

CONTROL I

ELEN3016

Closed-Loop Control Systems

(Lecture 9)

Overview

- First Things First!
- PID Control - Revision
- Ziegler-Nichols Tuning Methods
- Other Tuning Methods
- PD Control
- Tutorial Exercises & Homework
- Next Attraction!

First Things First!

- Miss prints & corrections
 - p 57: In item (b) in Sec. (3.7.2) $1 < \zeta < 0.06$ should read $1 > \zeta > 0.06$
 - p 67: 3rd block diagram, top right of Table 4.1 misses a division line.
 - p 83: the sentence above Eq. (4.66) should read "The closed-loop time-constant for Eq. (4.64) is"
 - p 84: 2nd term in the numerator of Eq (4.71) needs to be divided by K_1 .

First Things First!

- Lectures this week
 - Wednesday, 3 August, national elections day – no lectures.

PID Control - Revision

- Proportional control
 - Most important part of the PID control.
- Integral control
 - Reduces steady-state errors.
 - Introduces sluggishness: response lag & overshoot.
- Derivative control
 - Introduces anticipatory action – reduces sluggishness (i.e. improve responsiveness) and reduces as overshoot.

PID Control

- **Midnight Callout to the Plant**
 - Late-night boredom and curiosity led the plant operator to tamper with the PID controller causing an alarm and eventual plant shutdown due to the risk of plant operation becoming unsafe.
 - You, the *control engineer*, are called out well after midnight since production loss necessitates immediate action.
 - To minimise plant downtime there is no time to perform the standard painstaking setup procedure. So, how would you swiftly restore production?

PID Control

- Midnight Callout to the Plant (cont'd)
 - Your options are:
 - Some experimental tuning procedure
 - Set all PID parameters of all PID controllers to zero and tune these in the proper controller order and parameter order.
 - Some simple tuning method such as one of the Ziegler-Nichols methods applied to the PID controllers in the proper order.

Ziegler-Nichols Tuning Methods

- Process Reaction Method (PRM)
 - Open-loop step response of most systems has an S-shape called the *process reaction curve*.
 - Process reaction curve can be approximated by a time delay D (*transportation lag*) and a 1st-order system of maximum tangential slope R .
 - PRM assumes optimal response of the closed-loop system to occur for a ratio of success peaks of 4:1 which translates to a closed-loop damping ratio of $\zeta = 0.21$ using Burns' Eq. (3.71).
 - PRM not suitable for O/L systems with overshoot.

