Analysis and further development of near-wall models for large-eddy simulation

1 Background

For flows in industrial applications, at high Reynolds number, Reynolds-averaged Navier-Stokes (RANS) models provide results for mean flow quantities with engineering accuracy at moderate cost, [1]. For several situations, dominated by large-scale anisotropic vortical structures, for instance in wakes of bluff bodies, large eddy simulation (LES) however generally performs better than RANS (see ERCOFTAC workshops on refined turbulence modelling). Furthermore, LES by construction provides unsteady flow data that are indispensable for the investigation of several applications and phenomena (flow-generated noise, fluid structure interaction, phase-resolved multiphase flow etc). The principal drawback of LES, as compared to RANS, is the higher computational cost of at least a factor 10 (in many applications a factor 100 or more). The coupling of LES with statistical turbulence models for turbulent boundary layers is arguably the main strategy to reduce computational cost and make LES affordable for a wide range of industrial applications, [2].

Figure 1: Example LES illustrating a flow dominated by flow structures, the prediction of which is in the focus of the proposed project. The computation was carried out with the methods under study. The axisymmetric body is aligned with a uniform flow at \( Re = 12 \cdot 10^6 \) and flow measurements have been performed, [3]. Normalized axial velocity is shown on cross-planes at different stations along the hull. We also show an iso-surface of the second invariant of the velocity gradient, to illustrate the vortical structures generated in the wake flow. The iso-surface is coloured with the axial velocity. Finally, we indicate the surface flow with black lines on the body.
The book, [5], provides an overview of both theory and application of large-eddy simulation for incompressible flows. The application of the models under study, to problems in naval hydrodynamics, is described in, [4], which also includes references to the software OpenFOAM in which the models are implemented.

**Project description**

The overall aim of the proposed project is to improve the predictive capability of large eddy simulation, with near wall modelling, for flows with a significant influence of turbulent boundary layers and, in particular, realistic applications with unsteady separation at curved surfaces. This aim will be pursued along two complementary lines of research; (i) Theoretical numerical analysis of the properties of the algorithms and their dependence on parameters, as well as the formulation of appropriate model problems for the analysis; (ii) systematic large-scale computations of relevant flow cases which are well documented experimentally, in order to validate the model, investigate its range of applicability, find best practise guidelines and to improve the model.

Depending on the developments during the project, there is some flexibility concerning the focus and priority of the two lines of research described above. The methods developed within the project will be implemented in OpenFOAM, which is the open source software package for CFD which is most widely used. This allows an efficient distribution of the research results of the project, as well as their independent evaluation by other researchers in Sweden, Europe and the world.

**2 Supervision, contact and collaboration**

The PhD project will be supervised by Mattias Liefvendahl\(^1\)\(^2\) who has positions both at the Division of Scientific Computing at Uppsala University and at the Swedish Defence Research Agency, FOI. An essential component of the proposed project is to benefit from the interaction between the strong research environment in numerical analysis at Uppsala University and the extensive experience with LES for applications at FOI.

**References**


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