21/9-07

(1)

Selection of closed-loop time constant τ_c

Issues

(1.) Upper bound due to effective time delay (robustness)

SIMC-rule: $\tau_c \geq \theta$ $(=\tau_{c,min})$

(2.) Lower bound due to disturbance rejection (performance y)

$$K_c \geq \frac{|u_0|}{|y_{max}|}$$

← $|u_0|$ = input magnitude required for disturbance rejection

$|y_{max}|$ = max y

Gives

$\tau_c \leq \tau_{c,max}$

by use of

$$K_c = \frac{1}{k}\frac{\tau}{\tau_c+\theta}$$

Comment: If $\theta \approx 0$ then

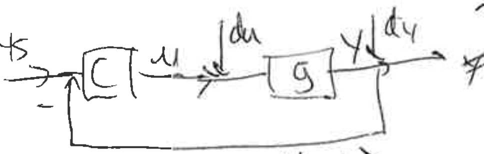
$$\tau_c \leq \frac{\tau}{k}\frac{|y_{max}|}{|u_0|} = \frac{|y_{max}|}{|y_0|}\cdot\tau$$

where $|y_0|$ = expected variation in $|y_0|$ with no control

("speed-up" $\frac{|y_0|}{|y_{max}|}$)

(3.) Upper bound due to input saturation (avoiding too large u)

1. Disturbances on input (d_u)



Good!

$$\frac{\Delta u}{-d_u} = \frac{cg}{1+cg} \approx \frac{1}{\tau_c s+1} \quad (\text{same as } \frac{y}{y_s}!)$$

(so no overshoot here!) so there is a requirement $\tau_c \geq \tau_{c,min}$

(5.) (BUT could be that there is a requirement because fast changes in u are not desired. ("filtering of input d_u required"))

2. Disturbances on output (d_y) or setpoint changes (y_s)

$$\frac{\Delta u}{d_y} = \frac{\Delta u}{y_s} = \frac{c}{1+gc} = \frac{1}{g}\frac{gc}{1+gc} = \frac{1}{g}\frac{1}{\tau_c s+1}$$

(a) Steady-state $(s\to 0)$ $\frac{\Delta u}{d_y} = \frac{1}{g(0)} = \frac{1}{k}$ (This we must be able to handle!) Has nothing to do with tuning.

Initial response $(s\to\infty)$. Assume $g(s) = \frac{k}{\tau s+1} \Rightarrow g(\infty) = \frac{k}{\tau s} \Rightarrow \frac{\Delta u}{d_y} = \frac{1}{g(\infty)}\frac{1}{\tau_c s} = \frac{1}{k}\frac{\tau}{\tau_c}$ ($s\to\infty$)

⇒ "Overshoot" initially in u is given by the "speed-up" τ/τ_c

Get requirement $\Delta u \leq \Delta u_{max}$ ⇒ $\frac{1}{k}\frac{\tau}{\tau_c} d_y \leq u_{max}$ ⇒ $\tau_c \geq \frac{d_y}{k \cdot u_{max}}\cdot\tau$ (u_y; max. allowed overshoot (!))

Maximum speedup allowed is $\frac{|u_{max}|}{|u_y|} > 1$

$|u_0|$ = input magnitude for s.s. output disturbance rejection

$$\tau_c \geq \frac{|u_y|}{u_{max}}\cdot\tau$$

Summary

1. $\tau_c \geq \theta$ (robustness)

2. $\tau_c \leq \frac{|Y_{max}|}{|Y_0|} \cdot \tau$ (speedup required for disturbance rejection)

   $|Y_0|$ = output magnitude w/o control (due to disturbances)

3. $\tau_c \geq \frac{|u_y|}{|u_{max}|} \cdot \tau$ (maximum speedup because input may saturate when there are output disturbances)

   $|u_y|$ = input change required to reject output disturbance (setpoint change) $= \frac{|d_y|}{K}$

4. $\tau_c \leq \tau_{c,setpoint}$ ← (Response time required for acceptable setpoint tracking)

   (Generally want as small as possible)

5. $\tau_c \geq \tau_{c,input}$ ← (Response time for filtering of input disturbances)

NOTE: $\frac{y}{y_s} = \frac{\Delta u}{du} \approx \frac{1}{\tau_c s + 1}$