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6-20

① 解：用解析法，$G(j\omega)=\frac{K(0.2j\omega+1)}{-\omega^2(0.02j\omega+1)}=\frac{K(20j\omega+1)}{-\omega^2(2j\omega+1)}=\frac{K(1+20j\omega)(1-2j\omega)}{-\omega^2(1+4\omega^2)}$

$=\frac{K(1+40\omega^2)+K\cdot 18j\omega}{-\omega^2(1+4\omega^2)}$

令 $|G(j\omega)|=1$

即 $K^2[(1+40\omega^2)^2+(18\omega)^2]=\omega^4(1+4\omega^2)^2$，$K=1$

解得 $\omega_c\approx 1.01\ rad/s$，此时 $\Phi(\omega_c)=\tan^{-1}(0.2\omega_c)-180^\circ-\tan^{-1}(0.02\omega_c)\approx-169.8^\circ$

$\therefore \gamma=180^\circ+\Phi(\omega_c)\approx 10.2^\circ$

② 令 $\Phi(\omega_p)=-135^\circ \Rightarrow \tan^{-1}(0.2\omega_p)-\tan^{-1}(0.02\omega_p)=45^\circ$

解得 $\omega_p\approx 6.492$

则此时 $20\lg h=0$ 即 $h=1$ 即 $|G(j\omega_p)|=1$

即 $K\approx 25.76$

6-22

令 $\Phi(\omega_p)=-135^\circ \Rightarrow \tan^{-1}(a\omega_p)=45^\circ \Rightarrow a\omega_p=1$

又有 $|G(j\omega_p)|=1$，即 $\left|\frac{1+ja\omega}{-\omega^2}\right|=1$ 即 $(\frac{1}{\omega^2})^2+(\frac{a}{\omega})^2=1$ 即 $\frac{1}{\omega_p^2}+a^2=\omega_p^2$

$\therefore \omega_p^4-a^2\omega_p^2-1=0 \Rightarrow \omega_p^4=2 \Rightarrow \omega_p^2=\sqrt{2} \Rightarrow \omega_p=2^{\frac{1}{4}} \Rightarrow \omega_p\approx 0.840896$.

$\therefore a\approx\frac{1}{\omega_p}=0.841$

7-2

① $E(z)=\sum_{n=0}^{\infty}a^n z^{-n}=\frac{1}{1-az^{-1}}=\frac{z}{z-a}$

④ $E(s)=\frac{1}{s}+\frac{1}{s^2}$

$\Rightarrow E(z)=\frac{z}{z-1}+\frac{Tz}{(z-1)^2}$

7-5

由终值定理（除了在 $z=1$ 处可能有一个一阶极点外，其他所有极点都在单位圆内）

① $x(\infty)=\lim_{z\to1}(z-1)X(z)=\lim_{z\to1}\left(z-\frac{z-1}{1-e^{-aT}z^{-1}}\right)=1$

② 存在极点在单位圆外，不存在 $x(\infty)$

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7-9

$$X(z)=\frac{z}{z-1}$$

$$Y(z)=\frac{(z+1)z}{(z-1)(z^2-1.4z+0.48)}$$

由终值定理

$$y(\infty)=\lim_{z\to1}(z-1)Y(z)=\lim_{z\to1}\frac{(z+1)z}{z^2-1.4z+0.48}=\frac{2}{0.08}=25$$

稳态误差两种算法：

① $e_{ss}=\frac{A}{1+K_p}$ $e_{ss}=\frac{AT}{K_v}$ $e_{ss}=\frac{AT^2}{K_a}$

$K_p=\lim_{z\to1}G(z)$ $K_v=\lim_{z\to1}(z-1)G(z)$ $K_a=\lim_{z\to1}(z-1)^2G(z)$

7-26

G(s)、H(s)间无开关，则 G(z)为 $Z[G(z)H(z)]$

(a) $G(s)H(s)=\frac{1}{(s+1)^2}$，且 $T=1$

$$\therefore Z[G(s)H(s)]=\frac{ze^{-1}}{(z-e^{-1})^2}=\cancel{G(z)}\,GH(z)$$

$$\therefore K_p=\lim_{z\to1}GH(z)\approx0.921$$

$$e(\infty)=\frac{1}{1+K_p}=0.52$$

(e.g. 7-28)
此外，若有零阶保持器

$\to G_h(s) \to G(s) \to$

则 $G(z)=\frac{z-1}{z}Z\left[\frac{G(s)}{s}\right]$

(b) G(s)、H(s)间有关，则 G(z)为 $Z[G(s)]\cdot Z[H(s)]$

$$GH(z)=\left(\frac{z}{z-e^{-1}}\right)^2$$

$$\therefore K_p=\lim_{z\to1}G(z)\approx2.50$$

$$\therefore e(\infty)=\frac{1}{1+K_p}=0.286$$

7-27

② $e_{ss}=\lim_{z\to1}(z-1)(1-\underbrace{\Phi(z)}_{\text{即}\frac{GH(z)}{1+GH(z)}})R(z)=\lim_{z\to1}(z-1)\underbrace{\Phi_e(z)}_{\text{即}\frac{1}{1+GH(z)}}R(z)$

(1) $R(z)=\frac{z}{z-1}$

$$e_{ss}=\lim_{z\to1}z\frac{(z^2-1.368z+0.368)}{z^2-z+0.632}=0$$

(2) $R(z)=\frac{\cancel{T}z}{(z-1)^2}$ ← 已给出 $\Phi(z)$，不必计算T ⇒ 7

$$e_{ss}=\lim_{z\to1}\frac{\cancel{T}z}{z-1}\frac{(z^2-1.368z+0.368)}{z^2-z+0.632}=\lim_{z\to1}\frac{z(z-0.368)}{z^2-z+0.632}=1$$

(3) $R(z)=\frac{z(z+1)}{(z-1)^3}$

$$e_{ss}=\lim\frac{z(z+1)}{}\frac{(z-0.368)}{}\to\infty$$