Problem Set 8

This problem set concerns representing nonlinear processes with linear system models. Our exothermic reactor can exhibit multiple steady-states for some values of the input variables and parameters. In this case, how do you define a single "reference condition" for a linear model, as we have in previous Lessons? Suppose we pick a single reference, and then fit the linear model around that condition. How well does that linear model describe changes near the reference condition? at one of the other possible references? Finally, we use numerical methods to solve the nonlinear model, looking particularly at the unstable behavior.

Use the spreadsheet "exothermic reactor for pset8.xls" to calculate steady-state conditions. Use your Matlab simulator code to solve the nonlinear problem.

(1) First of all, we have a linear model expressed in the usual dynamic parameters: time constant, damping coefficient, gains. The values assigned to those parameters depend on the reference conditions. Compare these values side-by-side at the two stable steady-states (use the conditions specified in the spreadsheet, or find different ones, as you prefer). This illustrates how two operating conditions might differ in their dynamic behavior, upon disturbance.

(2) Next, use the linear model to predict response to inputs: calculate the long-term T and C_A for a 20 K change in T_i at each stable steady state. For each steady state, use both sets of linear model parameters. Thus for a SINGLE inlet temperature change, you have a choice of 4 predicted responses. What does this mean, and which do you give your boss?

(3) In the long term after a step change, a new steady state is reached. Therefore, repeat (2) by calculating the new steady-state using the spreadsheet. Discuss why (3) and (2) differ, and whether the difference is significant. Do you trust these answers more than those of (2)?

(4) Now the adventure: code the nonlinear equations into the process model section of your Matlab simulator. The simulator template already includes an extra output variable - use this to represent the composition. Calculate the transient response to the step input in (2). The long-term response should be a new steady state – the one you calculated in (3). (This is open-loop, so leave the controller turned off.)

(5) So far, you've calculated for two stable reference conditions. With the nonlinear model, you should be able to start at the unstable condition, perturb it with a tiny pulse input, and see it move to one of the stable conditions. (The linear model predicts an exponential excursion – with the linear approximation, we lose the ability to connect the multiple steady states.)

(6) We might as well try to control this thing. With PI control, can you keep the process at the unstable reference condition? It may require some process and utility changes in addition to controller tuning - this is why we calculate dynamic behavior *before* building the equipment.