ABSTRACT FOR THE 1ST INTERNATIONAL WORKSHOP ON HIGH-ORDER CFD METHODS

Sreenivas Varadan[a], Kentaro Hara[b], Eric Johnsen[a], Bram Van Leer[b]

a. Department of Mechanical Engineering, University of Michigan, Ann Arbor
b. Department of Aerospace Engineering, University of Michigan, Ann Arbor

TEST CASE C3.5

1. Code Description:-

- Discretization:-

We have use two separate codes to numerically simulate this test case. The first one is a Finite difference code and the second one is based on the Discontinuous Galerkin method.

- Relevant solvers:-
  Our FD code uses a Weighted Essentially Non Oscillatory scheme for Shock capturing and explicit central differences, treated in a suitable manner, for smooth flows. A suitable switch triggers dissipation next to Discontinuities. Thus, since this problem is smooth, the code uses the Central scheme everywhere.
  For DG, we use up to P4 elements for the sub-cell solution representation. The Viscous terms of the Navier-Stokes equations are treated using a high-order Recovery method. For both codes, explicit Range-Kutta time stepping is used.

- High order capability:-
  We use a fifth-order Weno blended with a sixth-order central scheme for our finite difference code.
  For our Discontinuous Galerkin code, we have the choice of using up to P4 Legendre polynomials for the sub-cell representation. This would generally give fifth-order accuracy (p+1).

- Parallel Capability:-
  Our codes are parallelized using a 3-D Domain decomposition based on the message-passing interface (MPI).

- Post Processing:-
  We use the Hdf5 Parallel libraries for Parallel I/O. Hdf5 is a commonly used scientific data format for large datasets. The Visualization is done with the Visit Visualization software.

2. Case Summary:-

- Convergence criteria:-

Since this test case develops into a fully turbulent flow starting from well-regularized initial conditions, the convergence criterion is based on the smallest scales of the problem. For a Direct Numerical simulation, the grid spacing should be of the order of the Kolmogorov scale. A rough estimate of the Kolmogorov scale for this problem shows that a grid of 512^3 is necessary for a DNS.

- Machines used:-

We have used 160 processors at the Center for Advanced Computing cluster at the University of Michigan.

- Taubench CPU times:-

On one core of the Nyx machine, one TauBench unit is equivalent to 16.5 seconds of compute time.

3. Mesh:-

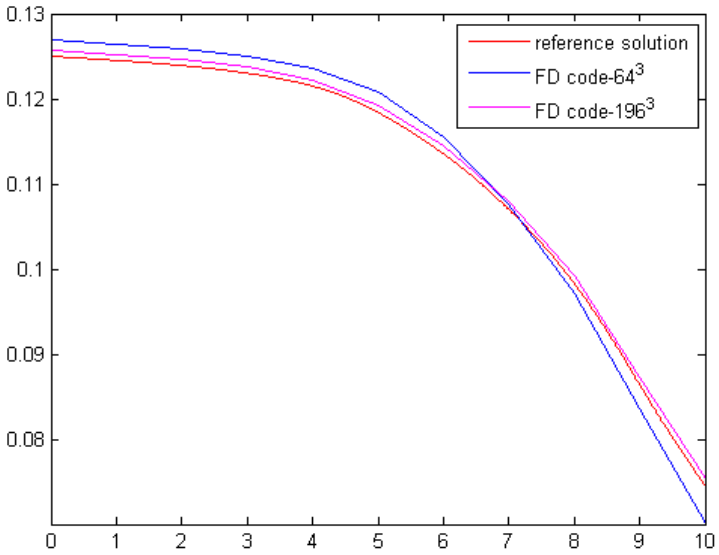
- The domain size is as given in the description with L chosen to be 1.
- We use structured meshes with Periodic Boundary conditions.

4. Results:-

   For the abstract, we have chosen grid sizes of 64^3, 196^3. We also only present results from the finite difference code. For the Full data submission, a more rigorous convergence analysis and the results from our DG code would be provided.

   We use the compressible Navier-Stokes equations with a non-dimensional time step of 1e-3. The final time is chosen to be 10 Tc. The results are compared to the reference solution provided.

Fig.1 Temporal Evolution of Total Kinetic Energy



For a 64^3 grid, the Kinetic Energy is initially over predicted. But the solution on the 196^3 grid agrees well with the reference solution.

Fig.2 Temporal Evolution of Enstrophy

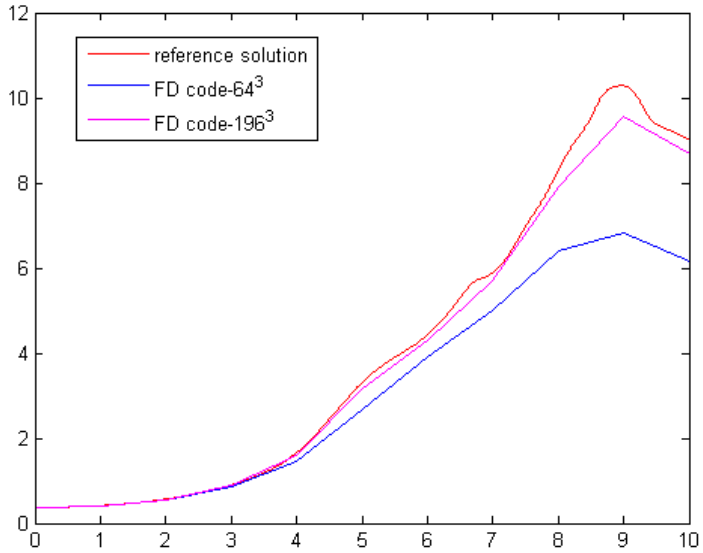
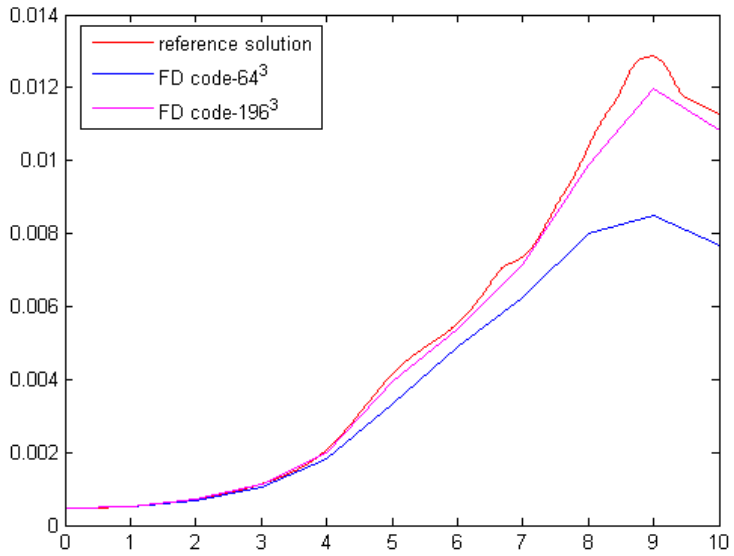


Fig.3 Temporal Evolution of Kinetic Energy Dissipation Rate

Here, we use the Low Mach number assumption and approximate the Dissipation rate from the Enstrophy integral.



Compute time in work units

The compute time in seconds (T2) was divided by the Taubenchmark time (T1) to get the work units.

Grid size	Work units
64^3	18.1818
196^3	512.1212