ME 637 PARTICLE TRANSPORT, DEPOSITION AND REMOVAL-II
Spring 2005

INSTRUCTOR: G. Ahmadi, Room 267 CAMP (268-2322)
Office Hours: MW 12:30 - 2:30 p.m. Tues. 1:30 - 2:30 p.m.
TEXT: None

COURSE WEB SITE: http://www.clarkson.edu/projects/crcd/

Course Objectives

1. To provide a fundamentals of particle transport and deposition in turbulent flows.
2. To familiarize the students with the computational modeling of dilute two-phase flows.
3. To familiarize the students with the industrial applications of dilute multiphase flows.
4. To familiarize the students with the modern experimental techniques in aerosol transport analysis.
5. To familiarize the students with the industrial applications of aerosols.

Course Learning Outcomes

Objective 1:
- Students will be able to solve aerosol transport and deposition in turbulent flows.

Objective 2:
- Students will be able to formulate and analyze charged particle transport and deposition.

Objective 3:
- Students will be able to perform computational fluid dynamics and particle trajectory analysis in turbulent flows.

- Students will demonstrate using the FLUENT Code for solving particle transport in turbulent flows.
- The student will be able to perform an experimental study of aerosol transport and deposition processes.

Objective 4:
- Students will become familiar with the industrial gas cleaning and separation processes.
- Students will become familiar with pollution transport and lung deposition

COURSE OUTLINE

REVIEW of VISCOUS FLOWS
- Navier-Stokes Equation
- Simple Flows
- Creeping Flows

- Drag on Spherical Particles

REVIEW OF COMPUTATIONAL FLUID MECHANICS

- Finite Difference and Finite Volume Methods
- Introduction to Gambit and Unstructured Fluent Code

REVIEW OF TURBULENCE MODELING

- Algebraic Models
- Two-Equation Models
- Stress Transport Model
- Rate-Dependent Models
- PDF Models

AEROSOLS

- Review of Drag, Lift, Virtual Mass and Basset Forces, BBO Equation
- Review of Nonspherical Particles
- Review of Brownian Motions
- Review of Particle Deposition Mechanisms
- Aerosol Transport in Turbulent Flows
- Wall Deposition in Turbulent Flows
- Inertia Impaction
- Particle Charging Mechanisms
- Electrostatic Forces
- Thermophoretic Forces
- Aerosol Coagulation
- Coagulation by Turbulence and Shear Fields

COLLOIDS

- Introduction to Colloids
- Double Layer Forces
- Electrokinetic Phenomena

SIMULATION METHODS

- Sublayer Model of Turbulence
- Particle Deposition on Smooth and Rough Wall
- Sublayer Simulation of Charged Particle
- Approximate Simulation of Instantaneous Turbulent Flows
- DNS and Large Eddy Simulation of Turbulence (Dr. McLaughlin)
- Particle Transport and Deposition in Turbulent Flows (Dr. McLaughlin)
- Brownian Motion of Nano-particles in Turbulent Flows
- Nonspherical Particle Transport in Turbulent Flows

EXPERIMENTAL TECHNIQUES

- Turbulent Flow Measurement (Hot-Wire, PIV, Laser-Doppler) (Dr. Glauser, Dr. Hiroshi, Syracuse University)
- Particle Concentration and Velocity Measurements (Phase-Doppler, PIV) (Dr.Taylor)

- Particle Production (Dr. Goia)
- Aerosol Sampling Techniques and Aerosol Instrumentation (Dr. Dhaniyala)
- Advanced Surface Cleaning Techniques (laser, cryogenic, ultrasonic) (Dr. Cetinkaya)

APPLICATIONS

- Microcontamination Control and Clean Room Operation (Dr. Cetinkaya)
- Xerography (Dr. Fan, Xerox)
- Indoor Air Quality (Dr. Zhang, Syracuse University)
- Computational Methods for Indoor Air (Dr. Dang, Syracuse University)
- Lung Deposition and Inhalation Drug Delivery
- Filtration Processes and Gas Cleaning
- Combustors and Boilers
- Spray formation

EVALUATION METHOD:

