MENG555 Computational Fluid Dynamics (CFD)

Year and Semester: Graduate
Credit Hour: (3,0) 3
Pre/Corequisite(s): -

Catalog Description:
Conservation laws of fluid motion and boundary conditions.The finite volume method for convection-diffusion problems. Solution algorithms for pressure-velocity coupling in steady flows. Solution of discretized equations. The finite volume method for unsteady equations. Implementation of boundary conditions. Turbulence and its modeling. Methods for dealing with complex geometries.

Prerequisite by Topic:
The student will be expected to have a good background in heat transfer and fluid dynamics and should have some programming experience with FORTRAN 90, or C or C++.

Textbooks:
1) An Introduction to Computational Fluid Dynamics, H. K. Versteeg and W. Malalasekera, 2nd Edition, Pearson, 2007.
2) Computational Fluid Dynamics, A practical Approach, Jiyuan Tu et al., 3rd Edition, BH, 2018.

References:
1. "Numerical heat transfer and fluid flow" S.V. Patankar, Hemisphere, 1980.
2. The finite volume method in computational fluid dynamics, An advanced introduction with OpenFoam and Matlab, F. Moukalled et al., Springer, 2016.

Course Objectives :
1. To introduce the basic principles in computational fluid dynamics
2. To develop methodologies which facilitate the application of the subject to practical problems

COURSE OUTLINE

Week 1 **Introduction: (1 week)**
What is CFD? How does a CFD code work? Problem solving with CFD.

Week 2-3 **Conservation laws of fluid motion and boundary conditions: (2 weeks)**
Governing equations of fluid flow and heat transfer: Conservation of mass momentum and energy. Navier–Stokes equations for a Newtonian fluid. Classification of fluid flow equations.

Week 4-5 **The finite volume method for diffusion problems: (2 weeks)**
The finite volume method for one-dimensional steady state diffusion. The tri-diagonal matrix algorithm. The finite volume method for two and three-dimensional steady state diffusion. Application of TDMA method to two and three-dimensional problems.

Week 6 **The finite volume method for convection-diffusion problems: (1 weeks)**

Steady one dimensional convection and diffusion. The central difference, upwind, hybrid, power law, QUICK and other higher order schemes. Stability problems of the schemes. TVD schemes; flux limiter functions.

Week 7 **Solution algorithms for pressure-velocity coupling in steady flows: (1 week)**
The staggered and non-staggered grids. The momentum equations. The SIMPLE, SIMPLER, SIMPLEC and PISO algorithms.

Week 8 **The finite volume method for unsteady flows: (1 week)**
One-dimensional unsteady heat conduction. Explicit, implicit and Crank-Nicholson schemes. Implicit methods for two-and three-dimensional convection-diffusion problems. Transient SIMPLE and PISO algorithms.

Week 9-11 **Turbulence and its modeling: (3 weeks)**
Transition from laminar to turbulent flow. Effect of turbulence on time averaged Navier-Stokes equations. Characteristics of simple turbulent flows. Free turbulent flows. Flat plate boundary layer and pipe flow. Turbulence models. Mixing length model The k-e model. Reynolds stress equation models. Algebraic stress equation models. LES methods. Some recent advances.

Week 12-13 **Methods for dealing with complex geometries: (2 weeks)**
Body-fitted co-ordinate grids for complex geometries. Cartesian vs. curvilinear grids. Curvilinear grids-difficulties. Block structured grids. Unstructured grids. Discritesation in unstructured grids. Discretisation of the diffusion, convection and source terms. Calculation of surface areas, volumes and gradients. Assembly of discretised equations. MIM method. TVD schemes in unstructured grids. High order convection schemes in unstructured grids.

Computer Usage:
Students are required to write simple computer programs for solving simple one-dimensional convection-diffusion and two-dimensional diffusion problems. CFD assignements will be given to be solved by using ANSYS CFX.

Teaching Techniques:
Over-head projector is used in the classroom.

GRADING POLICY

Mid-term Examination	20%
Computer projects	50%
Final Examination	30%

Instructor: İbrahim Sezai