On Low Reynolds Modelling Robustness for Industrial Flows and Feedback to L.E.S.

F. Billard\textsuperscript{1}, U. Gaitonde\textsuperscript{1}, Y. Addad\textsuperscript{1}, and D. L. Laurence\textsuperscript{1,2}

The aim of this work is to develop a RANS model as simple as eddy viscosity models, with good predictive capabilities to correctly reproduce near-wall effects, with emphasis on robustness when used in an industrial code such as Code_Saturne. It stems from a $v^2-f$ based model (Durbin (1991)) (thus not requiring any ad-hoc damping function, distance to the wall dependent), and combines code-friendly modifications of Lien \& Durbin (1996) and Laurence \textit{et al} (2004). The output, the $\phi-\alpha$ model is a model robust (code-friendly boundary conditions) and accurate (no neglected terms). It replaces the elliptic relaxation of Durbin (1991) by the elliptic blending (Manceau (2002)) to enhance its robustness.

The $\phi$-$\alpha$ model

The grid is generated using integral scales computed from a RANS model predictions. Here it is important for RANS models to be able to predict the correct levels of $k$ and $\varepsilon$ which can be then used for the input turbulent length scale in the automatic, python based, grid generator.

Ongoing work: a) improvement of the $\phi$-$\alpha$ model using ingredients coming from other models such as Launder \& Sharma model (1974) in order to strengthen the coupling between turbulence and mean velocity. b) $\varepsilon$ equation needs additional terms when used down to the wall. Comparison of the term used by the model of Laurence \textit{et al} (2004) (dashed red line) and by the one of Launder \& Sharma (1974)(black).

Predictions of the buoyancy-induced relaminarisation of an upward flow inside a heated pipe (DNS of You \textit{et al} (2003)). The $\phi-\alpha$ is the only model able to correctly predict the low levels of $k$ for the heat transfer regime associated with relaminarization. On the other hand, the k-\omega SST model predicts a turbulent flow regardless of the heat flux.

- \textbf{a)} Nusselt number as a function of the buoyancy parameter.
- \textbf{b)} turbulent energy profiles for the 3 regimes.

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|c|}
\hline
\textbf{model} & $U^\text{max}(Y=0.03)$ & $U^\text{max}(Y=0.19)$ & Difference ($\%$) \\
\hline
$\phi-\alpha$ & 20.40 & 20.40 & 10\textsuperscript{-5}\% \\
Launder & 21.16 & 21.16 & 10\textsuperscript{-5}\% \\
Sharma & 19.66 & 19.58 & 0.4\% \\
\hline
\end{tabular}
\end{table}

\begin{flushleft}
\textbf{c)} 3D view of the grid near the inlet jet zone.
\end{flushleft}