Seventh HRLM Symposium, 19-21 September 2018, Berlin, Germany

Session:

Hybrid RANS/LES investigation of the interaction of a longitudinal vortex with an inclined airfoil

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Introduction

Engine nacelles of modern commercial aircraft are often equipped with small vortex generators (strakes) to avoid early flow separation of the adverse-pressure-gradient boundary layer on the main wing in low-speed flight. In numerical flow simulations, conventional RANS models show a tendency to overly dissipate these free vortices. Therefore, we study an application scenario for hybrid RANS-LES methods to account for longitudinal vortices and their interaction with airfoils, in order to clarify some open questions: the grey-area problem for free vortices and the extension of synthetic turbulence to such large-scale turbulent structures, the influence of mesh design and resolution, as well as the modelling of the RANS and LES regions over the airfoil. Three approaches are compared: Firstly, pure IDDES [1] is employed with its inherent switching mechanism to wall-modelled LES. Secondly, the switching in the IDDES is controlled by algebraic sensors [2] which activate the WM-LES and the injection of synthetic turbulence upstream of the interaction region of the free vortex with the attached boundary layer. Thirdly, the entire boundary layer is treated in RANS mode.

Test case setup

For this investigation we developed a generic test case with a longitudinal vortex and an inclined airfoil, see Fig. 1. We designed a vortex with characteristics similar to a strake vortex [3], which is introduced into the flow by volume source terms at an internal actuator disk.

The synthetic turbulence approach of [4] is extended for the application to free vortices, so that small-scale turbulent structures can be introduced into the RSM-based HRLM in the region close to the plane where the vortex is generated by the actuator disc. This method has been tested for a simple free vortex, and the results of this preliminary study will be summarized in the paper.

For the interaction of the vortex with the inclined airfoil, the effect of a structured or unstructured grid type is compared using two similar grids, which contain about $26 \cdot 10^6$ points with a wall-normal boundary-layer resolution of 60 points. The spacings in the grid amount to $\Delta x^+ \approx 400$ (streamwise), $\Delta y^+ \approx 300$ (spanwise) and $\Delta z^+ \approx 1$ (wall-normal), which is considered sufficient for a wall-modelled LES.

We consider the HGR01 airfoil at an incidence of $\alpha = 10°$, a Reynolds number of $Re = 1.98 \cdot 10^6$ and a Mach number of $Ma = 0.155$. The vortex extends over a diameter of $0.1c$ which is comparable to the dimension of a realistic strake-vortex. The vortex is generated one chord length upstream of the leading edge of the airfoil and travels downstream closely to the upper side of the airfoil (see Fig. 1). The effect of the grid type and the modelling scheme on the boundary-layer solution will be analysed in terms of the skin-friction distribution and other relevant data in comparison with reference RSM-based RANS results.

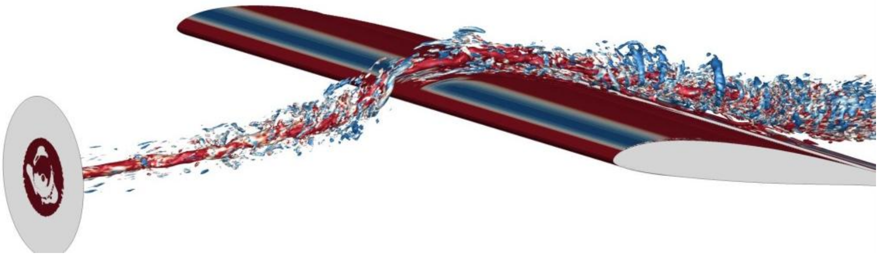

Fig. 1: Resolved vortex traveling downstream along the upper side of the HGR01 airfoil. The boundary layer is treated in RANS mode.

Bibliography

[1] M. L. Shur, P. R. Spalart, M. K. Strelets and A. K. Travin, "A hybrid RANS-LES approach with delayed-DES and wall-modelled LES capabilities," *International Journal of Heat and Fluid Flow*, vol. 29, pp. 1638-1649, 2008.

[2] S. Probst, "Hybrid RANS/LES Simulation Strategy for High-Lift Applications with Disturbed Inflow," in *Progress in Hybrid RANS-LES Modelling*, Y. Hoarau, S. H. Peng, D. Schwamborn and A. Revell, (Eds.), *NNFMMD*, vol. 137, Springer, 2018.

[3] T. Landa, L. Klug, R. Radespiel, S. Probst and T. Knopp, "Experimental and Numerical Analysis of a Streamwise Vortex downstream of a Delta and Wing," *AIAA 2018-XXXX*, 2018.(accepted for presentation)

[4] D. G. François, R. Radespiel and A. Probst, "Airfoil Stall Simulations with Algebraic Delayed DES and Physically Based Synthetic Turbulence for RANS-LES Transition," *AIAA 2014-2574*, 2014.