Process Model and PI/PID Controller Tuning

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Overview

- The Process Data
  - A Second/Third Order System
- The Test Data
  - Open Loop
  - Step Response
- The Process Model
  - First Order System plus Deadtime
  - Show that this Model is Adequate for Tuning
- Tuning Calculations
  - Open Loop Ziegler-Nichols Method
- Closed Loop Testing
  - IAE – Integral of the Absolute value of the Error
  - Decay and Overshoot Ratios, Oscillation Period

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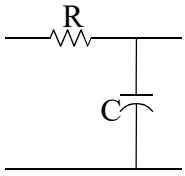
Process Time Constant

- RC Time Constant - τ (t_p)
  - Capacitance: Response dominated by system capacity
  - Resistance: Response dominated by system resistance

First order system: $g(t) = e^{-t/\tau}$, $\tau = RC$

The time it takes for the controlled variable to reach 63.2% of its final value (First Order)



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Process Deadtme

- Deadtime – t_d
  - The time that elapses from the moment a change is introduced into an element of the control loop and the moment the output begins to change
    - Also called transport lag or distance/velocity lag

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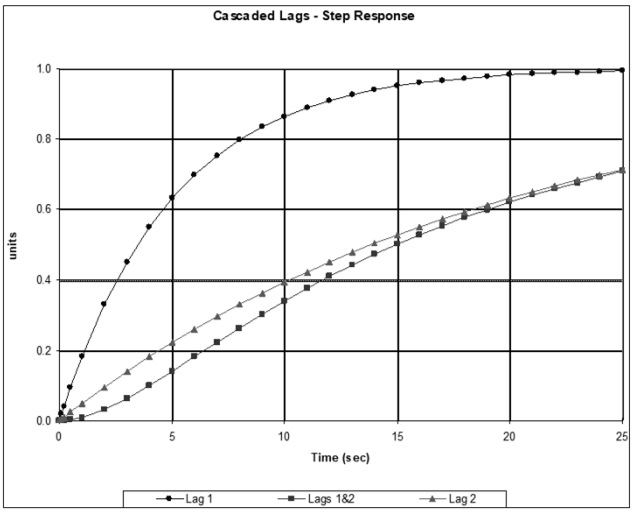
Process Response



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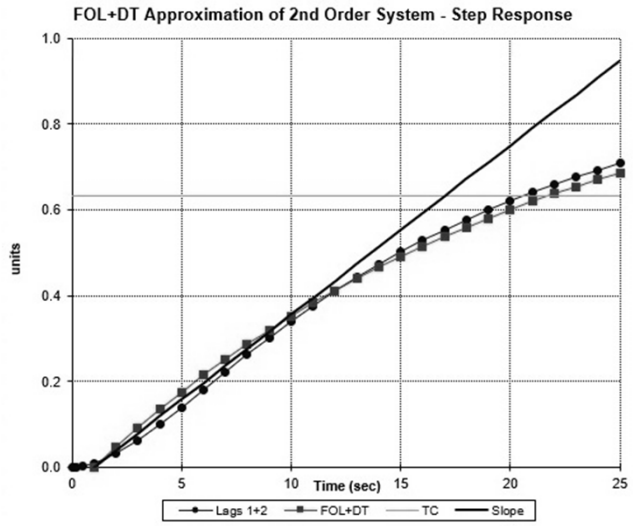
Process Response



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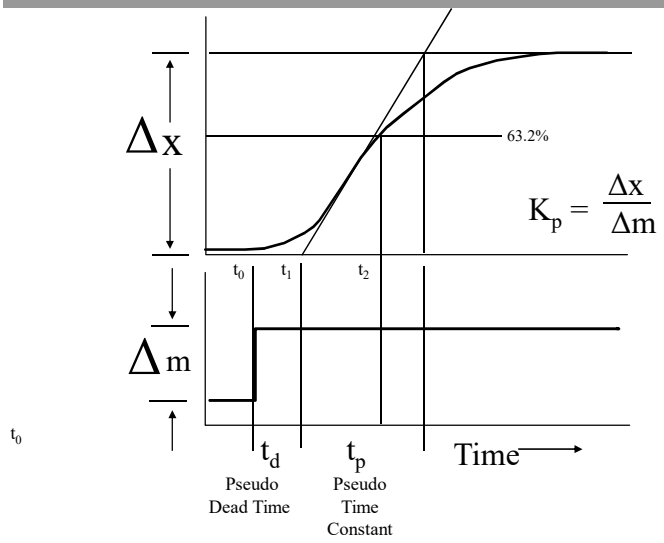
Open Loop Response Testing



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PID Control Response

The PID Controller is a Lead/Lag Compensator

Proportional – Entire control time, mainly between transient and steady state – low gain

Integral (Reset) – Steady-state response – high gain
Phase lag decreases stability

Derivative (Rate) – Transient response – high gain
Phase lead increases stability
Sensitive to Noise

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Ziegler-Nichols Controller Tuning
Coefficients from Open-Loop Test

Proportional Gain Only: $K_c = \frac{t_p}{K_p t_d}$ (K_{cp})

Proportional plus Integral (PI):

Gain $K_c = \frac{0.9 t_p}{K_p t_d} = 0.9 K_{cp}$

Reset (Minutes / Repeat) $T_i = 3.33\ t_d$

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Ziegler-Nichols Controller Tuning
Coefficients from Open-Loop Test

Proportional + Integral + Derivative (PID):

Gain $K_c = \frac{1.1 t_p}{K_p t_d} = 1.1 K_{cp}$

Reset (Minutes / Repeat) $T_i = 2.0\ t_d$

Derivative (Minutes) $T_d = 0.5\ t_d$

Where: K_p = Process Gain, t_d = Dead Time Delay, t_p = Process Time Constant

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Formal Tuning Criteria

- Integral of the absolute value of the error (IAE):

$$IAE = \int |e| \, dt$$

- Integral of the square of the error (ISE):

$$ISE = \int e^2 \, dt$$

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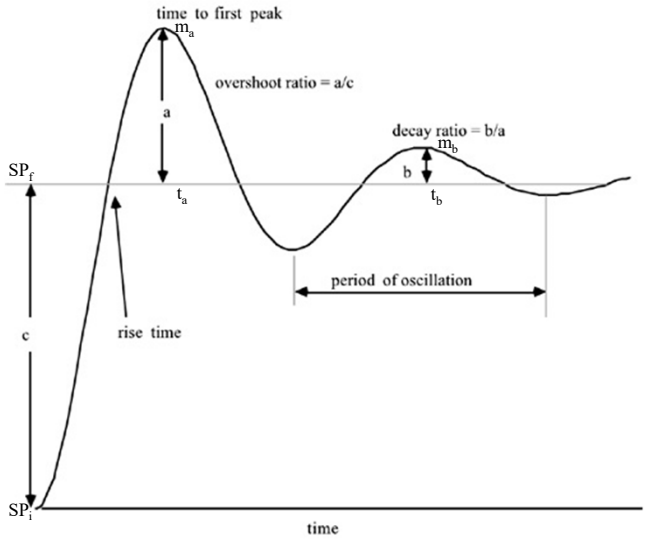
Formal Tuning Criteria



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