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ASSESMENT OF A HYBRID LES-RANS CONCEPT BASED ON EDDY-VISCOSITY REDUCTION USING RESOLVED REYNOLDS STRESSES

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ABSTRACT

The computational cost of LES in near-wall flows increases with the Reynolds number almost as rapidly as that of DNS. To overcome this problem, several approaches to combine RANS in near wall regions to LES have been developed. The present study focuses on the method proposed by Medic et al. [1]. It is based on matching the shear stress obtained from averaged RANS and LES equations leading to a RANS-based correction for the near-wall eddy viscosity. For simple wall-parallel flows the eddy viscosity in the near-wall region is obtained as

$$\nu_T^{nw} = \nu_T^R + \langle \tilde{u}'\tilde{v}' \rangle / (\mathrm{d}\langle \tilde{u} \rangle / \mathrm{d}y) \qquad (1)$$

with y the wall-normal coordinate, ν_T^R the eddy viscosity provided by a RANS model and the tilde indicating resolved quantities. The last term in (1) usually leads to a reduction of ν_T^{nw} compared to ν_T^R. A generalisation of (1) is presented in [2]. The extent of the area where this near-wall treatment is applied is set by the user, and an SGS model is applied elsewhere. This typically leads to a discontinuous eddy-viscosity at the interface. The terms ν_T^R and $\mathrm{d}\langle \tilde{u} \rangle / \mathrm{d}y$ in (1) can be obtained either from pre-computed tables for a reference flow such as a zero-pressure gradient boundary layer or by solving the RANS-model simulataneously with the LES using $\langle \tilde{u} \rangle$ as input ("dynamic coupling"). The latter is required for complex flows but was only addressed briefly in [1].

We implemented the dynamic coupling approach and applied it to fully developed turbulent plane channel flow at $Re_\tau = 395$ and 950 with the Smagorinsky model in the outer region. Unfortunately, the method turned out to be very sensitive to details of the simulation. 1) SGS modelling: Changing the Smagorinsky constant from 0.1 to 0.18 had a substial effect for the higher Reynolds number. 2) Position of interface (Fig. 1): with $Re_\tau = 395$ and the interface at $y^+ = 40$, a strong discontinuity in $\mathrm{d}\langle \tilde{u} \rangle / \mathrm{d}y$ occurs at the interface while a relatively smooth velocity profile is obtained when the interface is at $y^+ = 20$, as in [1]. Medic et al. [1] showed that a distorted velocity profile is obtained if the correction term in (1) is omitted. According to the present results, however, strongly distorted velocity profiles can be obtained also with the correction term activated. 3) Averaging procedure: dynamic coupling requires the averaged LES velocity field as input for the RANS transport equation. Temporal, spatial and

spatio-temporal in the course of the simulation averaging was tested. It turned out that spatial averaging alone led to asymmetric velocity profiles. Most results were obtained with temporal averaging. For the data below spatio-temporal averaging was used.

The observed sensitivity of the dynamic coupling was observed to be inherent to the method. We provide the following explanation: As soon as ν_T has a discontinuity at the interface, the mean velocity gradient exhibits a jump (Fig. 1, left). If $\mathrm{d}\langle\tilde{u}\rangle/\mathrm{d}y$ is overestimated, the RANS model produces an unphysical peak in the production rate P^R of the RANS-TKE k^R (Fig. 1, right). This generates unphysically high values of k^R and hence ν_T^R so that the ν_T-jump at the interface is increased. Additionally, the higher ν_T damps the resolved fluctuations, thus reducing the correction term in (1), hence further increasing the turbulent viscosity. In this way any discontinuity in ν_T may be self amplifying depending on the modelling details. To show that the spurious peak in P^R is really responsible for the mean-velocity jump, the peak was artificially cut away. This almost removed the jump (not shown).

As an attempt to eliminate the discontiuity in ν_T in general case, a smoothed interface with continuous ν_T was also tested. Fig. 1 shows that this does not solve the problem since even a continuous but non-monotonic ν_T may lead to locally increased $\mathrm{d}\langle\tilde{u}\rangle/\mathrm{d}y$ and thus to an unphysical peak in P^R.

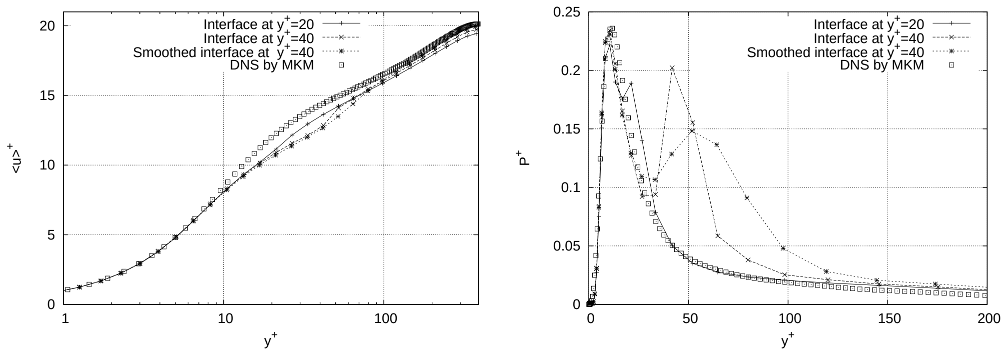

Figure 1: Mean velocity (left) and RANS energy production rate P^R (right) for channel flow at $Re_\tau = 395$. DNS data from [3].

Computations of the separated flow over periodic hills were performed as well and will be presented at the conference. Here, the distortion of the mean velocity profile is less severe and the agreement with the data from [4] is better.

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