The 18th International Conference on Finite Elements in Flow Problems (FEF2015)
16-18 March 2015, Taipei, Taiwan

Development of the Implicit Quiet Direct Simulation (QDS) Scheme and its Parallelization

Yi-Hsin Lin[1] and Matthew Ross Smith[2]

[1] Department of Mechanical Engineering,
National Cheng Kung University, Tainan, Taiwan
n16021189@mail.ncku.edu.tw
[2] Department of Mechanical Engineering,
National Cheng Kung University, Tainan, Taiwan
msmith@mail.ncku.edu.tw

Key Words: *Quiet Direct Simulation, QDS, Kinetic Theory of Gases, Computational Fluid Dynamics, CFD, Parallel Computing, Intel Phi Coprocessor*.

Kinetic-Theory based techniques for Computational Fluid Dynamics (CFD) have consistently played a role in the simulation of compressible fluid flows. Many consider the starting point for these kinetic-theory based solutions to be based on the Equilibrium Flux Method (EFM) proposed by Pullin in JCP in 1980. In EFM, the fluxes of conserved quantities are computed by taking integrals of the Maxwell-Boltzmann equilibrium distribution function at cell interfaces. The complete flux integral is split into two components – based on left and right hand side contribution from opposing cells at an interface – and hence represents a form of vector splitting. While simple to evaluate, the integrals used in EFM result in a series of complex expressions containing the expensive error and exponential functions. Another potential problem with the EFM approach is its application to implicit time stepping – while investigated by authors in the past, the approach is often quite complicated and also time consuming. Here we discuss the application of the Quiet Direct Simulation (QDS) method to implicit time stepping. The QDS method, originally proposed as the Quite Direct Simulation Monte Carlo (QDSMC) by Albright et al was rebranded as a Finite Volume Method (FVM) solver and renamed as QDS. With this approach, the flux integrals used by EFM are numerically evaluated using Gauss-Hermite quadrature, avoiding the expensive aforementioned functions and simultaneously providing a series of simple (non-linear) expressions for the inviscid flux. Previous implementations of the QDS solver have been exclusively explicit in nature due to the formulation of the method. We discuss the method employed for implementation of the implicit time stepping and detail efforts to parallelize the approach. Results are shown for several simple benchmark problems and contrasted against the conventional explicit results.