1. [Design Optimization Problem Formulation]

(design variables) $x_1$ = product A in kg, $x_2$ = product B in kg

(objective function) maximize the profit = $10x_1 + 8\,x_2$

(constraints) $0.4x_1 + 0.5x_2 \le 100$ (raw material C), $0.6x_1 + 0.5x_2 \le 80$ (raw material D),

$0 \le x_1 \le 70$, $0 \le x_2 \le 110$ (limits on products)

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2.

(1) $\frac{1}{2}mV_0^2 = F_{avg}\Delta \xrightarrow{F_{avg}=\eta F_{\max}} \Delta = \frac{V_0^2}{2\eta a_{\max}} = \frac{\left(48\frac{km}{hr}\frac{1000m}{km}\frac{hr}{3600\sec} = 13.33\frac{m}{\sec}\right)^2}{2(0.8)\left(20g = 20\left(9.8\frac{m}{\sec^2}\right) = 196\frac{m}{\sec^2}\right)} = 0.567m$ (5 pts)

(2) $F_{avg} = \eta F_{\max} = \eta(ma_{\max}) = (0.8)(1000kg)\left(196\frac{m}{\sec^2}\right) = 156{,}800N$ (5 pts)

(3) $P_M = 386t^{1.86}b^{0.14}\sigma_Y{}^{0.57} = 386\left(\frac{b}{60}\right)^{1.86}b^{0.14}\sigma_Y{}^{0.57} = 386\left(\frac{b^2}{60^{1.86}}\right)\sigma_Y{}^{0.57} \rightarrow b = \left[P_M\frac{60^{1.86}}{386\sigma_Y{}^{0.57}}\right]^{\frac{1}{2}}$

$\xrightarrow{P_M = 0.25F_{avg} = 39200N} b = \left[(39200)\frac{60^{1.86}}{386(207)^{0.57}}\right]^{\frac{1}{2}} = 99.3mm \rightarrow t = \frac{b}{60} = 1.655mm$ (7 pts)

$mass = 2(1000mm)(4\text{ sides})(99.3mm)(1.655mm)\left(7.83\times10^{-6}\frac{kg}{mm^3}\right) = 10.29kg$ (3 pts)

(4) $\left.\begin{aligned}(P_M)_{hex} &= 1.075(P_M)_{sq}\\ (P_M)_{sq} &= 386t^{1.86}b^{0.14}\sigma_Y{}^{0.57} = 386t^{1.86}(60t)^{0.14}\sigma_Y{}^{0.57} = Ct^2\end{aligned}\right\} \rightarrow 39200N = \begin{cases}(P_M)_{sq} = Ct_{sq}^2\\ (P_M)_{hex} = 1.075Ct_{hex}^2\end{cases}$

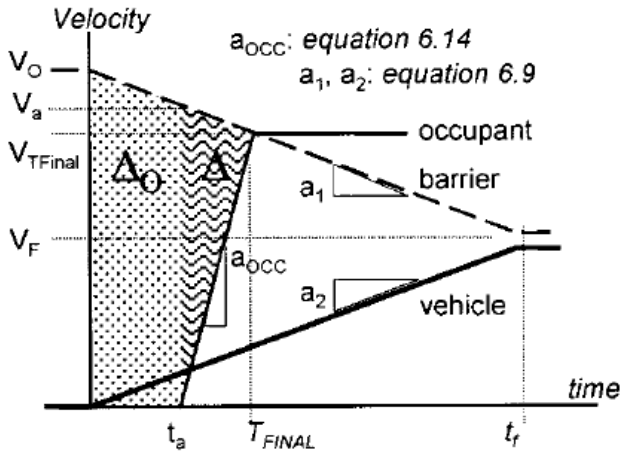
$\rightarrow t_{hex}^2 = \frac{1}{1.075}t_{sq}^2 \rightarrow t_{hex} = 0.9645t_{sq} = 1.596mm,\ b_{hex} = 60t_{hex} = 95.76mm$ (3 pts)

$l_{hex} = (60t_{hex}/2)\times\tan 30° = 55.287mm$

$mass = 2(1000mm)(6\text{ sides})(l_{hex})t_{hex}\left(7.83\times10^{-6}\frac{kg}{mm^3}\right) = 8.29kg(2\times4.145)$ (2 pts)

(5) hexagonal section: mass savings of 0.72 kg (5 pts)

3.



