Implicit Large Eddy Simulation for the High-Order Flux Reconstruction Method

Hui Zhu*, Song Fu¹, Lei Shi², ZJ Wang²
1: School of Aerospace Engineering, Tsinghua University, China
2: Dept. of Aerospace Engineering, University of Kansas, USA
* Corresponding author: zhu-h12@mails.tsinghua.edu.cn

The Flux Reconstruction Method/ Correction Procedure via Reconstruction (FR/ CPR) is a high-order numerical method for computational fluid dynamics. It combines the Finite Element method and the Finite Volume method, with a polynomial distribution of variables in a computational cell, and Riemann solver applied at the cell boundaries. The FR/ CPR method has a similar resolving ability to the famous Discontinuous Galerkin Method (DG), but the efficiency is higher.

The FR/ CPR method has demonstrated its potential in large eddy simulations (LES) of turbulent flows with relatively low Reynolds numbers. However, the computational cost becomes a serious limiting factor for high Reynolds flows, especially in the vicinity of the wall boundaries, due to the isotropic mesh requirement of LES and the limited scale of turbulent vortices there. A promising approach to reduce the cost of these simulations is the hybrid Reynolds-Averaged Navier-Stokes (RANS)/LES approach. In this paper, a new hybrid RANS-Implicit LES approach for the high-order FR/ CPR method is presented, using a simple algebraic version of the Spalart-Allmaras model in the vicinity of solid walls, and implicit LES approach elsewhere.

Despite its simplicity, this approach shows good performance in simulating turbulent flow at relatively high Reynolds numbers. Firstly, results of the cylinder flows at a subcritical Reynolds number confirmed the ability of implicit LES based on the high-order FR/ CPR method. Then, simulations of turbulent channel flows and periodic hill flows are used to test the hybrid approach, and results show that this approach is able to resolve the velocity profiles in both cases. Finally, the implicit LES approach is applied to the forward-facing step flows inside a subsonic boundary layer to explore the mechanism of flow transition.

REFERENCES