VORTICAL STRUCTURE OF FLOWING OVER A BLUFF BODY

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Abstract Vortical structures are obtained by performing numerical simulations of flow past a bluff body (a square prism) using Scale-Adaptive Simulation models (SAS-SST) and Large Eddy Simulation (LES) models. The results show that the two turbulent models have almost the same accuracy in capture vortex within the calculated Re region.

INTRODUCTION

Flow past a bluff body (like a cylinder or a square prism) is the classical example of a globally unstable flow. Even when computed with a classical Unsteady Reynolds-averaged Navier–Stokes equations (URANS) model, the simulation will typically provide an unsteady output. However, the simulation[1] flow past a circular cylinder using URANS models (SST model) produce a single mode vortex shedding even at a relatively high Re number of Re=10^6, and this s contradiction to experimental observation.

The Scale-Adaptive Simulation (SAS)[2,3,4] is an improved URANS formulation, which performs like standard RANS models in steady flows, but allows the resolution of the turbulent spectrum in unstable flow conditions. The SAS concept is based on the introduction of the von Karman length-scale (L_{vK}) into the turbulence scale equation, and the L_{vK} does not appear in any standard RANS model. The information provided by the L_{vK} allows SAS models to dynamically adjust to resolved structures in a URANS simulation, which results in a LES-like behavior in unsteady regions of the flow field.

The original SAS model was formulated as a two-equation model, with the variable $\Phi = \sqrt{k}L_t$ for the scale equation:

$$\frac{\partial(\rho k)}{\partial t} + \frac{\partial(\rho \overline{U}_j k)}{\partial x_j} = P_k - c_\mu^{3/4}\rho\frac{k}{\Phi^2} + \frac{\partial}{\partial x_j}\left(\frac{\mu_t}{\sigma_k}\frac{\partial k}{\partial x_j}\right)$$

$$\frac{\partial(\rho\Phi)}{\partial t} + \frac{\partial(\rho \overline{U}_j \Phi)}{\partial x_j} = \frac{\Phi}{k}P_k\left(\zeta_1 - \zeta_2\left(\frac{L_t}{L_{vK}}\right)^2\right) - \zeta_3\rho k + \frac{\partial}{\partial x_j}\left(\frac{\mu_t}{\sigma_\Phi}\frac{\partial \Phi}{\partial x_j}\right)$$

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

$$L_{vK} = \kappa\left|\frac{\overline{U}'}{\overline{U}''}\right|; \quad \overline{U}' = S = \sqrt{2S_{ij}S_{ij}}; \quad \overline{U}'' = \sqrt{\frac{\partial^2 \overline{U}_i}{\partial x_j \partial x_j}\frac{\partial^2 \overline{U}_i}{\partial x_k \partial x_k}}; \quad S_{ij} = \frac{1}{2}\left(\frac{\partial \overline{U}_i}{\partial x_j} + \frac{\partial \overline{U}_j}{\partial x_i}\right); \quad L_t = \frac{\Phi}{\sqrt{k}}$$

The L_{vK} term can be transformed and implemented into any other scale-defining equation resulting in SAS capabilities as in the case of the SAS-SST model. For the SAS-SST model, the additional term resulting from the transformation has been designed to have no effect on the SST model's RANS performance for wall boundary layers.

Based on the concept that large scales are problem-dependent and difficult to model, whereas the smaller scales become more and more universal and isotropic and can be modeled more easily, LES[5,6] is motivated to filter the Navier-Stokes equations over a finite spatial region and aimed at only resolving the portions of turbulence larger than the filter width.

Are the vortexes similar or not flow over the bluff body using LES model and SAS-SST model? Do they have the same accuracy? Here we give a simulation flow past a square prism.

RESULTS

The simulation results, which of flow past a square prism using LES and SAS-SST models, are depicted in Figure 1 and Figure 2 separately. It was shown that two turbulent models have almost the same accuracy in capture vortex within the calculated Re region.

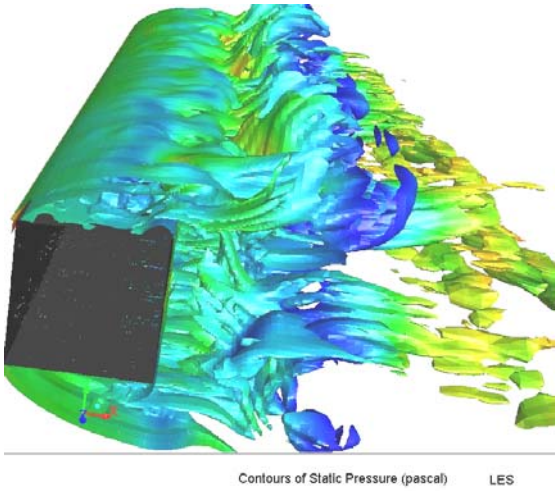

Figure 1. LES simulation of flow past a square prism.

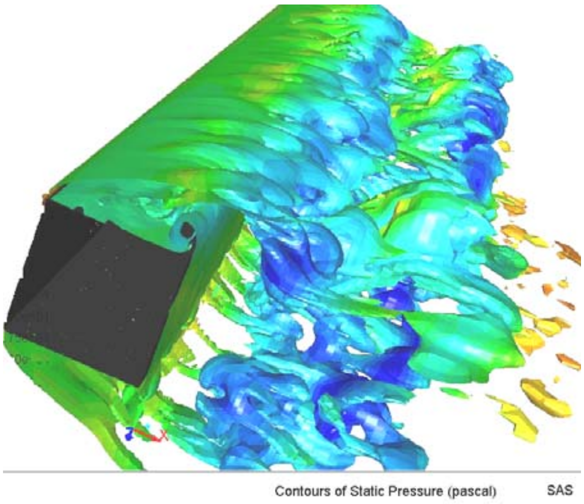

Figure 2. SAS simulation of flow past a square prism (SAS-SST model).

References

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