Introduction

1. Motivation
2. Stirred tank blending system
3. Classification of control strategies
4. Distillation column
5. Control system design
6. Changes based on ChE 361 comments
7. Overview of the course
Motivation for Process Control

- The technological environment
  - More complex and integrated plants
  - Highly constrained operation
  - Increased utilization of batch processing

- The economic environment
  - International competition
  - Rapidly changing economic conditions
  - Tighter product quality specifications
  - Demand for higher production rates
  - Higher energy and raw material costs
  - More stringent environmental and safety requirements
Continuous and Batch Processes

(a) Heat exchanger
(b) Chemical reactor
(c) Cracking furnace
(d) Distillation column

(e) Semi-batch reactor
(f) Wood chip digester
(g) Plasma etcher
(h) Kidney dialysis unit
Elements of Process Control

- Process modeling
  - Knowledge embedded in mathematical description
  - A core competency of chemical engineers
  - Model used for dynamic analysis and control system design

- Process dynamics
  - Study of unsteady-state (transient) behavior
  - Startups/shutdowns, disturbance effects, production rate changes
  - Underemphasized in other ChE courses

- Process control
  - Design and implementation of automatic control systems
  - Flow control, temperature control, composition control, unit operation control, plantwide control, etc.
  - Essential background for any chemical engineer
Stirred Tank Blending System

Mixture of A and B

Control valve

Pure A

Overflow line

x

w
Control Problem

- Control objective
  - Adjust $w_2(t)$ such that $x(t) = x_{sp}$ despite variations in $x_1(t)$

- Notation
  - Controlled output: $x(t)$
  - Setpoint: $x_{sp}$
  - Manipulated input: $w_2(t)$
  - Disturbances input: $x_1(t)$

- Design problem
  - Steady-state solution of control problem
    \[
    \overline{w} = \overline{w}_1 + \overline{w}_2 \quad \overline{x}_2 = 1, \overline{x} = x_{sp} \rightarrow \overline{w}_2 = \overline{w}_1 \frac{x_{sp} - \overline{x}_1}{1 - x_{sp}}
    \]
    - Does not account for process dynamics or time-varying disturbance $x_1(t)$
Feedforward Control System

- Measure $x_1$ and adjust $w_2$
- Modify steady-state design equation

$$w_2(t) = \overline{w_1} \frac{x_{sp}(t) - x_1(t)}{1 - x_{sp}(t)}$$

- Does not account for process dynamics or other possible time-varying disturbances ($w_1$)
Feedback Control System

- Measure $x$ and adjust $w_2$
- Proportional controller

$w_2(t) = \overline{w}_2 + K_C [x_{sp}(t) - x(t)]$

$K_C > 0$

- Accounts for any disturbance but yields slower response than feedforward controller
Feedforward and Feedback Control

- **Feedforward control**
  - Measure the disturbance input
  - Respond to disturbance *before* it affects the process
  - Requires model of disturbance effect
  - Impractical for complex processes with many disturbances

- **Feedback control**
  - Measure the controlled output
  - Respond to disturbance *after* it affects the process
  - Requires no model of disturbance effect
  - Most widely used method

- **Feedforward/feedback control**
  - Measure the disturbance input and the controlled output
  - Combination of the two control strategies
Control Problem

- Controlled outputs
  - Product compositions \((x_D, x_B)\)
  - Pressure \((P)\)
  - Reflux drum and column base levels \((h_D, h_B)\)

- Manipulated inputs
  - Product flow rates \((D, B)\)
  - Reflux flow rate \((R)\)
  - Condenser and reboiler duties \((Q_D, Q_B)\)

- Disturbance inputs
  - Feed flow rate and composition \((F, x_F)\)

- Complex control system design problem

- Failure of a column control system:
  [CSBSafetyVideoExplosionatBPRefinery.mp4](#)
Process Control Hierarchy

1. Measurement and Actuation
   (< 1 second)

2. Safety and Environmental/Equipment Protection
   (< 1 second)

3a. Regulatory Control
    (seconds-minutes)

3b. Multivariable and Constraint Control
    (minutes-hours)

4. Real-Time Optimization
   (hours-days)

5. Planning and Scheduling
   (days-months)
Control System Development
Controller Design

- The process of determining a mathematical description of the controller

- Traditional approach
  - Controller design based on process knowledge
  - No explicit model is utilized
  - Controller tuning parameters adjusted to achieve satisfactory performance
  - PID control
  - Adequate for “simple” processes

- Model-based approach
  - Process knowledge embedded with dynamic model
  - Model used directly for controller design and tuning
  - Advantageous for “complex” processes
  - Model-based control
  - A major focus of this course
Comments from ChE 361

- Stop using Powerpoint for lectures → Sorry
- Post Powerpoint slides → Yes
- Use recitation section → Yes
- Incorporate more Matlab → Yes
- Eliminate quizzes → Yes
- Shorten exams → Yes
Overview of the Course

- Course syllabus
- Course schedule
- Course website