Industrial Applications of Wall-Resolved Large Eddy Simulations
-The Present Status and their Perspectives-

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Abstract

To date, Reynolds-Averaged Navier-Stokes Simulations (RANS) is most widely used in industries. RANS is cheap in its computational costs, and provides an accurate prediction as long as the flow does not have large separations. However, since RANS models turbulent eddies in all scales and large-scale turbulence strongly depends on the individual flow, the accuracy and/or the applicability of RANS is limited, which prevents it from becoming a complete alternative for testing. Recently, hybrid methods such as Detached-Eddy Simulation (DES), which combines RANS applied near the wall and Large-Eddy Simulation (LES) elsewhere has been applied to industrial flows. However, the accuracy of DES is essentially the same as that of RANS in the near-wall regions.

Wall-Resolved Large Eddy Simulation (WR-LES) directly computes the streamwise vortices that are responsible for the production of turbulence in the boundary layer. It provides almost the same accuracy as Direct Numerical Simulation (DNS) and is expected to become a complete alternative of testing. However, these streamwise vortices scales to the viscous length scale and very small in a high Reynolds number flow and applications of WR-LES to a high-Reynolds-number industrial flow requires a large-scale computation.

The ultimate goal of this study it to completely replace various tests made in industries by WR-LES and bring about a revolutionary change in the way that industries produce their products. To this end, we developed two LES solvers, FrontFlow/blue (FFB) and FrontFlow/X (FFX), respectively, based on the Finite Element Method (FEM) and the Lattice Boltzmann Method (LBM). Both solvers are particularly designed for the large-scale industrial applications in high performance computing (HPC) environments. In fact, we have achieved 700 billion element WR-LES by FFB and 2 trillion grid WR-LES by FFX.

In this plenary talk, a brief introduction to these solvers will firstly be made and then the latest applications of the WR-LES, in turbomachinery engineering, automobile aerodynamics/aeroacoustics and ship hydrodynamics, will be presented. Finally, the perspectives of the simulations in HPC environments will be shown and further boosting of the HPC simulations by the use of artificial intelligence (AI) will be referred to.