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Home Work #3

1. A metallic wire embedded in a strain gage is 4.2 cm long with a diameter of 0.07 mm. The gage is mounted on the upper surface of a cantilever beam to sense strain. Before strain is applied, the initial resistance of the wire is 64 Ω. Strain is applied to the beam, stretching the wire 0.1mm, and changing its electrical resistivity by $2 \times 10^{-8}$ Ωm. If Poisson's ratio for the wire is 0.342. Find the change in resistance in the wire due to the strain to the nearest hundredth ohm.

Length of wire (L): 4.2cm/42mm
Diameter (d): 0.07mm
Resistance (R): 64Ω
Stretched the wire (dL): 0.1mm
Resistivity (dρ): 2 *10^-8Ωm
Poissons Ratio (v): 0.342

Formula Used to find the relative change in resistance: $\frac{\boldsymbol{dR}}{\boldsymbol{R}} = (\mathbf{1} + \mathbf{2}\boldsymbol{v})\boldsymbol{\varepsilon L} + \frac{\boldsymbol{d\rho}}{\boldsymbol{d}}$

- $\boldsymbol{\varepsilon L} = \frac{dL}{L} = \frac{0.1mm}{42mm} = \mathbf{0.0024}$
- $\mathrm{R} = \rho * \frac{\mathrm{L}}{\mathrm{A}}$. Where A is cross sectional area **Area**: $\boldsymbol{A} = \pi r^2 = 0.035\mathrm{mm}^2 * \pi = \mathbf{0.0039mm^2}$
- , L length of the wire, and ρ is resistivity. We will use this formula to find the resistivityρ: $\boldsymbol{\rho} = \frac{\mathrm{RA}}{\mathrm{L}} = \frac{64\Omega*(0.0039\mathrm{mm}^2)}{42\mathrm{mm}} = \mathbf{5.943 * 10^{-3}\Omega mm/\ 5.5943 * 10^{-6}\Omega m.}$

$$\frac{\boldsymbol{dR}}{\boldsymbol{R}} = (1 + 2(0.342)) * 0.0024 + \left(\frac{2 * 10^{-8}\Omega m}{5.943 * 10^{-6}\Omega m}\right) = 0.00404 + 3.365 * 10^{-3}$$

$$= \mathbf{4.38 * 10^{-3}}$$

3. A metallic strain gage has a resistance of 350 Ω at zero strain. It is mounted on a 1-m-long column. The column is strained axially by 1 cm. Determine a typical resistance (in Ω) of such a gage under its strained condition.

R= 350Ω at no strain

Length of the column **(L)**: 1m/1000mm

Strain Axially by **(ΔL)**: 1cm/10mm

Ge ~2

$\mathbf{Ge} = \frac{\mathbf{\Delta R}}{\mathbf{R}} * \frac{\mathbf{L}}{\mathbf{\Delta L}}$. Where **ΔR** is the change in resistance due to strain, and **ΔL** is the change in length due to strain.

$\mathbf{\Delta R} = \text{Ge} * \frac{\Delta \text{L}}{\text{L}} * \text{R} = 2 * \frac{10\text{mm}}{1000\text{mm}} * 350\Omega = \mathbf{7\Omega}$**.** 7Ω is how much the gage resistance has changed due to the axial strain.

**So, the typical resistance of this gaga under its strained condition is 350Ω + 7Ω = 357Ω**

4. A resistive accelerometer is fabricated with an internal mass of 1 gm and 2-mm-long strain gages, each having a spring constant of 300 N/m. When the gages are strained by 2 % in a direction parallel to the strain gages, determine (a) the acceleration (in m/s$^2$) in the direction parallel to the strain gages and (b) the acceleration (in m/s $^2$) in the direction perpendicular to the strain gages.

Internal Mass **(m)**: 1g

Length of gage **(L)**: 2mm

Spring Constant **(k)**: 300N/m

Strain force **(ε)**: 2%/0.002 perpendicular

Formula used to find the displacement of a mass, due to acceleration: **ΔL**$=\frac{\boldsymbol{m}}{\boldsymbol{k}} * \boldsymbol{a}$; where **m** is mass, **k** spring constant, and **a** is acceleration.

