Investigation of advanced turbulence modeling approaches for aeroacoustic problems

X. Huang[1,2], M. Schäfer[1,2]

[1]Graduate School Computational Engineering,
Technische Universität Darmstadt, Germany
{huang, schaefer}@gsc.tu-darmstadt.de

[2]Institute of Numerical Methods in Mechanical Engineering,
Technische Universität Darmstadt, Germany
{huang, schaefer}@fnb.tu-darmstadt.de

ABSTRACT

Aeroacoustic studies have drawn increasingly more attention in the past years. One of the main tasks is to accurately simulate the acoustic field with a reasonable computational cost. An efficient approach to simulate the acoustic field generated by low Mach number flows is the expansion about incompressible flow (EIF). This approach decomposes the compressible field into an incompressible field and acoustic fluctuations [1, 3]. Based on this decomposition, the acoustic field is governed by the linearized Euler equations (LEE) with an acoustic source term, which can be obtained by solving the incompressible Navier-Stokes equations [2]. The simulation accuracy of the acoustic field strongly depends on that of the flow field. For the simulation of turbulent flow in engineering problems, direct numerical simulation (DNS) cannot be applied due to its unaffordable computational cost. A turbulence model is usually adopted to characterize the unresolved turbulence scales, leading to a significant reduction in computational cost. In Large Eddy Simulation (LES), about 10% of the turbulence is modeled while about 90% is resolved. Delayed Detached Eddy Simulation (DDES) is a hybrid RANS/LES method, wich switches between LES and Reynolds Averaged Navier-Stokes (RANS) modes according to the grid resolution. However, its main drawback is the loss of high-frequency components in the flow. Consequently, the high-frequency acoustic quantities can not be calculated accurately.

In this work, we study the influence of different turbulence models on the simulation accuracy of acoustic quantities. Considering an aeroacoustic benchmark test case, we compare the accuracy loss of acoustic quantities for different turbulence models including LES and DDES. To compensate the accuracy loss of acoustic quantities in the high-frequency region, the high frequency fluctuation is rebuilt using a synthetic reconstruction model. We adopt this model for the DDES simulation and investigate the performance change. A clear improvement of the high-frequency spectrum can be observed.

This work was supported by the "Excellence Initiative" of the German Federal and State Governments and the Graduate School of Computational Engineering at Technische Universität Darmstadt.

REFERENCES

[1] Hardin, J. and Pope, D. An Acoustic/Viscous Splitting Technique for Computational Aeroacoustics. *Theoretical and Computational Fluid Dynamics.* (1994) **6**:323-340.

[2] M. Kornhaas, M. Schäfer, and D.C. Sternel. Efficient numerical simulation of aeroacoustics for low Mach number flows interacting with structures. *Computational Mechanics.* (2015) **55**:1143-1154.

[3] Shen, W. and Sørensen, J. Comment on the aeroacoustic formulation of Hardin and Pope. *AIAA Journal.* (1999) **37(1)**:141-143.