Department of Mechanical & Aerospace Engineering
CARLETON UNIVERSITY

AERO 4304: Computational Fluid Dynamics

Winter 2013

Course Outline

Introduction and course objective

Computational fluid dynamics (CFD) is the science of predicting the behaviour of a fluid flow through the numerical solution of the equations of motion that govern the flow. The use of CFD in industrial settings is increasing rapidly, and numerous sophisticated CFD software packages are available. It is important that engineers who work in CFD have a solid foundation in both fluid mechanics and numerical analysis; an indiscriminate user of CFD software can easily produce colourful but meaningless results. Therefore, *the objective of this course is to present the fundamentals of CFD so that students become knowledgable users of CFD software.* To accomplish this objective, the course will present the theory in combination with substantial hands-on practice using the commercial CFD software ANSYS CFX®.

Instructor

Joshua Brinkerhoff
Office: 3230-A Mackenzie Building
E-mail: jbrinker@connect.carleton.ca
Office hours: by email appointment

Reference material

1. Course lecture notes and slides
2. Supplementary textbooks:
   - Anderson, J. D. *Computational Fluid Dynamics—The Basics with Applications*. McGraw-Hill.
   - Ferziger, J.H. and Perić, M. *Computational Methods for Fluid Dynamics*. Springer.
   - Tannehill, J.C., Anderson, D.A., and Pletcher, R.H. *Computational Fluid Mechanics and Heat Transfer*. Second edition. Taylor & Francis.
   - Versteeg, H.K. and Malalasekera, W. *An Introduction to Computational Fluid Dynamics: The Finite Volume Method*. Longman Scientific & Technical.

Course WebCT site

A WebCT site will be used for communication and posting of course material, including lecture notes. The course WebCT site can be accessed from http://webct.carleton.ca. Please refer to the WebCT site frequently in order to keep up-to-date with the course material that is posted there.

Assignments

Three assignments will be assigned throughout the term. The assignments are intended to give students practice with ANSYS CFX® and other course material. Reports of maximum 5 pages will be collected and marked.

Project

Students will be assigned a project to simulate a fluid flow in ANSYS CFX®. The project will have two interim memos due during the term and culminate in a final report. The purpose of the project is to apply the principles presented in the lectures to setup and simulate a fluid flow and then assess the accuracy and set-up of the simulation. A detailed description of the project and the instructions and due dates of the project deliverables are presented in the project handout.

Examinations

A final exam will be scheduled by Scheduling and Examination Services. Course notes and lecture slides can be brought into the exam. According to the policy of the Faculty of Engineering and Design, the marked final examination papers will not be returned to students.

Preliminary marking scheme

- 20% for the assignments
- 30% for the course project
- 50% for the final exam

Tentative course topics

1. *Introduction to CFD*: motivation; history; overview of CFD methodology; CFD software packages.
2. *The governing equations and their behavior*: conservation principles; derivation of conservation laws; simplified models of fluid flow (incompressible, inviscid, potential flow); dimensionless form of the governing equations; classification of partial differential equations.
3. *Numerical methods*: discretization schemes (finite-differences, finite-volume, finite element) and their properties.
4. *Finite difference methods*: Taylor's series expansions; effect of grid refinement; analysis of truncation error; implementation of boundary conditions; discretization schemes for elliptic, parabolic, hyperbolic problems; solution of algebraic systems of equations; numerical stability and accuracy.
5. *Finite volume methods*: Discretization methods for conduction and convection-diffusion problems (upwind, QUICK, exponential and hybrid schemes); pressure-velocity coupling in steady flows; discretization of unsteady flows.
6. *Turbulence modeling:* Reynolds-averaged Navier-Stokes (RANS) equations; Reynolds stress and the turbulence closure problem; eddy-viscosity and mixing length models; Reynolds-stress models; large-eddy simulation; direct numerical simulation.
7. *Advanced/emerging topics*: transition modeling; parallel computing; multigrid methods; immersed boundary methods.

Accommodation statement

Pregnancy and/or religious obligation: Write to me with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. For more details visit the Equity Services website http://www.carleton.ca/equity/accommodation/student_guide.htm

Students with disabilities requiring academic accommodations: Register with the Paul Menton Centre for Students with Disabilities (PMC) for a formal evaluation of disability-related needs. Registered PMC students are required to contact the PMC, 613-520-6608, every term to ensure that I receive your Letter of Accommodation, no later than two weeks before the first test or assignment requiring accommodations is due. If you only require accommodations for your formally scheduled exam(s) in this course, please submit your request for accommodations to PMC by the deadlines published on the PMC website: http://www2.carleton.ca/pmc/new-and-current-students/dates-and-deadlines/. You can visit the Equity Services website to view the policies and to obtain more detailed information on academic accommodation at http://carleton.ca/equity/accommodation