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Session:

Hybrid RANS/LES of an Adverse Pressure Gradient Turbulent Boundary Layer Using an Elliptic Blending Reynolds Stress Model and Anisotropic Linear Forcing

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Although scale-resolving simulations (SRS) of turbulent boundary layers (TBLs) have been performed for many years (e.g. Spalart[1], Wu & Moin, Schlatter et al.), SRS of industry-relevant external flows remain difficult. One of the main limitations stems from the fact that using classical techniques, it is necessary to include the whole industrial configuration, even if scale-resolving is only important in a small subdomain. This requirement adds not only to the costs of the simulation, but also to the uncertainties associated with modelling (e.g. grey-area mitigation when using Detached Eddy Simulation or similar variants, such as the Partially-Averaged Navier-Stokes Method), and numerical treatments (resolution, time-steps).

In the past, several methods for generating accurate boundary conditions in subdomains of external flow fields have been tested on high Reynolds number zero pressure gradient (ZPG) TBLs. Recently, a hybrid RANS/LES scheme based on a combination of the Elliptic-Blending Reynolds Stress Model[2] (EB-RSM), Anisotropic Linear Forcing[3] (ALF) and classical Large Eddy Simulation (LES) has been used to simulate the noise generated by the interaction of a ZPG TBL with a cavity positioned in a large airfoil[4]. Only the region close to the cavity was simulated using LES and inflow conditions were provided by the EB-RSM/ALF method. Compared to a true WRLES, that would have included the whole domain, this approach significantly reduced the overall computational costs but still provided accurate results.

In this work, we will study the applicability of the EB-RSM/ALF combination for the prediction of an adverse pressure gradient TBL. EB-RSM/ALF simulations results will be compared to an experimental study by DLR. In the experiment, the adverse pressure gradient is generated above a flat plate using a NACA-0012 profile at an angle of attack of 10°. High fidelity measurements of the Reynolds Stresses, the mean velocity profile, the wall pressure spectra and the spatial correlation were

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performed[5]. The data were originally used to validate numerical simulations with the Fast Random Particle Mesh Method[6].

We will especially emphasize the influence of two relevant aspects for complex flow situations:

i. On realistic geometries it is often difficult to achieve well converged solutions of Reynolds Stress Model based RANS: Instabilities of the models or discrepancies in the physical modelling are a common drawback. We show that it is necessary to include the wind-tunnel geometry in the EB-RSM simulation to generate accurate velocity TBL profiles, but that even in this case the calculated Reynolds Stresses in the TBL differ up to 20% from the measured values. We also investigate the influence of this error on the transient TBL characteristics generated by ALF in a small subdomain of interest. In addition, the influence of using pure isotropic forcing, instead of anisotropic, is studied.

ii. On simple geometries zonal forcing methods are usually applied upstream of the region of interest. In case of complex geometries this assignment becomes difficult. We show in our case that this classical forcing approach leads to insufficient results and study how different geometrical forcing zones can improve the results.

References

[1] Spalart, P., "Direct simulation of a turbulent boundary layer up to R_θ = 1410," Journal of Fluid Mechanics, Vol. 187, pp. 61-98.

[2] Lardeau, S., and Manceau, R., "Computations of canonical and complex flow configurations using a robust formulation of the elliptic-blending Reynolds-Stress model," 10th International ERCOFTAC Symposium on Engineering Turbulence Modelling and Measurements, Marbella, Spain, 2014.

[3] De Laage de Meux, B., Audebert, B., Manceau, R., and Perrin, R., "Anisotropic linear forcing for synthetic turbulence generation in large eddy simulation and hybrid RANS/LES modeling," Physics of Fluids, Vol. 27, No. 3, 2015, p. 035115.

[4] Erbig, L., Hu, N., and Lardeau, S., "Experimental and Numerical Study of Passive Gap Noise", 24th AIAA/CEAS Aeroacoustics Conference, 2018.

[5] Hu, N., and Herr, M., "Characteristics of Wall Pressure Fluctuations for a Flat Plate Turbulent Boundary Layer with Pressure Gradients," 22nd AIAA/CEAS Aeroacoustics Conference, 2016. AIAA 2016-2749

[6] Hu, N., Reiche, N., and Ewert, R., "Numerical investigation of wall pressure fluctuations for zero and adverse pressure gradient turbulent boundary layers using synthetic anisotropic turbulence", 23rd AIAA/CEAS Aeroacoustics Conference, 2017. AIAA 2017-3200.