ChE 4530: Process Dynamics and Control Summer 2023

Instructor: Dr. Mark Roberts, 204 Earle Hall, mrober9@clemson.edu

Class format: Online synchronous and asynchronous Office hours: TBD

Prerequisites: Students should have some background in chemical engineering thermodynamics, fluid mechanics, mass and heat transfer, differential equations, and at least a little knowledge on separations and reactions
(Clemson Students: MATH 2080, CHE 2300, and CHE 3300 (coreq)

Required Text (Supplement):

Supplemental Text: Chemical and Bio-Process Control, 5th ed., J. B. Riggs and M. N. Karim, J.S. Alford, Ferret Publishing, 2016 (3rd and 4th editions are okay).

Course Pack will be available on Web Portal (https://www.clemson.edu/canvas/)

Electronics: Electronic devices (smart phone / tablet / laptop computer) will be required for in-class (or virtual) assignments.

Course Outcomes: At the end of the course you should be able to:

- Explain and apply basic concepts of chemical process dynamics and control.
- Construct process control diagrams and information flow chart for chemical processes.
- Derive, solve, and interpret dynamic models of simplified chemical processes.
- Specify and troubleshoot common control system hardware.
- Select appropriate PID tuning method, tune basic PID control loops, and interpret the process response.
- Compare and contrast several advanced control techniques.
- Select and apply advanced control schemes to improve control objectives and/or meet safety requirements.

These operational outcomes will require you to reflect upon previously learned fundamental theory and process models (prerequisites) and engage you in critical thinking by making and justifying choices.

Course Grading:		**Final Average**	**Course Grade**
Homework/Quiz	5%	90 – 100	A, very good to excellent
Projects (4 total)	25 %	80 - 89	B, good to very good
Exams (mid/final)	70 %	70 - 79	C, competent, satisfactory
		60 - 69	D, marginal, questionable
		<60	F

Supplemental Course Information

Individual Chapter Outcomes (based on ***Chemical and Bio-Process Control***):

Chapter 1

1. Explain how the process works given a process flow diagram (PFD).
2. Given a control objective, illustrate a feasible control strategy. Identify the controlled variable (CV) with a sensor. Show a signal going from the sensor to a controller to an actuator, which changes a manipulated variable (MV) that influences the CV properly.
3. Study a process and instrumentation diagram (P&ID) and explain how the control strategy works; i.e., physically where the signals go and how the MVs affect the CVs.

Chapter 2

1. Explain the primary differences between single loop controllers, supervisory control systems, and distributed control systems.
2. Explain the role of each component in a basic control loop.
3. Calculate an unknown using the normal relationships involving measured variable value and the zero, span, and mA signal from the sensor/transmitter.
4. Convert mA to psi and psi to mA for I/P and P/I converters.
5. Identify the components of a pneumatic control valve and explain the purpose of each.
6. Select (size) a control valve given sufficient information on the operating requirements. (You should understand the homework on this topic thoroughly.)
7. Determine whether a control actuator should be ATO or ATC for a given application.
8. Size an orifice given sufficient information on the flow measurement requirements.
9. Use the characteristics in Table 2.3 to evaluate the performance of control hardware.

Chapter 3

1. Derive a process model starting from a dynamic mass and/or energy balance. This means starting from the general, rigorous case, using appropriate simplifying assumptions and approximations, and inserting appropriate models.
2. Pose a simple, empirical model to represent the behavior of a sensor or actuator, and estimate reasonable values of model parameters.
3. Solve simple ordinary differential equations that can be integrated directly and substitute in an initial condition to eliminate the integration constant.
4. Develop lumped parameter model from conservation equation (unsteady balance on mass, moles, or energy)

Chapter 4

1. Transform functions from the time-domain to the s-domain
2. Transform functions from the s-domain to time-domain
3. Determine poles of time-domain and s-domain functions and explain how they affect dynamic behavior.

Chapter 5

1. Linearize non-linearities that are present in transfer functions
2. Define and convert transfer functions using deviation variables
3. Derive the transfer function for any standard chemical process or operation
4. Represent an individual or overall process as a block diagram
5. Develop a complete transfer function by combining transfer functions of individual processes

Chapter 6

1. Characterize processes according to familiar types
2. Subject s-domain models to idealized inputs, examine and interpret results
3. Analyze results and develop model in time and/or s-domain (first order, second order, deadtime, integrating process)

Chapters 7,8,9

1. Know basic characteristics of P, I, and D control modes (mathematical form in time and Laplace domain, how each works, pros and cons)
2. Determine closed loop transfer function and resulting dynamics and final value.
3. Determine required controller action (direct or reverse) from valve action and process gain. Explain control loop response by stepping around the loop.
4. Describe typical control loop "architecture" for flow, level, pressure, temperature, and composition loops. Recommend choice of manipulated variable and selection of control modes (P, I, D). Recommend initial value of Kc and Ti from process knowledge.
5. Know how to apply sensor filtering; pros and cons.
6. Calculate common performance criteria from closed loop data (%OS, DR, settling time, IAE, etc. from CV vs. time)
7. Diagnose tuning problem from closed loop performance data (examine output or MV and CV vs. time, recognize probable cause of poor performance, recommend improvements by application of tuning factor or individual parameter change.)
8. Know how to apply open and closed loop tests and how to use results to recommend values for proportional gain, integral time, and derivative time.
    - open loop step => FOPTD => CC or CM settings
    - **open loop ATV** => ATV settings
    - closed loop ZN, Smith/ZN, **Riggs or Robbins field tuning** => settings
9. Recognize and interpret common terminology (end of chapter lists).

Chapter 10

1. Understand how to troubleshoot a process and/or control scheme

Chapter 12

1. Describe advanced methods of process control
2. Implement cascade control to reduce the effect of specific types of disturbances.
3. Apply ratio control to reduce the effect of feed flow rate changes
4. Utilize general feedforward control as a general methodology to compensate for measured disturbances.

Chapter 13

1. Discuss practical enhancements to PID control
2. Describe when to use inferential control to improve performacne
3. Utilize adaptive controller tuning for highly non-linear processes
4. Implement override/select controls for process safety vs. economics

Chapter 14

1. Develop strategies to overcome PID implementation issues
2. Describe the consequence of reset wind-up and how to implement anti-reset windup algorithms
3. Implement bumpless transfer for stable setpoint tracking
4. Incorporate split flow control for improved control over wide process conditions