Conventional Practice Sets

Electrical & Electronic Measurements

Contents

6 CHAPTER

Primary Sensing Elements and Transducers

Q.1 A metallic strain gauge has resistance of 120 Ω and a gauge factor of 2. It is installed on an aluminium structure which has a yield point stress of 0.2 GN/m^2 and Young's modulus of 68.7 GN/m^2, determine the change in resistance of the gauge that would be caused by loading the material to yield point.

Solution:

Given that,

Gauge factor, $$G_f = 2 = \frac{\Delta R/R}{\Delta L/L} = \frac{\Delta R/R}{\epsilon}$$

Young's modulus, $$E = \frac{\text{Stress}}{\text{Strain}} = 68.7 \times 10^9 \text{ N/m}^2$$

Stress, $$S = 0.2 \times 10^9 \text{ N/m}^2$$

Strain, $$\epsilon = \frac{\text{Stress}}{E} = \frac{0.2 \times 10^9}{68.7 \times 10^9} = \frac{0.2}{68.7}$$

$$\frac{\Delta R}{R} = (G_f)\,\epsilon = 2 \times \frac{0.2}{68.7}$$

Change in resistance, $$\Delta R = \frac{0.2 \times 2 \times 120}{68.7} = 0.6987\ \Omega \approx 0.7\ \Omega$$

Q.2 A strain gauge is bonded to a beam 0.1 m long and has a cross-sectional are 0.4×10^{-3} m^2. Young's modulus of elasticity for steel is 207 GN/m^2. The strain gauge has a unstrained resistance of 240 Ω and a gauge factor of 2.20. When the load is applied, the gauge's resistance changes by 0.013 Ω. Calculate the change in length of the steel beam and the amount of force applied to the beam.

Solution:

We have

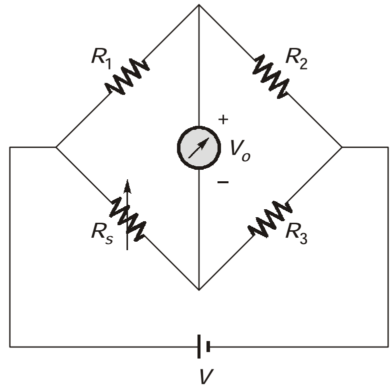
Gauge factor, $$G_f = \frac{\Delta R/R}{\Delta L/L}$$

Change in length, $$\Delta L = \frac{(\Delta R/R)\cdot L}{G_f} = \frac{(0.013/240)\cdot(0.1)}{2.2} = 2.462 \times 10^{-6} \text{ m}$$

Stress, $$S = \epsilon E = E \cdot \frac{\Delta L}{L} = \frac{207 \times 10^9 \times 2.462 \times 10^{-6}}{0.1} = 5.096 \times 10^6 \text{ N/m}^2$$

Force, $$F = S \cdot A = 5.096 \times 10^6 \times 0.4 \times 10^{-3} = 2.0384 \times 10^3 \text{ N}$$

Q.3 A strain gauge forms one arm of the bridge shown in the figure below and has a nominal resistance without any load as $R_s = 250\ \Omega$. Other bridge resistances are $R_1 = R_2 = R_3 = 250\ \Omega$. The maximum permissible current through the strain gauge is 30 mA. During certain measurement when the bridge is excited by maximum permissible voltage and the strain gauge resistance is increased by 1% over the nominal values. What is the output voltage V_o in mV.



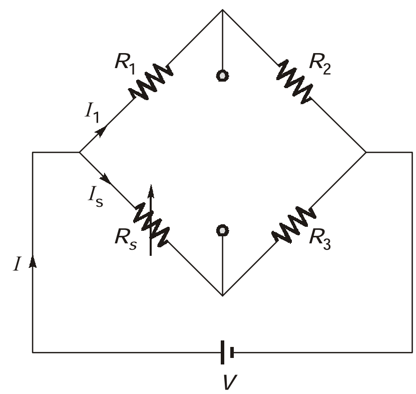
Solution:

Given that:

