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HYBRID LES-RANS: ESTIMATION OF RESOLUTION USING TWO-POINT CORRELATIONS, ENERGY SPECTRA AND DISSIPATION SPECTRA IN RE-CIRCULATING FLOW

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ABSTRACT

Hybrid LES-RANS simulations have been carried out for the flow over a bump in a duct. Measurements were carried out by ONERA in the DESider project [1]. $Re_h = 0.93 \cdot 10^6$ based on the bump height, h. The simulations were carried out using only a slice in the central region and periodic boundary conditions in the spanwise direction, z.

$32/64/128$ cells are used in the z-direction. The matching plane between LES and URANS is prescribed along fixed grid planes; the URANS region near the upper and the lower walls extends 12 wall-adjacent cells. The mean inlet boundary conditions are taken from URANS simulations of the entire bump using a zonal version of the Reynolds stress$-\omega$ model [2]; in the slice region the results of the URANS simulations match the experimental data. Synthetic turbulent fluctuations are superimposed on the mean inlet profiles [3].

Coarse grids were purposely chosen since this is of high relevance for industrial flows. The inlet boundary layer is indeed very poorly resolved. The spanwise (z) and streamwise (y) grid spacing are $0.44/0.22/0.11$ and 0.33, respectively, when scaled with the inlet boundary layer thickness and the corresponding resolutions in wall units are $1800/900/450$ and 1300. Consequently, on the coarse and the medium mesh (32 and 64) the spectra of the resolved fluctuations do not exhibit any physical realism. However, the resolved turbulence downstream of the bump exhibits clear $-5/3$ ranges – also on the coarse mesh – both in the recirculation region and in the shear layer.

Since in this flow we have one homogeneous direction (z), we can investigate how the dissipation is distributed over the spanwise wavenumbers, κ_z. In particular, it is convenient to look at the components of the viscous dissipation which involve the spanwise derivative. e.g. $\varepsilon_{zz} = \nu(\partial w'/\partial z)^2$. It is usually assumed that the it is large for the largest wavenumbers (smallest resolved scales). However, it is found that it is largest for small-to-mid-range wave numbers. Furthermore, in theory, $\kappa_z^2 E_{ww}$ can be used to compute the spectral distribution of $\partial w'/\partial z$; it is found that this is not true. The reason is that the finite volume method is inaccurate in evaluating the velocity gradient at the highest wavenumbers.

The SGS dissipation, $\varepsilon_{SGS} = 2\langle \nu_T \bar{s}_{ij}\bar{s}_{ij}\rangle$, is evaluated both in the boundary layer on the bump and downstream of the bump. It is found that, in the poorly resolved boundary layer, the SGS dissipation is created by the time-averaged flow, i.e. by $\varepsilon_{SGS,mean} = 2\langle \nu_T\rangle\langle \bar{s}_{ij}\rangle\langle \bar{s}_{ij}\rangle$. As we move further downstream, the SGS dissipation is progressively taken over by the resolved fluctuations, i.e. by $\varepsilon'_{SGS} = \varepsilon_{SGS} - \varepsilon_{SGS,mean}$. The relation between ε'_{SGS} and $\varepsilon_{SGS,mean}$ seems to be a good measure of how much of the energy spectrum is resolved.

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