for both cases, demonstrating again the correctness of the IDDES computations.

With better understanding of unsteady flow features, effective control practices are illustrated. We conduct IDDES of AFC with a harmonic actuation on the BFS and pulsed blowing on the NACA0015 aerofoil for the reattachment and separation control. For the BFS case, it is found that the optimum excitation frequency equals to the step-mode frequency. The pairing process is enhanced by harmonic actuation, forming the largest scale spanwise coherent structures in the shear layer, with 40% the maximum reduction of the bubble length. For the aerofoil case, with the optimum excitation frequency that determined by the vortex-shedding mode, 63% the increase of the lift to drag ratio is obtained.