529a - Applications of MathCAD in Undergraduate Process Control

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Process control at the undergraduate level has always been so mathematically rigorous that we typically teach a course in advanced mathematics rather than focusing on issues of process modeling and control. The computer software, MathCAD, offers a host of tools that can serve as important aids in teaching process control to undergraduate chemical engineers. These include symbolic mathematics to solve a system of equations, Laplace transformations and linear sets of differential equations; numerical techniques for non-linear systems; and stability analysis of transfer functions using MathCAD programming techniques. This paper will examine some of these uses, including an example of a symbolic solution to a block diagram, a differential equation solution with automation and finally a root locus stability analysis of a transfer function hyperlinked to a power point lecture taken from a process control course.

In this presentation, knowledge of process control is assumed. Three specific examples are presented using MathCAD hyperlinked to the PowerPoint presentation to demonstrate specific tools and their application to topics at the beginning, middle and towards the end of an undergraduate process control course. In particular, a block diagram is solved symbolically for the transfer function using simultaneous equations in a solver block.

This example is followed by a comparing the dynamic response of a non-linear differential equation (equation 1) for an isothermal CSTR to that of its linearized version for two different set point changes.

$$V \frac{dC_A}{dt} = F\, C_{A_{in}} - F\, C_A - \frac{V\, k_1\, C_A}{\left(1 + k_2\, C_A\right)} \tag{1}$$

Various methods to integrate the non-linear differential equation including a MathCAD program using a second order Runge-Kutta technique (Ralston's method), and two built-in techniques are presented. The non-linear equation is linearized and solved using Laplace transformations and compared to the non-linear results.

Finally, a transfer function for a second order system with lag (equation 2) using a proportional controller is presented and its stability determined using the root locus technique.

$$G_p(s) = \frac{1}{(s+1)\left[(5s+1)(0.5s+1)\right]} \tag{2}$$

In this example, a transfer function is solved starting at the open-loop roots followed by the solution at incremental increases in gain using a MathCAD program to generate a results matrix. The imaginary parts of the results are plotted against the real portion to generate the root-locus diagram during the presentation. The approach presented generates the root locus diagram rapidly, permitting more detailed study of transfer function stability.

A goal of this presentation is to demonstrate that far more problems in control can be undertaken interactively by the professor and solved by the students using this powerful tool. By removing some of the repetitious calculations in the process control course, while still retaining the detailed calculation sequence, one can solve more problems in process control and less that are purely mathematical or graphical exercises.