Maximum current through the strain gauge = 30 mA i.e. maximum current flow through the strain gauge before increase resistance of strain gauge

i.e. $R_s = 250\ \Omega$

when load is open or without load



$$I = I_1 + I_s$$

and $I_1 = I_s = 30$ mA

$$I = 60 \text{ mA}$$

$$V = I \times R_{eq}$$

$$= 60(250) \times 10^{-3} = 15 \text{ V}$$

Hence output voltage V_o

$$V_o = V\left[\frac{R_2}{R_1 + R_2} - \frac{R_3}{R_s + R_3}\right]$$

R_s increase with 1%

$$R_s = 250 + \left(\frac{1}{100} \times 250\right) = 252.5\ \Omega$$

$$R_1 = R_2 = R_3 = 250\ \Omega$$

$$V_o = 15\left[\frac{250}{250 + 250} - \frac{250}{252.5 + 250}\right] = 0.037313 \text{ V} = 37.313 \text{ mV}$$

Q.4 A single strain gauge having resistance of 120 Ω is mounted on a steel cantilever beam at a distance of 0.15 m from the free end. An unknown force *F* applied at the free end produces a deflection of 12.7 mm of the free end. The change in gauge resistance is found to be 0.152 Ω. The beam is 0.25 m long with width of 20 mm and a depth of 3 mm. The Young's modulus for steel is 200 GN/m^2. Calculate the gauge factor.

Solution:

Given that,

Strain gauge resistance = 120 Ω

Moment of inertia of beam,

$$I = \frac{1}{12} bd^3 = \frac{1}{12} \times 0.02 \times (3 \times 10^{-3})^3 = 45 \times 10^{-12} \text{ m}^4$$

Q.17 A load cell consists of a solid cylinder of steel 40 mm in diameter with four strain gauges bonded to it and connected into the four arms of a voltage sensitive bridge. The gauges are mounted to have Poisson's arrangement.

If the gauges are each of 100 Ω resistance and the gauge factor 2.1, the bridge excitation voltage 6 V, determine the sensitivity of the cell in V/kN. Modulus of elasticity for steel is 200 GN/m^2 and the Poisson's ratio is 0.29. A load of 1 kN is applied to the load cell.

Solution:

A load of 1 kN is applied to the load cell.

Stress, $$S = \frac{1\times 10^3}{\frac{\pi}{4}(40\times 10^{-3})^2} = 0.79577\times 10^6 \text{ N/m}^2$$

Strain, $$\epsilon_l = \frac{S}{E} = \frac{0.79577\times 10^6}{200\times 10^9} = 0.39788\times 10^{-5} = 3.9788\times 10^{-6}$$

$$\therefore \quad \frac{\Delta R}{R} = \epsilon G_f = 3.9788\times 10^{-6}\times 2.1 \simeq 8.3555\times 10^{-6}$$

The voltage output of the bridge is

$$\Delta V_o = 2(1+v)\left[\frac{(\Delta R_1/R)}{4+2\left(\frac{\Delta R_1}{R}\right)}\right]V_i = 2(1+0.29)\left[\frac{8.3555\times 10^{-6}}{4+2\times 8.3555\times 10^{-6}}\right]\times 6$$

$$= 32.3357\times 10^{-6}\text{ V} = 32.3357\ \mu\text{V}$$

Hence sensitivity is 32.3357 μV/kN or 323357×10^{-4} μV/kN

Q.18 A thermistor has a resistance of 3980 Ω at the ice point (0°C) and 579 Ω at 62°C. The resistance temperature relationship is given by $R_T = aR_o e^{b/T}$ with usual notation. Calculate

(a) the constants a and b.

(b) the temperature varies from 50°C to 120°C.

Solution:

Given that

The resistance at ice point (0°C), R_o = 3980 Ω.

Absolute temperature at ice point = 273 K°

Given that, $$R_T = aR_o e^{b/T}$$

$$3980 = a\times 3980\, e^{(b/273)}$$

or, $$1 = a\, e^{(b/273)} \qquad \text{...(i)}$$

Resistance at 62°C is R_T = 579 Ω

Absolute temperature corresponding to 62°C is

$$T = 273 + 62 = 335\text{K}^\circ$$

Hence, $$579 = a\times 3980\, e^{(b/335)} \qquad \text{...(ii)}$$

Solving (i) and (ii), we have

$$a = 30\times 10^{-6} \text{ and } b = 2843.564$$

Absolute temperature at 50°C = 273 + 50 = 323K°

Resistance at 50°C = $30\times 10^{-6}\times 3980\times e^{(2843.564/323)}$ = 794.9885 Ω