Homework #8

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(PIV) Measurement

8.4 The sensitivity of the transducer of Exercise 8.3 can be increased if the input voltage v_s is increased. If each gage in the bridge can dissipate 0.5 W of power, determine the maximum sensitivity that can be achieved without endangering the strain-gage ($R_g = 350\ \Omega$) sensors.

จาก 8.3 โจทย์กำหนด

Poisson's ratio

$E = 29{,}000$ ksi , $\nu = 0.29$, $S_g = 2$, $v_s = 10$ V , $A = 0.02\ in^2 - 20\ in^2$

จากสูตร

$$S = \frac{v_o}{P} = \frac{S_g(1+\nu)\,v_s}{2AE}$$

[A เพิ่ม → S ลด]

1 ksi = 1000 psi

$$S = \frac{(1+0.29)\,10}{2(0.02)(29{,}000 \times 1000)}$$

$$S = 11.12\ \mu V/V$$

8.8 Design a beam-type load cell with variable range and sensitivity. Use aluminum ($E = 10{,}000{,}000$ psi, $\nu = 0.33$, and $S_f = 20{,}000$ psi) as the beam material and four electrical resistance strain gages ($S_g = 2.00$ and $R_g = 350\ \Omega$) as the sensors. Design the load cell to give the following sensitivities and corresponding range:

$(v_o/v_s)^*$ (mV/V)	Range (lb)
2	1000
3	500
4	200

จาก eq. 8.8 $\quad v_o = \dfrac{6 S_g P x\, v_s}{E b h^2} \quad$ — (1)

$$; \quad \frac{v_o}{v_s} = \frac{6 S_g P x}{E b h^2}$$

จาก P_{max} ; $\quad \left(\dfrac{v_o}{v_s}\right)_{max} = \dfrac{6 S_g P_{max}\, x}{E b h^2}$

$$\frac{x}{bh^2} = \left(\frac{v_o}{v_s}\right)_{max} \times \frac{E}{6 S_g P_{max}} \quad \text{— (2)}$$

; $b = 2h$, $x = 25h$

ⓐ $\left(\frac{V_o}{V_s}\right)^* = 2$, $P_{max} = 1000$

จาก (2) ; $\frac{x}{bh^2} = \left(\frac{V_o}{V_s}\right)_{max} \cdot \frac{E}{6S_g P_{max}}$

$$\frac{2.5\cancel{h}}{2h \cdot h^{\cancel{2}}} = \frac{2 \cdot 1\times10^7}{6 \cdot 2 \cdot 1000}$$

$$h^2 = \frac{6\times2.5\times2\times1000}{2\times1\times10^7\times2}$$

$$h^2 = 7.5\times10^{-4} \quad in^2$$

; $h = \sqrt{7.5\times10^{-4}} = 0.027$ in ##

$\therefore$ $x = 2.5\times0.027 = 0.0675$ in และ $b = 2\times0.027 = 0.054$ in

ⓑ $\left(\frac{V_o}{V_o}\right)_{max} = 3$, $P_{max} = 500$

; $$\frac{2.5h}{2h\cdot h^2} = \frac{3\times1\times10^7}{6\cdot 2\cdot 500}$$

$$h^2 = \frac{6\times2\times2.5\times500}{2\times1\times10^7\times3}$$

$$h^2 = 2.5\times10^{-4} \quad in^2$$

; $h = \sqrt{2.5\times10^{-4}} = 0.0158$ in

$\therefore$ $x = 2.5\times0.0158 = 0.0395$ in , $b = 2\times0.0158 = 0.0316$ in ##

ⓒ $\left(\frac{V_o}{V_o}\right)_{max} = 4$, $P_{max} = 200$

จากข้อ a, b เราสามารถสรุปสูตรสำหรับหา h^2 โดยที่ 3 $\left(\frac{V_o}{V_o}\right)_{max}$, P_{max} ไม่คงที่ได้ คือ

$$h^2 = K\left(\frac{V_o}{V_s}\right)_{max} \cdot \frac{1}{P_{max}} \quad ; \quad K = 1.5\times10^{-6}$$

; $h^2 = 1.5\times10^{-6} \cdot \frac{4}{200} = 3\times10^{-8}$ in^2

; $h = \sqrt{3\times10^{-8}} = 0.1732\times10^{-3}$ in

$\therefore$ $x = 2.5\times0.1732\times10^{-3} = 0.433\times10^{-3}$ in , $b = 2\times0.1732\times10^{-3} =$ 0.3464×10^{-3} in ##

8.9 Design a ring-type load cell with an LVDT sensor. The load cell should have a capacity of 10,000 lb. The radius-to-thickness ratio of the ring R/t should be 10. Select an LVDT for this application from Table 5.1. Use steel (E = 30, 000, 000 psi and $\nu = 0.30$) for the ring. Determine the sensitivity S_t for your transducer.