- $a = \Delta L * \frac{k}{m}$
- $\varepsilon = \frac{\Delta L}{L}$ ➔ **ΔL**$=\varepsilon * L = 2\% * 2mm = \mathbf{0.04}\boldsymbol{mm}/\ \mathbf{4 \times 10^{-5}}\boldsymbol{m}.$

**(A)** $\boldsymbol{a} = 4 * 10^{-5}m * \frac{300\frac{N}{m}}{0.001Kgm} = \mathbf{12}\frac{\boldsymbol{m}}{\boldsymbol{s^2}}$

**(B)** $\boldsymbol{\Delta L} = \varepsilon * L = 98\% * 2mm = \mathbf{1.96}\boldsymbol{mm}\ /\mathbf{0.00196}\boldsymbol{m}$

$$\boldsymbol{a} = \Delta L * \frac{k}{m} = 0.00196m * \frac{300\frac{N}{m}}{0.001Kgm} = \mathbf{588}\frac{\boldsymbol{m}}{\boldsymbol{s^2}}$$

5. A variable-capacitance relative humidity sensor has a capacitance of 10 μ F at 10 % relative humidity and 35 μ F at 50 % relative humidity. Determine (a) its capacitance at 78 % relative humidity, (b) its capacitance at 0 % relative humidity, and (c) its sensitivity

**10μF at 10%**

**35μF at 50%**

**Relative Humidity:** $\boldsymbol{C = A + B * RH}$; where **C** is capacitance, **A** and **B** are constants, and **RH** is the percent of relative humidity.

$10\mu F = A + 10\%B$______________[1]

$35\mu F = A + 50\%B$______________[2]

Equation 1-2 ➔
$$10\mu F = A + 10\%B$$
$$-35\mu F = -A - 50\%B \quad \text{\_\_\_\_\_\_\_\_\_\_[3]}$$
$$\boldsymbol{-25\mu F = 0 - 40\%B}[\boldsymbol{4}]$$

Solving equation 4 we find $\boldsymbol{B} = \frac{-25\mu F}{-40\%} = \boldsymbol{62.5\frac{\mu F}{\%}}$.

Substitute B into equation [1] and solve for $\boldsymbol{A} = 10\mu F - 62.5\frac{\mu F}{\%} * 10\% = \boldsymbol{3.75\mu F}$

**(A)** Capacitance at 78%:
$\boldsymbol{C} = A + B * RH = 3.75\mu F + 62.5\mu F * 78\% = \boldsymbol{52.5\mu F}$

**(B)** Capacitance at 0%:
$\boldsymbol{C} = A + B * RH = 3.75\mu F + 62.5\mu F * 0\% = \boldsymbol{3.75\mu F}$

7. The Strouhal number, St , depends only on the Reynolds number, Re .For a cylinder in cross-flow, St is constant and equals 0.21 for 6000 ≤ Re ≤ 60 000. For a vortex shedding flowmeter using a 1-cm-diameter cylindrical element placed in water under standard conditions in this Re range, determine the range of shedding frequencies (in Hz).

**Given:** Density of water **(ρ):** $1\frac{kg}{m^3}$

Viscosity of water **(μ):** $8.94 * 10^{-4}\frac{N}{m^2}$

**dc**= 1cm/0.01m

**St**= 0.21 for 6000≤ Re ≤60000

**Solution: - Solve the equation (**$\boldsymbol{Rec} = \frac{\rho * Uc * dc}{\mu}$) for the velocity **Uc** and substitute it into the following formula $\boldsymbol{fs} = \frac{St*U}{2\pi D}$.

$$U_{6000} = \frac{Rec*\mu}{\rho*dc} = \frac{\mathbf{6000}\times 8.94\times\frac{10^{-4}\,N}{m^2}}{1\frac{Kg}{m^3}\times 0.01m} = \frac{5.364\frac{N}{m^2}}{0.01\frac{k}{m^2}} = \mathbf{536.4}\,\frac{\boldsymbol{m}}{\boldsymbol{s}};$$

$$U_{60000} = \frac{Rec*\mu}{\rho*dc} = \frac{\mathbf{60000}\times 8.94\times\frac{10^{-4}\,N}{m^2}}{1\frac{Kg}{m^3}\times 0.01m} = \frac{53.64\frac{N}{m^2}}{0.01\frac{k}{m^2}} = \mathbf{5364}\,\frac{\boldsymbol{m}}{\boldsymbol{s}};$$

$$fs_{6000} = \frac{St*U}{2\pi D} = \frac{0.21*536.4\frac{m}{s}}{2\pi*0.01m} = \left(\frac{112.644\frac{m}{s}}{0.0623m}\right) = \mathbf{1792.78}\,\frac{\mathbf{1}}{\boldsymbol{seconds}};$$

$$fs_{60000} = \frac{St*U}{2\pi D} = \frac{0.21*5364\frac{m}{s}}{2\pi*0.01m} = \left(\frac{1126.44\frac{m}{s}}{0.0623m}\right) = \mathbf{18080.89}\,\frac{\mathbf{1}}{\boldsymbol{seconds}};$$

**Range of Frequencies are: 1792.78Hz ≤ $f_S$ ≤ 18080.89Hz**