Exam 1 (March 10, CAMP 175, 7-8:30 pm) 25%
Final Exam (Final Exam week) 30%
Computational Projects 30%
Lab work 5%
Homework 10%

COURSE DESCRIPTION

Review of viscous flow theory. Creeping flows around a sphere. Introduction to turbulent flows and turbulent modeling. One and several equation models. Drag, lift, virtual mass and Basset forces acting on particles. Wall effects and nonspherical particles. Aerosol transport and dispersion in turbulent flows. Turbulent diffusion and wall deposition of aerosols. Particle charging mechanics and electrostatics forces. Thermophoretic and electrophoretic effects. Introduction to colloids and electrokinetic phenomena. Computational aspects of aerosol dispersion and deposition in turbulent flows. Sublayer model approach. Approximate simulation of turbulence and turbulence transport. DNS simulation methods. Nonspherical particle transport in turbulent flows. Coagulation of aerosols due to shear and turbulence. Experimental techniques for turbulent flow measurements. Hot-wire anemometry, Isokinetic sampling. Particle concentration and velocity measurements with phase-doppler, and PIV. Applications to microcontamination control, air pollution, combustor, spray and particle deposition in human lung. Clean room equipment, xerography, surface cleaning in microelectronic and imaging industries.

REFERENCES

- W.C. Hinds, Aerosol Science and Technology, Wiley, New York (1983, 1999).
- J. Happel and H. Brenner, Low Reynolds Number Hydrodynamics, Martinus Nijhoff (1983).
- N.A. Fuchs, The Mechanics of Aerosols, Dover (1989).
- V.G. Levich, Physicochemicals Hydrodynamics, Prentice-Hall, New York (1962).
- P.A. Baron and K.W. Willeke, Aerosol Measurement, Principles, Techniques, and Application, Wiley, Interscience, New York (2001).
- F. White, Viscous Flow, McGraw Hill, New York (1974).
- R.L. Panton, Incompressible Flow, John Wiley, New York (1984).
- H. Schlichting, Boundary Layer Theory, McGraw Hill, New York (1979).
- J.O. Hinze, Turbulence, McGraw Hill, New York (1975).
- H. Tennekes and J.L. Lumley, A First Course in Turbulence, MIT Press, Cambridge (1981).
- G.M. Hidy, Aerosols, Academic Press, New York (1984).
- G.M. Hidy and J.R. Brook, The Dynamics of Aerocolloididal Systems Pergamon Press, London (1970).
- Papavergos and Hedley, Chem. Eng. Rs. Des., Vol. 62, September 1984, pp. 275-295.
- S.K. Friedlander, Smoke, Dust and Haze, Fundamentals of Aerosol Dynamics, 2nd Ed. Oxford University Press, Oxford (2000).
- J. H. Vincent, Aerosol Science for Industrial Hygienists, Pergamon Press, Oxford (1995).
- D.J.Quesnel, D.S. Rimai and L.H.Sharpe, Particle Adhesion: Application and Advances, Taylor and Francis, New York (2001).
- G. Ahmadi, Overview of Digital Simulation Procedures for Aerosols Transport in Turbulent Flows, in "Particles in Gases and Liquids 3: Detection, Characterization, and Control," Ed. by K.L. Mittal, Plenum Press, New York, pp. 1-21 (1993).
- G. Ahmadi, Overview of Computational and Analytical Modeling of Particle Transport and Deposition in Turbulent Flows, Scientia Iranica Vol. 1, 1-23 (1994).
- H. Zhang and G. Ahmadi, Aerosol Particle Transport and Deposition in Vertical and Horizontal Turbulent Duct Flows, J. Fluid Mechanics, Vol. 406, pp. 55-80 (2000).
- M. Soltani, H. Ounis, G. Ahmadi, and J.B. McLaughlin, Direct Numerical Simulation of Charged Particle Deposition in a Turbulent Flow, Int. J. Multiphase Flow, Vol. 24, pp. 77-94, (1988).
- M.R. Spina and W.W. Nazaroff, Particle deposition from turbulent flow: Review of published research and its applicability to ventilation ducts in commercial buildings, http://repositories.cdlib.org/lbnl/LBNL-51432/