Table 5.1 Performance Characteristics for LVDTs, DCDTs, RVDTs

A. Linear Variable Differential Transformers

Model Number	Nominal Linear Range (in.)	Linearity ± Percent — Percent of Full Range: 50	100	125	150	Sensitivity [(mV/V)/0.001 in.]	Impedance (Ω): Primary	Secondary
050 HR	± 0.050	0.10	0.25	0.25	0.50	6.3	430	4000
100 HR	± 0.100	0.10	0.25	0.25	0.50	4.5	1070	5000
200 HR	± 0.200	0.10	0.25	0.25	0.50	2.5	1150	4000
300 HR	± 0.300	0.10	0.25	0.35	0.50	1.4	1100	2700
400 HR	± 0.400	0.15	0.25	0.35	0.60	0.90	1700	3000
500 HR	± 0.500	0.15	0.25	0.35	0.75	0.73	460	375
1000 HR	± 1.000	0.25	0.25	1.00	1.30[a]	0.39	460	320
2000 HR	± 2.000	0.25	0.25	0.50[a]	1.00[a]	0.24	330	330
3000 HR	± 3.000	0.15	0.25	0.50[a]	1.00[a]	0.27	115	375
4000 HR	± 4.000	0.15	0.25	0.50[a]	1.00[a]	0.22	275	550
5000 HR	± 5.000	0.15	0.25	1.00[a]	—	0.15	310	400
10000 HR	±10.000	0.15	0.25	1.00[a]	—	0.08	550	750

[a] Requires reduced core length.

วิธีทำ

จากสูตร $S_t = \dfrac{1.79 S R^3 V_s}{E w t^3}$ —— (1)

เลือก LVDT 100 HR มีค่า S = 4.5 mV/V/0.001 in.

แทนค่า Parameter ที่โจทย์ให้ใน (1) ;

จาก $S_t = \dfrac{1.79 S R^3 V_s}{E w t^3}$

$$= \frac{1.79 \times S}{E w} \times \left(\frac{R}{t}\right)^3 \times V_s$$

$$= \frac{1.79 \times 4.5}{3 \times 10^7 \times 1.181} \times 10^3 \times V_s$$

$$\therefore S_t = 0.227 \times 10^{-3}\ V_s \quad \#$$

8.12 Determine the sensitivity of a torque cell if E = 30,000,000 psi, $\nu = 0.30$, v_s = 8 V, D = 1 in., S_g = 2.00, and R_g = 350 Ω.

วิธีทำ จากสูตร $S = \dfrac{16(1+\nu) S_g V_s}{\pi D^3 E}$

โจทย์กำหนดมาให้ E = 30,000,000 psi , $\nu = 0.3$, $V_s = 8$, $D = 1$, $S_g = 2$ and $R_g = 350$ แทนในสมการ ;

$$S = \frac{16(1+0.3) \times 2 \times 8}{\pi \times 1^2 \times 3 \times 10^7}$$

$$S = 3.5311 \times 10^{-6}\ \text{mV/V} \quad \#$$

8.15 A torque cell with a capacity of 500 ft·lb is supplied with a calibration constant of $(v_o/v_s)^* = 4$ mV/V and a recommendation that the input voltage $v_s = 10$ V. If the cell is used with $v_s = 8$ V and a measurement of v_o yields 18 mV, determine the torque T.

วิธีทำ กำหนดค่าแนะนำ $C = 500$ ft.lb , $\left(\frac{V_o}{V_s}\right)^* = 4$ mV/V , $V_s = 10$ V

$$C = \frac{\pi D^3 E}{16(1+\nu) S_g v_s} \qquad T_{max} = \frac{\pi D^3 S_\tau}{16} \qquad \left(\frac{v_o}{v_s}\right)_{max} = \frac{S_\tau S_g (1+\nu)}{E} \qquad T = \underbrace{\frac{\pi D^3 E}{16(1+\nu) S_g v_s}}_{C} v_o$$

$$500 = \frac{\pi D^3 E}{16(1+\nu) S_g V_s} \quad \text{—(1)}$$

$$4 \text{ mV/V} = \frac{S_\tau S_g (1+\nu)}{E}$$

$$\frac{E}{S_g(1+\nu)} = \frac{S_\tau}{4 \text{ mV/V}} \quad \text{—(2)}$$

$$500 = \frac{\pi D^3}{16} \cdot \frac{S_\tau}{4\times10^{-3}} \cdot \frac{1}{V_s} \quad \text{—(3)}$$

$$500 = \frac{T_{max}}{4\times10^{-3} \times 10} = 20$$

$$T = \frac{T_{max}}{S_\tau} \cdot \frac{E}{(1+\nu) S_g} \cdot \frac{V_o}{V_s} \quad \text{—(4)}$$

$$= \frac{T_{max}}{S_\tau} \cdot \left(\frac{V_s}{V_o}\right)_{max} \cdot \frac{1}{S_\tau} \cdot \frac{V_o}{V_s}$$

$$= \frac{20}{S_\tau} \cdot \frac{1}{4\times10^{-3}} \cdot \frac{1}{S_\tau} \cdot \frac{18\times10^{-3}}{8}$$

$$\boxed{T = \frac{11.25}{S_\tau^2} \quad \text{หรือ} \quad T \propto \frac{1}{S_\tau^2}}$$