Ladeinde, Foluso; **Cai, Xiaodan**; **Visbal, Miguel R.**; **Gaitonde, Datta V.**

Turbulence spectra characteristics of high-order schemes for direct and large eddy simulation. (English) Zbl 1038.76020

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Summary: We discuss the comparative resolution of high-wavenumber portion of compressible turbulence energy spectrum by some high-order numerical schemes. Included are essentially nonoscillatory (ENO) schemes, weighted essentially nonoscillatory schemes (WENO), and compact differencing schemes. The governing equations are Navier-Stokes equations, and the objective is to identify the numerical scheme that best represents the physics of compressible turbulence. Mach number values of 0.1, 0.5 and 0.7 are studied. The compact differencing schemes need filters for numerical stability. It is found that a parameter in the filter scheme provides some flexibility for controlling the physical turbulence energy transfer rate at high wavenumbers, vis-à-vis the numerical dissipation at those scales. Although ENO schemes do not require filters for numerical stability, the present study shows that the addition of filters improves the energy transfer process at high wavenumbers. Without filtering, with relatively coarse grids, numerical turbulence caused by stencil adaptation persists. This limits the useful wavenumber resolution range of ENO schemes. The WENO schemes do not require the stabilizing filters, but the results tend to be slightly more dissipative. Finally, at low Mach numbers, the current compact differencing and filter scheme formulation gives better results, but as the Mach number increases the relative suitability of the ENO method increases.

MSC:

76F65 Direct numerical and large eddy simulation of turbulence
76M20 Finite difference methods applied to problems in fluid mechanics
76F50 Compressibility effects in turbulence

Cited in **8** Documents

Keywords:

essentially nonoscillatory schemes; compressible turbulence; energy spectrum; weighted essentially nonoscillatory schemes; compact differencing schemes; Navier-Stokes equations; filter scheme; numerical stability

Software:

FDL3DI

Full Text: DOI

References:

[1] Cai, X.; O'Brien, E.E.; Ladeinde, F., Uniform Mean scalar gradient in grid turbulence: asymptotic probability distribution of a passive scalar, Phys. fluids, 8, 9, 2555-2558, (1996) · Zbl 1027.76593

[2] Cai, X.; O'Brien, E.E.; Ladeinde, F., Thermodynamic behavior in decaying, compressible turbulence with initially dominant temperature fluctuations, Phys. fluids, 9, 6, 1754-1763, (1997)

[3] Cai, X.; Ladeinde, F.; O'Brien, E.E., DNS on SP2 with MPI, (), 491-495

[4] Fyfe, D.J., Economical evaluation of runge – kutta formulae, Math. comp., 20, 392-398, (1966) · Zbl 0143.17207

[5] D. Gaitonde, J.S. Shang, Practical aspects of high-order accurate finite volume schemes for electromagnetics, Paper AIAA-97-0363, Reno, NV, 1997

[6] D. Gaitonde, M.R. Visbal, High-order schemes for Navier-Stokes equations: Algorithm and implementation into FDL3DI, Technical Report # AFRL-VA-WP-TR-1998-3060, Air Force Research Laboratory, Wright-Patterson AFB, OH, 1998

[7] Ghosh, S.; Matthaeus, W.H., Low Mach number two-dimensional hydrodynamic turbulence: energy budget and density fluctuations in a polytropic fluid, Phys. fluids A, 4, 148, (1991) · Zbl 0850.76276

[8] Harten, A.; Osher, S.; Enquist, B.; Chakravarthy, S., Some results on uniformly high order accurate essentially non-oscillatory schemes, Appl. numer. math., 2, 347-377, (1986) · Zbl 0627.65101

[9] Harten, A.; Osher, S.; Enquist, B.; Chakravarthy, S., Uniformly high order accurate essentially non-oscillatory, J. comput. phys., 71, 231-303, (1987) · Zbl 0652.65067

[10] Jiang, G.; Shu, C.-W., Efficient implementation of weighted ENO schemes, J. comput. phys., 126, 202-228, (1996) · Zbl 0877.65065

[11] Ladeinde, F.; O'Brien, E.E.; Cai, X., An efficient parallelized ENO procedure for direct numerical simulation of turbulence, J. sci. comput., 38, 11, 215-242, (1996) · Zbl 0896.76054

[12] Ladeinde, F.; O'Brien, E.E.; Cai, X.; Liu, M., Advection by polytropic compressible turbulence, Phys. fluids, 48, 11, 2848-2857, (1995) · Zbl 1026.76532

[13] Lele, S.K., Compact finite difference schemes with spectral-like resolution, J. comput. phys., 103, 16-42, (1992) · Zbl 0759.65006

[14] Liu, X.-D.; Osher, S.; Chan, T., Weighted essentially nonoscillatory schemes, J. comput. phys., 115, 200-212, (1994) · Zbl 0811.65076

[15] Passot, T.; Pouquet, A., Numerical simulation of compressible homogeneous flows in the turbulence regime, J. fluid mech., 181, 441-466, (1987) · Zbl 0633.76054

[16] Rogerson, A.M.; Meiburg, E., A numerical study of the convergence properties of ENO schemes, J. sci. comput., 5, 2, 151-167, (1990) · Zbl 0732.65086

[17] Shu, C.-W., Numerical experiments on the accuracy of ENO and modified ENO schemes, J. sci. comput., 5, 2, 127-149, (1990) · Zbl 0732.65085

[18] C.-W. Shu, Essentially non-oscillatory and weighted essentially non-oscillatory schemes for hyperbolic conservation laws, ICASE Report No. 97-65, 1997

[19] Shu, C.-W.; Osher, S., The efficient implementation of essentially non-oscillatory shock-capturing schemes, J. comput. phys., 77, 439-471, (1988) · Zbl 0653.65072

[20] Shu, C.-W.; Osher, S., The efficient implementation of essentially non-oscillatory shock-capturing schemes, II, J. comput. phys., 83, 32-78, (1989) · Zbl 0674.65061

[21] Shu, C.-W.; Zang, T.A.; Erlebacher, G.; Whitaker, D.; Osher, S., High order ENO schemes applied to two- and three-dimensional compressible flow, Appl. numer. math., 9, 45-71, (1992) · Zbl 0741.76052

[22] Thompson, J.F.; Warsi, Z.U.A.; Mastin, C.W., Numerical grid generation, (1985), North-Holland New York · Zbl 0598.65086

[23] M.R. Visbal, D.V. Gaitonde, High-order accurate methods for unsteady vortical flows on curvilinear meshes, Paper AIAA-98-0131, Reno, NV, 1998