SCALE-ADAPTIVE SIMULATION DEVELOPMENT IN THE DESIDER PROJECT

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ABSTRACT

Recently the authors have proposed the Scale-Adaptive Simulations (SAS) model for the simulation of unsteady turbulent flows [1,2]. The model is continuously developed within the EU project DESIDER. The formulation can operate in standard RANS mode, but has the capability of resolving the turbulent spectrum in unsteady flow regions. SAS models adapt the length-scale automatically to the resolved scales of the flow field. The distinguishing factor in the model is the use of the von Karman length-scale, L_{vK}: The SAS two-equation model reads:

$$\frac{\partial \rho k}{\partial t} + U_j \frac{\partial \rho k}{\partial x_j} = P_k - c_\mu^{3/4} \rho \frac{k^2}{\Phi} + \frac{\partial}{\partial y}\left[\frac{\mu_t}{\sigma_k}\frac{\partial k}{\partial y}\right]$$

$$\frac{\partial \rho \Phi}{\partial t} + \frac{\partial \rho U_j \Phi}{\partial x_j} = \zeta_1 \frac{\phi}{k} P_k - \hat{\zeta}_2 \mu_t S |U''| \frac{\Phi^2}{k^{3/2}} - \zeta_3 \rho k + \frac{\partial}{\partial y}\left[\frac{\mu_t}{\sigma_\Phi}\frac{\partial \Phi}{\partial y}\right]$$

$$\nu_t = c_\mu^{1/4} \Phi$$

$$L_{vK} = |U'| / |U''| \qquad |U'| = S \text{ and } |U''| = \sqrt{\frac{\partial^2 U_i}{\partial x_k^2}\frac{\partial^2 U_i}{\partial x_j^2}}$$

Contrary to standard URANS models, the SAS formulation provides a turbulent length-scale, which is not proportional to the thickness of the turbulent (shear) layer, but proportional to the local flow structure. This is illustrated by the following picture, which shows a cylinder in cross flow:

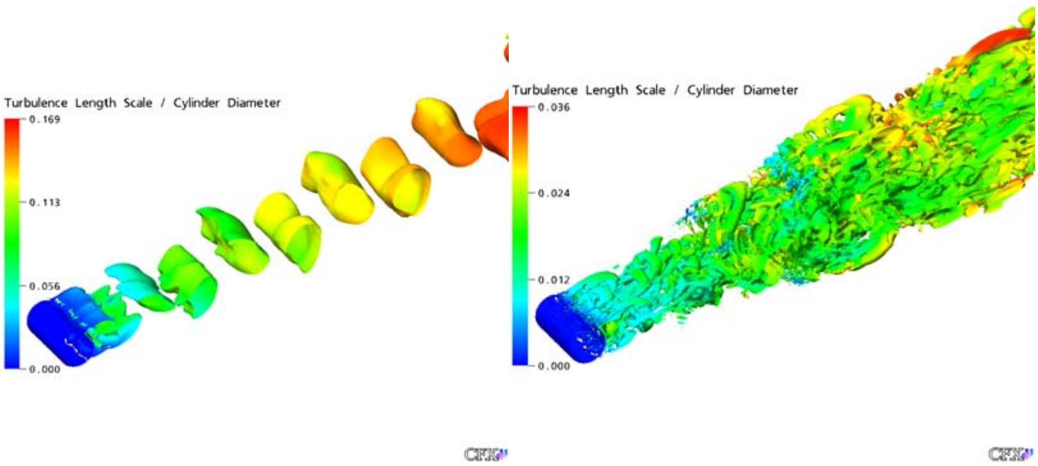

Figure 1 Cylinder in cross flow. Left: SST-URANS. Right: SST-SAS.

The left part of Figure 1 shows a standard SST-URANS simulation, with the single mode instability, typical for URANS models. The right part shows the SST-SAS solution. The SAS solution automatically applies the RANS mode in the attached boundary layers, but allows a resolution of the turbulent structures in the detached regime. This behaviour is in much better agreement with the true physics of the flow, as was also shown for other cases in Menter and Egorov [1, 2]. The “LES”-like capability of the model is achieved without an explicit dependency on the grid spacing, contrary to classical LES methods.

The SAS concept has recently also been ported to the SST turbulence model and is now used for a wide range of technical flows. Figure 2 shows a comparison of DES and SAS for the flow the ITS combustion chamber.

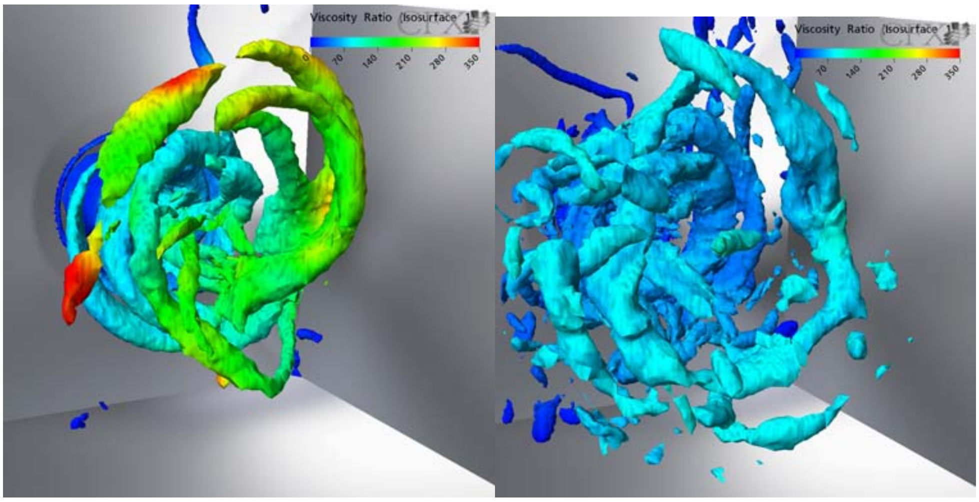

Figure 2 Turbulent structures in swirl combustor flow. Left – DES. Right – SAS

For this flow, the SAS model gives more detailed structures than the SST-DES model and (as will be shown in the paper) also a better agreement with the mean averaged experimental data.

The paper will give an overview of the current SAS model formulation and the underlying ideas behind the method. Results will be shown for basic testcases and complex industrial applications.

REFERENCES

[1] Menter, F. R. and Egorov, Y. (2004), “Re-visiting the turbulent scale equation,” Proc. IUTAM Symposium; One hundred years of boundary layer research, Göttingen.

[2] Menter, F. R. and Egorov, Y. (2005), “A scale-adaptive simulations model using two-equation models”. AIAA Paper 2005-1095, Reno 2005.