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

Session:

A rapid and low noise RANS-to-WMLES condition in curvilinear compressible ZDES simulations

Nicolas Renard, Sébastien Deck, Pierre-Elie Weiss

ONERA The French Aerospace Lab

The simulation of resolved wall-bounded turbulence using hybrid RANS/LES methods requires a turbulent injection at the inflow, provided for instance by the Synthetic Eddy Method (SEM) [1]. Compared with Wall Resolved Large Eddy Simulation, the boundary condition in a Wall-Modelled LES is more demanding because of the lack of resolution of the innermost turbulent dynamics. The performance of the method may be significantly improved by means of a Dynamic Forcing (DF) strategy [2]. However, the spurious acoustic footprint of most turbulent injection methods is not acceptable for aeroacoustic studies and specific attention has to be paid to this issue [3].

In the present study, a low-noise turbulent injection strategy is proposed for Zonal Detached Eddy Simulation (ZDES [4]) in its third mode performing a WMLES [5]. This strategy involves physics-based roughness elements triggering the modelled-to-resolved transition of turbulence and described by Zonal Immersed Boundary Conditions (ZIBC [6]). The approach is enhanced by the Dynamic Forcing, resulting in a relaxation distance smaller than 10 δ_0 and a strong reduction of the spurious noise (fig. 1). The resolved pressure fluctuations in the boundary layer are not dominated by spurious noise and have a physical spectral content (fig. 2), paving the way for applications such as high-lift multi-element aerofoil noise prediction (fig. 3).

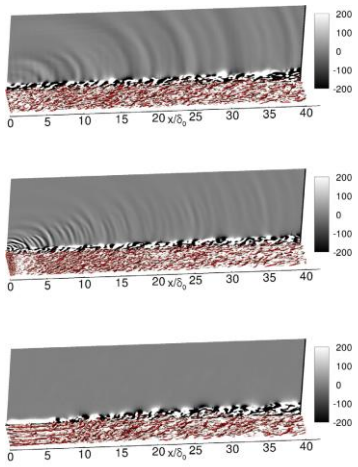

Fig. 1 Iso-Q criterion ($Q=0.25\ U_0^2/\delta_0^2$) coloured by sign(ω_x), instantaneous pseudo-dilatation field (gray scale). SEM (top), white noise (middle), new ZIBC-based approach (bottom).

Session:

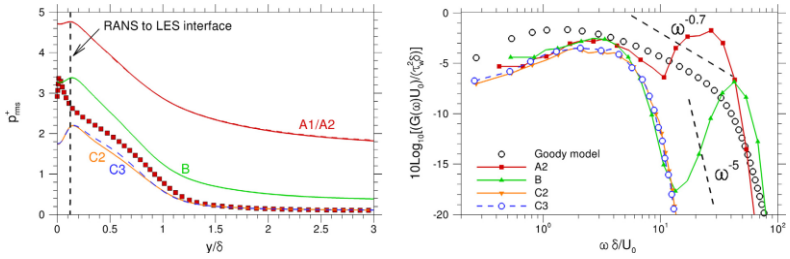

Fig. 2 Resolved pressure fluctuations in a flat-plate zero-pressure-gradient turbulent boundary layer at $Re_\theta = 5200$. Left: rms profile; right: power spectral density of wall pressure. Cases A: SEM, B: white noise, C: present new ZIBC-based approach.

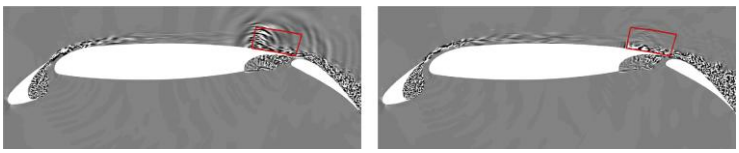

Fig. 3 Instantaneous pseudo-dilatation field around a high-lift configuration using white noise forcing on the left and the new ZIBC-based approach on the right

References

[1] M. Pamiès, P.-E. Weiss, E. Garnier, S. Deck, P. Sagaut, Generation of synthetic turbulent inflow data for large eddy simulation of spatially evolving wall-bounded flows, Phys. Fluids 21 (2009) 045103.

[2] R. Laraufie, S. Deck, P. Sagaut, A dynamic forcing method for unsteady turbulent inflow conditions, J. Comput. Phys. 230 (2011) 8647–8663, https:// doi .org /10 .1016 /j .jcp .2011.08 .012.

[3] M. Shur, P. Spalart, M. Strelets, A. Travin, Synthetic turbulence generators for RANS-LES interfaces in zonal simulations of aerodynamic and aeroacoustic problems, Flow Turbul. Combust. 93 (1) (2014) 63–92.

[4] S. Deck, Recent improvements of the Zonal Detached Eddy Simulation (ZDES) formulation, Theor. Comput. Fluid Dyn. 26 (6) (2012) 523–550, https:// doi .org /10 .1007 /s00162 -011 -0240 -z.

[5] S. Deck, N. Renard, R. Laraufie, P. Sagaut, Zonal Detached Eddy Simulation (ZDES) of a spatially developing flat plate turbulent boundary layer over the Reynolds number range $3150 < Re_\theta < 14000$, Phys. Fluids 26 (2) (2014) 025116, https://doi .org /10 .1063 /1.4866180.

[6] P.-E. Weiss, S. Deck, On the coupling of a zonal body-fitted/immersed boundary method with ZDES: application to the interactions on a realistic space launcher afterbody flow, Comput. Fluids (2017), https://doi .org /10 .1016 /j .compfluid .2017.06 .015, in press.