Exercises for Chapter 12

1. This problem treats the use of integral action in cascade control.

a. In Example 12.2, there is a P controller in the inner loop and a PI controller in the outer loop. Replace the P controller in the inner loop with a PI controller, and study the load disturbance responses. Compare with Figure 12.5. Can you explain the behavior of the response in P_1?

b. When do we need an integrator in the inner loop, when do we need an integrator in the outer loop, and when do we need to have integrators in both loops?

c. Discuss advantages and disadvantages of having integrators in the different loops.

2. The integrator windup problem in cascade control is discussed on pages 376–377. Discuss the solution and ensure that you understand how it works. Can you draw a block diagram for the solution, like the one in Figure 3.13 that describes antiwindup for a single controller?

3. Consider the Friction Stir Welding process used by SKB to seal 5 mm thick copper canisters. Assume that the process has two measurement signals:

* Torque M (Nm), needed by the motor to achieve a certain rotational speed of the tool (depends e.g. on the hardness of the copper)

* Tool temperature T ($°C$), which gives an estimate of the weld zone temperature.

Your goal is to use the tool rotational speed reference ω_{ref} (rpm) as the control signal to control the tool temperature properly.

Since the force control of the weld tool involves a pneumatic cylinder, the torque M will oscillate approximately as a sine-wave with a frequency of 1.75 Hz and an amplitude of 20 Nm. This can be viewed as measurement noise. The temperature measurements are assumed noise free.

The motor servo can be modeled as a second order process

$$\Omega(s) = \frac{4.6^2}{s^2 + 2 * 0.8 * 4.6 * s + 4.6^2}\Omega_{ref}(s)$$

We can assume that the value of the rotational speed reference ω_{ref} is initially 415 rpm in steady state. The power input to the copper canister can be calculated using the relation

$$P(s) = \frac{\pi}{30000} * \Omega(s) * M(s)$$

Assume that the mean value of the torque M is 1150 Nm in steady state. The tool temperature depends on the power input as

$$T(s) = \frac{11.6e^{-5s}}{(7s+1)^2} * P(s)$$

Assume steady state and that the following two known disturbances act on the process:

* A torque step disturbance of -100 Nm

* An unmeasurable power step loss of -1 kW

Control specifications:

Find a cascade controller with the goal having as small a total IAE as possible (calculated without measurement noise) over the two disturbances. Note that you don't have to find the minimum.

The rotational speed reference should not fluctuate more than ± 2 rpm due to the measurement noise

4. Discuss how to solve the antiwindup problem when the outputs from two PI controllers are connected to a selector.

5. Consider the chemical reactor in Figure 12.32. Read about the solution to the structuring problem. Is it possible to find a methodology for this kind of structuring?