6th HRLM Symposium, 26-28 September 2016, Strasbourg, France

On the von Karman length scale as a triggering parameter in eddy-resolving simulations of turbulent flows

R. Maduta[1,2] andS. Jakirlic[1]

[1]Institute of Fluid Mechanics and Aerodynamics / Center of Smart Interfaces
TechnischeUniversität Darmstadt, Alarich-Weiss-Straße 10, 64287 Darmstadt, Germany
[2]Outotec GmbH, Ludwig-Erhard-Strasse 21, D-61440 Oberursel, Germany

The von Karman length scale ($L_{vK} = \kappa S/|\nabla^2 U|$) represents a key element in triggering the flow to generate resolved turbulence in Scale-Adaptive Simulation (SAS, Menter and Egorov, 2010; *FTaC*, Vol. 85(1), pp. 113-138), analog to the role of grid spacing Δ ($= \sqrt[3]{\Delta_x \Delta_y \Delta_z}$) in Large-Eddy Simulation. Accordingly, the L_{vK} length scale mimics the length scale of resolved motion within the SAS framework, and the shear rate $S(= \sqrt{2S_{ij}S_{ij}})$ represents its frequency scale. Jakirlic and Maduta (2015; *IJHFF*, Vol. 51, pp. 175-194) applied the SAS methodology to a near-wall Reynolds stress model, the $\overline{u_i u_j}$model equation of which is coupled with the scale-supplyingequation governing the homogeneous part of theinverse turbulent time scale($\omega_h = \varepsilon_h/k$, with $\varepsilon_h = \varepsilon - 0.5D_k^{\nu}$). The model capability to account for the vortex length and time scale dynamics is, in line with the SST-SAS model (Menter and Egorov, 2010), enabled through an additional term in the corresponding length-scale determiningequation, providing selective enhancement of its production:

$$P_{SAS}^* = 2.3713\kappa S^2 \left(\frac{L}{L_{vk}}\right)^{1/2} - 3C_{RSM,2}k \max\left(\frac{(\nabla\omega_h)^2}{\omega_h^2}, \frac{(\nabla k)^2}{k^2}\right)$$

The key issue here is the ratio of the turbulent length scale$L = k^{1/2}/\omega_h$ to the von Karman length scale, formulated in terms of the secondderivative of the velocity field ($\nabla^2 U$).Generally,in accordance with its definition, the L_{vK}length scale exhibits different behavior under conditions of different flow straining (Figs. 1-3). Accordingly, it is not possible to unambiguouslyjudge about the influence of theP_{SAS}^* term on the flow by analyzing the L_{vK}lengthscale only. It is just one parameter in a fairly extensive model formulation. Actually, theentire term $S^2(L/L_{vK})^{1/2}$ has to be analyzed. Nevertheless, in Figs.1-3, showing the instantaneous field of the additional production term P_{SAS}^*, it is illustratedthat in the regions with weak rate of strain, as inthe flow core, the P_{SAS}^*term exhibits lower values compared to the immediate wall vicinityand highly unsteady separated shear layer regions characterized by intensified turbulence activity. It coincides clearly with the regions characterized by lower values of the ratio L_{vK}/Δ ($L_{vK}/\Delta < 1$). The full-length paper will give more detailed analysis about the structure of the P_{SAS}^* term as well as about its influence on the selective turbulence intensity enhancement contributing decisively to the improved prediction.

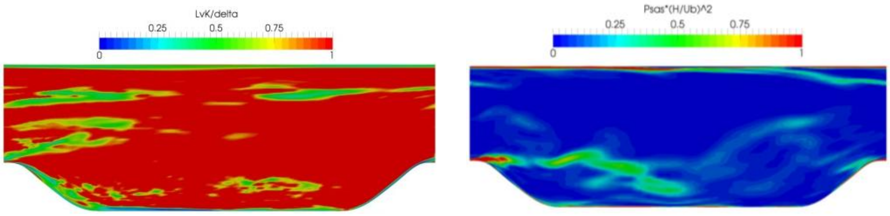

Figure 1: Flow over a 2D hill – iso contours of the L_{vK} length scale(normalized by grid spacing) and the P^*_{SAS} production terms

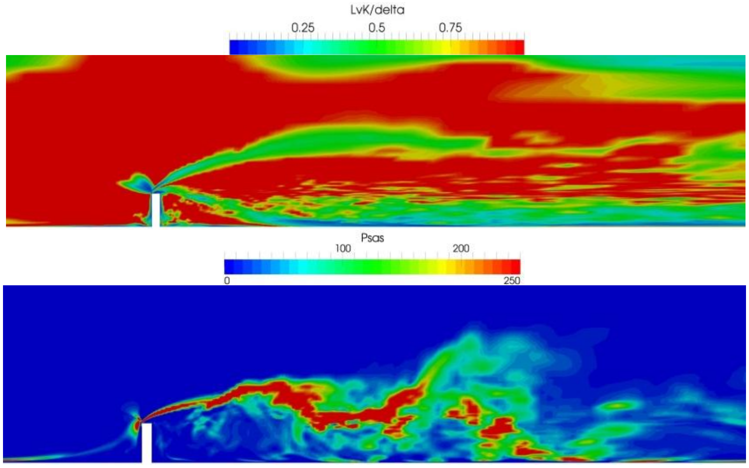

Figure 2: Flow over a 2D fence – iso contours of the L_{vK} length scale (normalized by grid spacing) and the P^*_{SAS} production terms

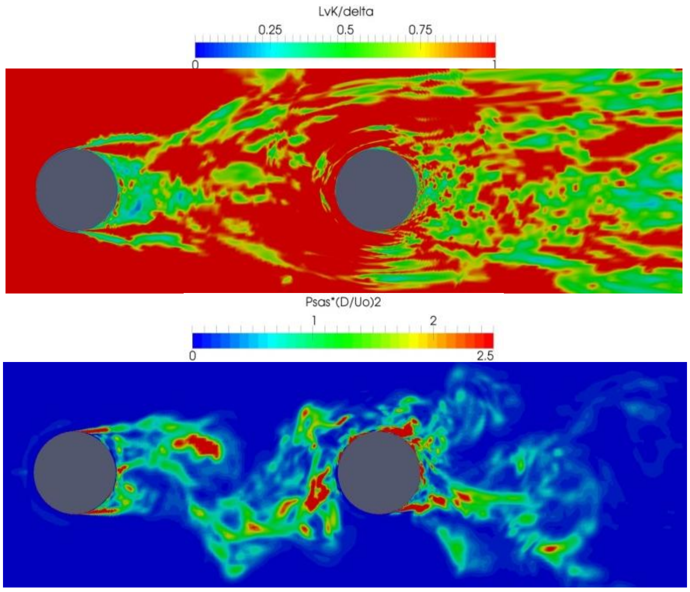

Figure 3: Flow past a 2D tandem cylinder – iso contours of the L_{vK} length scale (normalized by grid spacing) and the P^*_{SAS} production terms