Tue1.4 Hahn & Drikakis

Numerical experiments using high-resolution methods in compressible and turbulent flows

Marco Hahn & Dimitris Drikakis

School of Engineering, Fluid Mechanics & Computational Science Group, Aerospace Sciences Department,
Cranfield University, Cranfield, Bedfordshire MK43 0AL, UK
d.drikakis@cranfield.ac.uk
http://www.cranfield.ac.uk

The use of high-resolution methods as an implicit way to model and compute turbulent flows is an evolving area of research. The success of these methods to compute turbulent flows without need to resort to an explicit turbulence model has been demonstrated by a number of studies in the literature, e.g., (Boris 1992; Youngs 2003; Drikakis 2003) and, additionally, there are recent efforts aiming at a theoretical justification (Margolin & Rider 2001).

The desire for understanding better the physics encompassed by numerical methods, high-resolution methods in particular, is motivated by the fact that almost all practical computations in engineering are under-resolved. Numerical methods encompass numerical dissipation which acts to regularise the flow, thereby allowing shock propagation to be captured physically realistically even if it is not fully resolved on the computational mesh. Nonlinear mechanisms (limiters) in high-resolution methods guard the methods from catastrophic failures (due to nonlinear wave steepening or unresolved features) by triggering entropy producing mechanisms that safeguard the calculation when the need arises. The two key questions are: (i) what criteria should be used to design the nonlinear mechanism that triggers the entropy production, and (ii) to what extent numerical dissipation accounts for turbulent flow effects.

In this study, we present numerical studies of flows featuring shock waves and transitional/turbulent mixing, using high-resolution methods. We have performed numerical experiments using Godunov-type and hybrid, total variation diminishing (TVD) schemes, in the context implicit (very) large eddy simulation. By "very large" we imply that the simulation (and thus the flow) is largely under-resolved in terms of grid resolution. This results in magnifying the errors and differences in the results obtained by using variants of high-resolution schemes. The hybrid TVD schemes employed here are based on the combination of first-, second- and third-order non-oscillatory schemes. The schemes adapt the numerical dissipation locally in the flow field through a combination of sensor functions and limiters. We consider the cases of compressible decaying turbulence as well as compressible flow over open cavities to demonstrate some of the numerical effects and differences. Further, we discuss some accuracy and efficiency issues by comparing different Godunov-type methods for the shock-bubble interaction problem.

References

Boris JP, Grinstein FF, Oran ES, Kolbe RJ. Fluid Dyn. Res., 10: 199-228, 1992.

Youngs, D. AIAA-2003-4102.

Drikakis D, Progress in Aerospace Sciences, 39, 405-424, 2003.

Margolin LG, Rider WJ. Int. J. Numer. Meth. Fluids 39: 821-841, 2001.