Ziegler-Nichols Tuning Methods

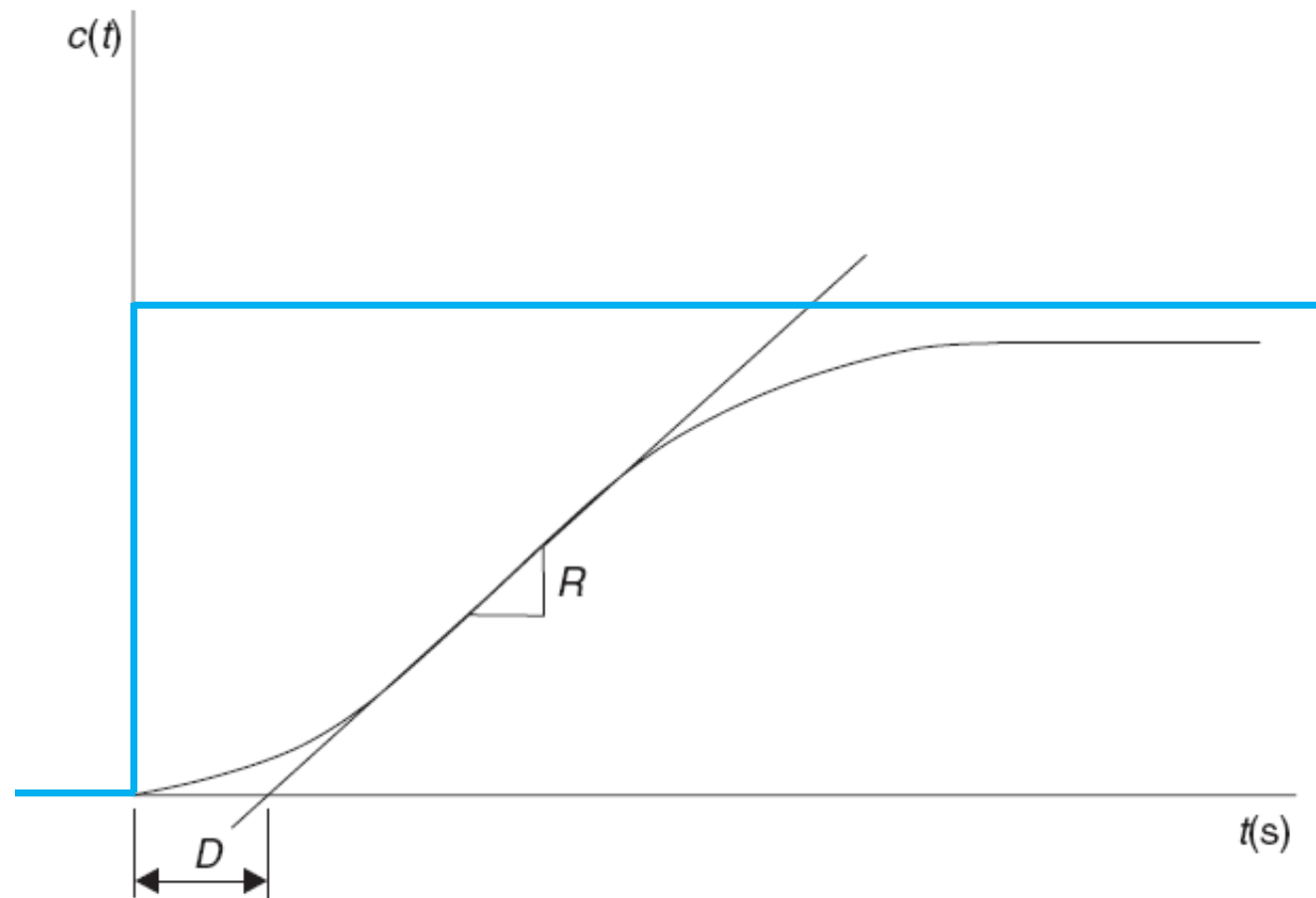


Fig. 4.29 Process reaction curve.

Ziegler-Nichols Tuning Methods

$$U(s) = K_1 \left(1 + \frac{1}{T_i s} + T_d s \right) E(s)$$

Table 4.2 Ziegler–Nichols PID parameters using the Process Reaction Method

<i>Controller type</i>	K_1	T_i	T_d
P	$1/RD$	—	—
PI	$0.9/RD$	$D/0.3$	—
PID	$1.2/RD$	$2D$	$0.5D$

Ziegler-Nichols Tuning Methods

- Continuous Cycling Method (CCM)
 - Closed-loop response method using P-control, at first, to characterise the system.
 - Adjust K_1 (proportional gain) until system O/P becomes marginally stable (oscillate w/o damping).
 - This value of K_1 is called the *ultimate gain* K_u .
 - The period of the oscillation at the ultimate gain is called the *ultimate period* T_u .

Ziegler-Nichols Tuning Methods

$$U(s) = K_1 \left(1 + \frac{1}{T_i s} + T_d s \right) E(s)$$

Table 4.3 Ziegler–Nichols PID parameters using the Continuous Cycling Method

<i>Controller type</i>	K_1	T_i	T_d
P	$K_u/2$	—	—
PI	$K_u/2.2$	$T_u/1.2$	—
PID	$K_u/1.7$	$T_u/2$	$T_u/8$

PID Control

- PID tuning methods abound!
 - Classical approaches to PID controller tuning [1–3].
 - Intelligent PID controller tuning [4].
 - Computational intelligence-based PID controller tuning:
 - Immune algorithm [5, 6].
 - Genetic algorithm [7].

PID Control

- Literature Survey

1. A. O'Dwyer, *Handbook of PI and PID Controller Tuning Rules*, Imperial College Press, 1st edition, 2003.
2. A. O'Dwyer, "PI and PID Controller Tuning Rules: An Overview and Personal Perspective," *ISSC 2006*, June 28-30, pp. 161–166, 2006.
3. J.C. Basilio, SR Matos, "Design of PI and PID Controllers with Transient Performance Specification," *IEEE Trans. Educ.*, vol. 45, no. 4, pp. 364–370, November 2002.
4. D.H. Kim, "Intelligent Tuning of the 2-DOF PID Controller On the DCS for Steam Temperature Control of Thermal Power Plant," *IEEE Industrial Application Society (I&CPS 2002)*, May 5-8, 2002.

PID Control

- Literature Survey (cont'd)

5. D.H. Kim, JH Cho, "Design of Robust PID Controller with Disturbance Rejection for Motor using Immune Algorithm," Proceedings of the 4th *International Conference on Hybrid Intelligent Systems (HIS04)*, 2004.
6. D.H. Kim, "Intelligent tuning of a PID Controller using an Immune Algorithm," *Trans. KIEE*, vol. 51-D, no.1, pp. 8–16, 2002.
7. R.A. Krohling, J.P. Rey, "Design of Optimal Disturbance Rejection PID Controllers using Genetic Algorithms," *IEEE Trans. Evolutionary and Computation*, vol. 5, no. 1, February 2001

PD Control

- For sluggish plants – use PD control

Proportional plus Derivative control action is expressed as

$$u(t) = K_1 e(t) + K_3 \frac{de}{dt} \quad (4.93)$$

Taking Laplace transforms

$$\begin{aligned} U(s) &= K_1 \left(1 + \frac{K_3}{K_1} \right) E(s) \\ &= K_1 (1 + T_d s) E(s) \end{aligned} \quad (4.94)$$

The inclusion of a derivative term in the controller generally gives improved damping and stability. This is discussed in more detail in Chapters 5 and 6.

Tutorial Exercises & Homework

- Tutorial Exercises
 - For the PD controller repeat the complete steady-state analysis performed for P, PI and PID control in Lecture 8.
- Homework
 - Example 4.6.1 (Burns, p. 92)
 - Example 4.6.3 (Burns, p. 100)


Conclusion

- PID Control – Revision
- Ziegler-Nichols Tuning Methods
- Other Tuning Methods
- PD Control
- Example 4.6.1 (p. 92) (**Self-study!**)
- Example 4.6.2 (p. 97) (**Discard!**)
- Example 4.6.3 (p. 100) (**Self-study!**)
- Tutorial Exercises & Homework

Next Attraction! – Miss It & You'll Miss Out!

- Case Study, Burns Sec. 4.6

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Thank you!
Any Questions?