

AA 214: Numerical Methods for Compressible Flows

1. Computational Fluid Dynamics (CFD)

- 1.1 What is CFD?
- 1.2 Why CFD?
- 1.3 What for CFD?
- 1.4 Impact of CFD
- 1.5 Anatomy of CFD

2. Hierarchy of Mathematical Models

- 2.1 Navier-Stokes equations
- 2.2 Large Eddy Simulation
- 2.3 Reynolds-averaged Navier–Stokes equations
- 2.4 Euler equations
- 2.5 Full potential equation
- 2.6 Small-perturbation potential equation – transonic regime
- 2.6 Linearized small-perturbation potential equation – subsonic and supersonic regimes

3. Conservation and Integral Forms and Discontinuities

- 3.1 Conservation law form
- 3.2 Integral form
- 3.3 Relations at discontinuities

4. Linearization and Characteristic Relations

- 4.1 Non conservation form and Jacobians
- 4.2 Linearization around a localized flow condition
- 4.3 Hyperbolic requirement
- 4.4 Characteristic relations and Riemann invariants
- 4.5 Boundary conditions

5. Representative Model Problems

- 5.1 Convection-diffusion equation
- 5.2 Burgers' equation
- 5.3 Scalar conservation laws
- 5.4 Riemann problems
- 5.5 Roe's approximate Riemann solver for the Euler equations

6. The Finite Difference Method

- 6.1 Conservative finite difference methods in one dimension
- 6.2 Forward, backward, and central time methods
- 6.3 Domain of dependence and CFL condition
- 6.4 Linear (von Neumann) stability analysis
- 6.5 Formal, global, and local order of accuracy
- 6.6 Upwind schemes in one dimension
- 6.7 Nonlinear stability analysis

6.8 Multidimensional extensions

7. The Finite Volume Method

7.1 Conservative finite volume methods in one dimension

7.2 Introduction to reconstruction-evolution methods

7.2 First-order upwind reconstruction-evolution methods

7.3 Introduction to second- and higher-order reconstruction-evolution methods

7.4 The MUSCL/TVD method

7.5 Steger-Warming flux vector splitting method for the Euler equations

7.6 Multi-dimensional extensions

8. Treatment of Boundary Conditions

8.1 Two types of boundaries

8.2 Two types of grids

8.3 General results

8.4 Solid boundaries

8.5 Far-field boundaries

9. Pseudo-Time Integration

9.1 Vector form of the semi-discrete Euler equations

9.2 Local time-stepping for steady-state problems

9.3 Dual time-stepping for unsteady problems

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