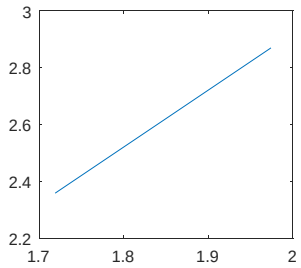

(1) Tfinal <-> F 바꿔서 쓴 경우 감점 -1 (V, t 각각)

(2) $\Delta_O, \Delta, a_{occ}$ 각 3점, 식으로 표현한 경우 각 1점 (기본 1점)

4.

(1) $f(t) = 4mr\omega^2 \frac{r}{L}\cos(2\omega t) = \frac{0.250}{3}\omega^2 \cos(2\omega t),\ |f(t)| = \frac{0.250}{3}\omega^2 [N]$

plot $\frac{0.250}{3}\omega^2$ *vs.* $\omega$ in log scale for $500\text{rpm}(8.33\text{Hz}) \le \omega \le 900\text{rpm}(15\text{Hz})$

| | |
|---|---|
| log f = -1.08+2log w<br>log f(w=8.33Hz)=2.36 [N]<br>log f(w=15Hz) = 2.87 [N]<br>500rpm = 52.36 rad/s, 900rpm = 94.25 rad/s<br>(5 pts) | log(F)[N] vs log(w)(rad/s) (5 pts)<br>  |

(2) modal model

$$\frac{X_{Output}}{F_{Input}} = \frac{\phi_{Input}\phi_{Output} / k_{Modal}}{(1-(\frac{\omega}{\omega_n})^2) + j\eta} + \frac{1}{M_{Effective,Output}\omega^2}$$

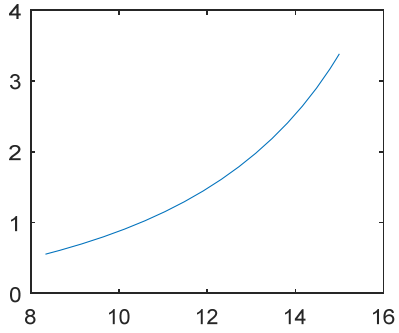
위 식으로부터 $Y_{Output} = \omega^2 X_{Output}$

$$\frac{Y_{Output}}{F_{Input}} = \frac{\phi_{Input}\phi_{Output} / m_{Modal}}{(1-(\frac{\omega}{\omega_n})^2) + j\eta} + \frac{1}{M_{Effective}}$$ (5 pts)

차체 고유진동수는 일반적으로 20 Hz, 일반적인 차체 무게 500 kg 가정하고 powertrain 무게($M_{effective}$) 무시, $\phi_{Input}$를 1 로 가정하면 (댐핑도 무시)

$$\frac{Y_1}{F_{Input}} = \frac{1/m}{(1-(\frac{\omega}{\omega_n})^2)}, \quad \frac{Y_1}{F_{Input}}(500rpm) = 0.00242, \frac{Y_1}{F_{Input}}(900rpm) = 0.00457$$

$$Y_1 = F_{Input}(\frac{1/m}{(1-(\frac{\omega}{\omega_n})^2)}) = 0.0833\omega^2(\frac{1/m}{(1-(\frac{\omega}{\omega_n})^2)}) = 0.553(500RPM), 3.369(900RPM)$$




abs(a)[m/s^2] vs f(Hz) (5 pts)

$Y_2 = Y_1$라고 가정 (일반적으로 column mount 위치에서는 $\phi_{Ouput}$ 가 감소하여 가속도 감소)

(3) 고유주파수에 가까워 질수록 피로 영역에 존재 (10 pts)