ME 705 CFD for INCOMPRESSIBLE FLOWS

Catalog Description

General philosophy of domain discretization, equation discretization and algebraic system solution. Conservation equations for thermofluidic transport. Structured grid generation with algebraic and differential techniques. Principles of the finite volume method and pressure-correction schemes. Discretization of mass, momentum and energy conservation equations using pressure-based methods. Detailed programming of the SIMPLE algorithm. Implementation of RANS based turbulence modeling.

Course Outline

Week 1. Introduction to CFD through the general philosophy of domain discretization, equation discretization, algebraic system solution and visualization. Review of the conservation equations for thermofluidic transport. Brief comparison of classical (density- and pressure-based) and alternative numerical solution techniques. Introduction to the Virtual Flow Lab software.

Week 2. Structured grid generation algorithms and hands-on programming of the linear/Hermite TFI, Laplace and Sorenson methods.

Week 3. Principles of the finite volume method. Integral representation of the incompressible flow equations. The idea of pressure correction for the solution of incompressible flow equations. Alternatives of pressure-correction formulation.

Week 4. Basics of the pressure-correction schemes. Possible choices (Central, Upwind, Quick, etc.) for diffusion and convection terms.

Week 5. Staggered vs. collocated grid arrangement. Iterative solution techniques (TDMA, Gauss-Seidel, Conjugate Gradient, GMRES, etc) for linear algebraic systems, familiarization with the existing linear algebra libraries.

Week 6. Idea of semi-discrete discretization for time-dependent problems. The idea of time marching. Implicit vs. explicit schemes, stability and efficiency issues.

Week 7. Basics of the algorithm of a pressure-correction based flow solver. Discussion about the necessary variables, data structures, general flow chart of the overall program, task-function matching and detailed data flow.

Week 8. Formulation and solution of momentum equations.

Week 9. Formulation and solution of pressure-correction and scalar transport equations.

Week 10. Implementation of wall/inflow/outflow type boundary conditions via the ghost-cell approach. Completing the basic flow solver and obtaining the first results. The concept of code validation.

Week 11. Formulation and implementation of time integration algorithms to study unsteady flow problems.

Week 12. Introducing the idea of RANS (Reynolds Averaged Navier Stokes) based turbulence modeling.

Week 13. Implementing zero- and one-equation turbulence models into the pressure-based flow solver.

Week 14. Performance evaluation of a flow solver. General discussion of performance related issues like multi-grid acceleration, solution-based adaptation, parallel programming etc.

Reference Material

Ferziger J.H. and Peric M., *Computational Methods for Fluid Dynamics*, Springer, 2001.
Versteeg H.K. and Malalasekera W., *An Introduction to Computational Fluid Dynamics*, Pearson Education, 2007.