ChE162: Dynamics and Control of Chemical Processes
Spring 2015
Course Information

Class website: https://bcourses.berkeley.edu/courses/1297290

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Description

Dynamic analysis of systems; development of mathematical and computational tools to analyze systems not at steady state; derivation of mass and energy balances of open systems building upon previous knowledge in thermodynamics, transport, and kinetics; feedback control; analysis of system stability; feedforward control; cascade control; override control; multi-input, multi-output systems

Prerequisite knowledge and/or skills

- Mathematics including understanding of differential equations and nonlinear algebraic equations
- Prior chemical engineering courses in thermodynamics, kinetics, and transport
- A general understanding of chemical engineering processes

Course Prerequisite(s)

- Transport and Separation Processes (ChE 150B)
- Math 53
- Math 54

Course Objectives and Outcomes

Objectives – The students learn:

- the ability to analyze systems not at steady state;

- the mathematical and computational tools to solve ordinary differential equations;
- the ability to derive mass balances, mass component balances, and energy balances in open systems;
- the differences between linear and nonlinear systems;
- the principles of feedback control systems, including proportional, integral, and derivative modes;
- approaches to analyze control system stability;
- experimental approaches to analyze control system stability, including measurement of ultimate gains and periods;
- the ability to tune feedback controllers using a variety of tuning relationships;
- experimental implementation of tuner control approaches;
- the principles, advantages, and limitations of feedforward control systems;
- analysis and tuning of cascade control systems;
- experimental design of cascade control;
- analysis and design of ratio and override control systems;
- the principles of multi-input, multi-output systems.

Outcomes – Students must be able to:

- develop mechanistic models of mass, component mass, and energy balances of open systems;
- analytically or computationally solve the resulting differential equations;
- understand how nonlinearities contribute to system behavior;
- incorporate mechanistic models into a feedback, feedforward, cascade, ratio, and override control system;
- analyze the stability of control systems, particularly feedback control;
- implement several approaches to optimally tune the parameters of a control system;
- understand the limitations of mechanistic models and understand approaches to experimentally/empirically characterize a dynamic system.

Topics Covered

1. Concepts and definitions of control;
2. Development of mathematical and computational tools for analyzing system dynamics;
3. Mechanistic modeling of processes;
4. Development of differential equations to model mass, mass component, and energy balances;
5. Analysis of first and higher order dynamic systems;
6. Development of feedback control concepts;
7. Mathematical and conceptual analysis of proportional, integral, and derivative feedback control modes;
8. Analysis of control system stability;
9. Tuning of feedback controllers and definition of criteria for tuning;
10. Feedforward and feedforward-feedback control systems;

11. Cascade control;
12. Ratio control;
13. Override control;
14. Multi-input, multi-output systems;
15. Concepts of control in biological systems.

Contribution of course to meeting the professional component

This course contributes to the students' knowledge of engineering topics, as required for process design.

Relationship of course to undergraduate degree program objectives and outcomes

This course provides an important synthesizing element for the undergraduate curriculum. It builds upon mass and energy balance concepts, synthesizes concepts developed earlier in the curriculum (thermodynamics, kinetics, transport, and mathematics), and introduces the concepts of process control, as needed for product and process-design development.

Why this course is useful

In the course students learn how operating chemical processes behave and how these processes must be governed (controlled) for safe and profitable operation. It is a required course for chemical engineers because a primary purpose of any control system is *process safety* and chemical engineers must have a thorough understanding of process safety.

Control system *synthesis* is the most demanding element of the course. Students gain experience in synthesis by studying control systems for specific processes such as chemical reactors, separation units, and heat exchangers. Class work is complemented by computer laboratory work because students must learn how to apply theoretical knowledge to real and simulated processes.

Control system *analysis*, like any other engineering discipline, has its set of tools. These tools, that are mathematical in nature, are covered in lectures and homework assignments. Control system analysis also requires process dynamics to be known in addition to the steady-state behavior that is the usual basis for process design and analysis. Consequently, the *dynamic behavior* of chemical processes forms a significant portion of the course. A good control system design always starts with a thorough knowledge of the process to be controlled (cause-effect relationships must be known). Again, students learn these tools both by theory and by practice in the laboratory.

Course Structure

In the course there are lectures, homework, computer lab sessions, two midterms covering process dynamics and basic controls, and a final covering the whole course.

The class meets in 1535 Tolman Hall for the computer lab sessions on Tu/W afternoons. Tu/W computer lab attendance is mandatory.

Computer lab assignments require the use of MATLAB/Simulink/Control tool box which is available in both 1535 Tolman Hall and 175 Tan Hall (R2014a version).

Computer lab assignments are structured so that the whole assignment can be completed in a 2-hour period. Students turn in key figures and other results at the end of the session as proof of completion of the assignment. Generally the assignment will be posted on the course web site the week before the computer lab.

Homework problems are assigned on Friday and handed in at the beginning of lecture the following Friday. No late homework will be accepted. There will be two one-hour midterms held during class, and no makeup exams will be held.

Grading

The grade for the course is determined by weighting the individual elements as follows:

Midterms	30 points
Final	30 points
Homework	15 points
Computer Laboratory	25 points

Textbook: Bequette, B.W. *Process Control, Modeling, Design and Simulation*., Prentice Hall, N.J.(2003)

CE162: Chemical Process Control
Fall 2013 Lecture Schedule

Week of	**Topic/Reading**
January 19 (2 lectures)	Introductions/ Course Structure/Ch.1: Introduction
January 26	Ch.2: Fundamental Models
February 2	Ch.2: Fundamental Models
February 9	Ch. 3: Dynamic Behavior
February 16	Ch. 3: Dynamic Behavior
February 23	Ch. 4: Empirical Models excluding 4.4 and 4.5 Midterm I, Wednesday, February 25 in class covering Ch 1-3
March 2	Ch. 5: Introduction to Feedback Control excl. 5.5, 5.8
March 9	Ch. 5: Introduction to Feedback Control excl. 5.5, 5.8
March 16	Ch. 6: PID Controller Tuning Midterm II, Wednesday, March 18 in class covering Ch 5
March 23	Spring Recess
March 30	Ch. 7: Frequency-response analysis
April 6	Ch. 10: Cascade and Feed-Forward Control
April 13	Ch. 10: Cascade and Feed-Forward Control
April 20	Ch. 11(only Section 11.5): Gain Scheduling
April 27	Ch 12: Ratio, Selective and Split-Range Control
May 4	Review
Monday, May 11	Final, 7-10 pm. Location to be assigned.

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