ME 714 Principles of Particulate Multiphase Flows

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Textbook: None

References:

L. S. Fan and C. Zhu, *Principles of Gas-Solid Flows*, Cambridge University Press, 1998 ISBN 0-521581486

C. Crowe, M. Sommerfeld and Y. Tsuji, *Multiphase Flows with Droplets and Particles*, CRC Press, 1998, ISBN 0-8493-9469-4

W. Sirignano, Fluid Dynamics and Transport of Droplets and Sprays, Cambridge University Press, 1999, ISBN 0-521-63036-3

L. Zhou, Theory and Numerical Modeling of Turbulent Gas-Particle Flows and Combustion, CRC Press, 1993, ISBN 0-8493-7721-8

Course Description:

Multiphase Flows cover all flows containing solid particles, droplets, and/or bubbles. The particles can be rigid as solids or deformable as droplets and bubbles. Principles of particulate multiphase flows are essential to the research and development of engineering systems for particulate handling and transport, process and reaction of particulate chemicals; mixing or separation of particulates, and other applications such as spray, coating and drying of particulates. This course is focus on the introduction of fundamental principles of mass, momentum, heat and mass transfer in particulate multiphase flows. Based on these principles, theories and governing equations for distinctive responses and motions of each phase and the dynamic interactions among phases are formulated. Typical industrial applications will also be illustrated.

Course Prerequisite: basic fluid mechanics or consent of instructor

Course Content

1. Introduction and characterization of particulate multiphase flows
2. Continuum Modeling of Single-Phase Flows
   - 2.1 Flows of Newtonian Fluids
   - 2.2 Flows in Porous Media
   - 2.3 Granular Flows: Kinetic Theory Modeling
   - 2.4 Non-Newtonian Fluid Flows
3. Transport of an Isolated Object: Solid Particle, Droplet and Bubble
   - 3.1 Momentum Transfer
   - 3.2 Heat Transfer
   - 3.3 Mass Transfer
   - 3.4 BBO Equation
4. Interactions of Particles, Droplets, and Bubbles
   - 4.1 Transport Properties of a Cloud of Particle
   - 4.2 Collision of a Pair of Solid Spheres
   - 4.3 Collision of Droplets, Solids and Bubbles
   - 4.4 Charge generation and charge transfer
5. Continuum modeling of multiphase flows
   - 5.1 Phase averages and averaging theorems
   - 5.2 Volume-Averaged Equations
   - 5.3 Volume-Time-Averaged Equations
   - 5.4 Turbulence Modulation
6. Continuum-Discrete Tracking Modeling of Multiphase Flows

6.1 Lagrangian Trajectory Modeling
6.2 Transport Coupling in Eulerian-Lagrangian Modeling

7. Gas-Solid Flow Systems
   7.1 Gas-solids Separation
   7.2 Fluidization
   7.3 Pneumatic Transport
8. Gas-Liquid & Liquid-Solid Flow Systems
   8.1 Droplet Transport and Sprays
   8.2 Bubble Column
   8.3 Sedimentation of Solids
9. Complex Multiphase Flows
   9.1 Reactive Multiphase Flows
   9.2 Multiphase Flows with Charges
   9.3 Gas-Solid-Liquid Flows
   9.4 Interactions with External Fields

Course Arrangement

Week	Subject	Assignment due
1	Introduction, Modeling of Single-Phase Flows-1	
2	Continuum Modeling of Single-Phase Flows-2	HW#1
3	Transport of an Isolated Object	
4	Interactions of Particles, Droplets, and Bubble	HW#2
5	Continuum modeling of multiphase flows	
6	Continuum-Discrete Tracking Modeling	HW#3
7	Gas-Solid Flow Systems-1	
8	Gas-Solid Flow Systems-2	HW#4
9	Gas-Liquid & Liquid-Solid Flow System-1	
10	Gas-Liquid & Liquid-Solid Flow System-2	
11	Complex Multiphase Flows-1	
12	Complex Multiphase Flows-2	HW#5
13/14	**Special topic presentation & discussions (25-min presentation + 15 min Q&A)**	**Presentation/Term project report**

Grade Calculation Method

(1) class attendance (20%)
(2) homework (40%)
(3) presentation and term report (20%)
(4) final exam (20%)

Final grade is based on accumulative grade. Substantial difference in accumulative grade (>20%) will lead to a downgrade in final grade category.

Homework Requirements

- For HW#1-4, every homework assignment consists of 4 problems (of which one must be self-defined). The self-defined problem can be a simplified problem based on a research paper, project or ideal conditions.

  The self-defined problem cannot be directly from existing textbooks. However it can be modified from existing textbooks. The problem must be up to the level of 700 level courses. All homework must be finally correct or accepted by instructor (after revisions).

- For HW#5, two (2) problems will either be assigned or be self-defined. The problem 5-1 should be solved using Lagrangian trajectory model and using numerical method to obtain a solution. The problem 5-2 should be solved using continuum (multi-fluid) model approach and using commercial code such as FLUENT.

  The problem cannot be directly from demo examples from commercial codes.

Special Topic Presentation

An individual presentation on a selected topic is required. The presentation can be a detailed introduction of a specific multiphase flow system or a good summary of the current research status on a specific multiphase flow topic (which is based on at least **10 complete references** from at least **3 different journals**/proceedings). **The summary should be only based upon literature surveys.**

<u>Presentation grade will be judged by the entire class.</u>