Séminaire du groupe Fluides ouvert à tous les membres du Lemta

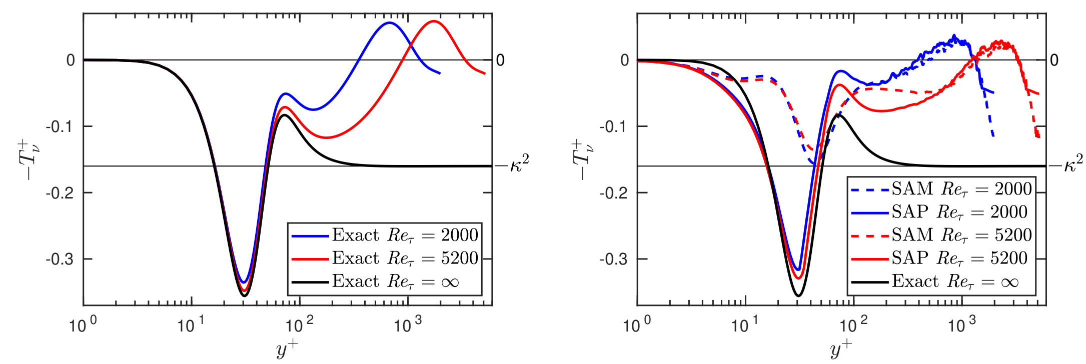
Vendredi 26 novembre 9h - 10h salle Coriolis - Emmanuel Plaut

Ideas for RANS (and hybrid RANS-LES) turbulence models based on a recent analytic theory - Towards CFD ?

I will start with a short presentation of the classical RANS approach, focussing on eddy-viscosity models like the $k - \epsilon$ model. It has three equations: the RANS equation for the mean velocity field, the k equation and the ϵ equation. Using the channel flow DNS database of Lee & Moser, I will confirm that the highly heuristical ϵ equation has some flaws. I will also advocate the ν_t model of Spalart & Allmaras, and the $k - \nu_t$ models of Menter et al. Interestingly, these latter models, also named 'Scale - Adaptive', are claimed to be 'instability sensitive', in that they may run in hybrid RANS-LES mode.

I will then present briefly the high Reynolds number theory of Stefan Heinz for some mean fields of 'turbulent wall flows': zero-pressure gradient boundary layer, channel and pipe flow.

The analytical expressions validated for ν_t , as the product of a function of y^+ and a function of y/δ, were used by Stefan Heinz and I as a starting point to derive a new exact transport equation for ν_t , which should be valid for all 'turbulent wall flows' as soon as the inner units Reynolds number $Re_\tau \gtrsim 500$, and in the limit $Re_\tau \to \infty$. This ν_t equation has one production and two dissipation terms. Remarkably, the first dissipation term is universal and peaks near the wall, in good agreement with the wall damping idea. All this yields a test and working bench of existing RANS models with a similar ν_t equation. I will show that the model of Spalart & Allmaras does not respect the flow physics in that it displays a production peak in the near-wall region. I will then propose a modified Scale - Adaptive model which behaves much more correctly than the original Menter's models in the near-wall region in channel flow but also, hopefully, near any wall, as soon as the flow remains attached. Last but not least, this new model may also function in hybrid RANS-LES mode.



The ν_t equation reading, in inner units, $-T_\nu^+ = -\frac{\partial}{\partial y^+}\left(\nu^+ \frac{\partial \nu^+}{\partial y^+}\right) = P_\nu^+ - D_\nu^+$ with P_ν^+ (resp. $-D_\nu^+$) the production (resp. dissipation) terms, the ν_t budget is presented by plots of $-T_\nu^+$ vs y^+, for channel flows.
Left: exact model; note the near-wall dissipation peak.
Right: exact model, one Scale - Adaptive (SA) model of Menter (SAM), our SA model Physically corrected (SAP).

The models in competition should now be tested with CFD simulations, first in simple configurations like the channel flow case, second in more complex configurations, displaying preferentially separated flow regions. The first task has just started, I will be happy to discuss ideas for the second one.

RANS = Reynolds Average Navier Stokes = Modèles de champs moyens
LES = Large Eddy Simulations = Simulations des grandes échelles
k = turbulent kinetic energy = énergie cinétique des fluctuations turbulentes
ϵ = turbulent dissipation = taux de dissipation de k
ν_t = turbulent viscosity or eddy viscosity in physical units ; ν^+ = eddy viscosity in inner units
y^+ = wall - normal distance in inner units ; y/δ = wall - normal distance in outer units