Large-Eddy Simulation of Turbulent Flows

ME EN 7960-003 Fall 2016

Instructor	Jeremy A. Gibbs, Ph.D. Email: jeremy.gibbs@utah.edu Office: MEK 2566 Hours: by appointment
Lecture	WEB 1460, Tues and Thurs, 3:40-5:00p
Credit	3 hours
Recommended Texts	*Elements of Direct and Large-Eddy Simulation* B.J. Geurts (R.T. Edwards, 2004), 329 pp. *Large Eddy Simulation for Incompressible Flows: An Introduction* P. Sagaut (Springer, 2000), 556 pp. *Turbulent Flows* S. B. Pope (Cambridge University Press, 2000), 771 pp.
Prerequisites	ME EN 5700/6700 (or equivalent) or Instructor consent
Useful courses	ME EN 7710 ME EN 7720
Grading	Homework 40% Project #1 25% Project #2 35%

Course Description

This course covers topics related to Large-Eddy Simulation (LES), an advanced Computational Fluid Dynamics (CFD) technique. LES is quickly replacing traditional Reynolds Averaged Navier-Stokes (RANS) modeling as the method of choice for researchers and practitioners studying turbulent fluid flow phenomena in engineering and environmental problems. LES explicitly solves for the larger scale turbulent motions that are highly dependent on boundary conditions, while using a turbulence model only for the smaller (and presumably more universal) motions. This is a distinct advantage over traditional RANS models where the effects of turbulence on the flow field are entirely dependent on the turbulence parameterizations.

Course Objectives

- Become familiar with the filtering concept in a turbulent flow and how the idea of scale separation forms the basis for LES.
- Gain familiarity with the filtered forms of the conservation equations (e.g., mass, momentum, turbulent kinetic energy), how they are derived, and how the different terms in the equations can be interpreted.
- Obtain a basic working knowledge of common subgrid-scale (SGS) parameterizations used in LES of turbulent flows.
- Understand how to carry out *a priori* analysis of SGS models from experimental and Direct Numerical Simulation (DNS) data sets.
- Understand common techniques for *a posteriori* evaluation of SGS models and what conditions are necessary and sufficient for a "good" SGS model.
- Become familiar with LES SGS models and techniques used in specific flow cases of interest (e.g., isotropic turbulence, high-Reynolds number boundary layers, turbulent reacting flows, etc.)

Course Outline

- Intro and motivation
- Analysis tools
- Turbulence and scale separation
- Equations of motion
- Filtering
- Filtered equations of motion
- Approaches to turbulence modeling
- Numerics and LES
- Basic SGS models
  - eddy viscosity
  - similarity
  - nonlinear
  - mixed
  - dynamic models
- Using Fourier methods to simulate isotropic turbulence (Project #1)
- Evaluating LES (*a posteriori*)
- Evaluating SGS models (*a priori*, Project #2)
- Special Topics in LES (cover some set of the following examples)
  - Boundary and initial conditions
  - Anisotropic models
  - Probability based methods
  - Lagrangian particle models
  - LES of compressible and/or reacting flows
  - LES case studies of interest

Homework

Approximately 3 homework assignments will be given during the semester. These assignments will focus on basic topics and ideas that will be needed in the projects (statistics of turbulence, filtering, power spectra estimation, model formulations, etc.). The assignments will be given throughout the semester when material is covered with an emphasis on the time period before the 1st project.

Project #1

Project #1 will focus on the application of LES SGS models in 3D turbulence simulations. Students will be provided a basic 3D numerical code which they will add their own SGS models to and will then examine the effect of base model type, model coefficient specification, and grid resolution on the resolved simulated velocity fields. The project will be submitted in the form of a short report (~4 pages) outlining the basics of the simulation code used, the chosen SGS models, and the results of parameter studies.

Project #2

Project #2 will consist of gaining experience on doing *a priori* analysis of LES SGS models from experimental or numerical data. Data sets from various experimental setups (high speed turbulence sensors, PIV) or high resolution DNS will be provided for students to use in the projects based on their research interests. Alternatively, if students have appropriate data sets (experimental or numerical) that they wish to use for their project they will be free to do so. The project will be submitted in the form of a short report (~4-6 pages) including: basics and background of the SGS models to be tested, a short description of the data set used in the analysis, and a short summary of key results/insights gained from the tests. In addition to the project report, all students will be required to give a short presentation (~15 minutes) during the last weeks of class.

Useful Information

University of Utah Accommodations Policy (III.Q)

University of Utah Student Code of Conduct

College of Engineering Guidelines

Department Of Mechanical Engineering Graduate Advising Guide