Indian Institute of Technology Bhubaneswar

School of Infrastructure

Subject Name : Solid Mechanics	Subject Code: CE2L001

Tutorial No. 6 Date: October 30, 2025

Instructions:
Provide neatly labeled diagrams whenever necessary.

1. A 45-degree strain rosette is used to measure strains on a steel surface. The readings are $\epsilon_a = 100\,\mu$m/m, $\epsilon_b = 400\,\mu$m/m, and $\epsilon_c = 900\,\mu$m/m. Determine the principal strains and stresses.

2. Consider a 60° strain gauge rosette to be mounted on the surface of a specimen as shown in Fig. 1.

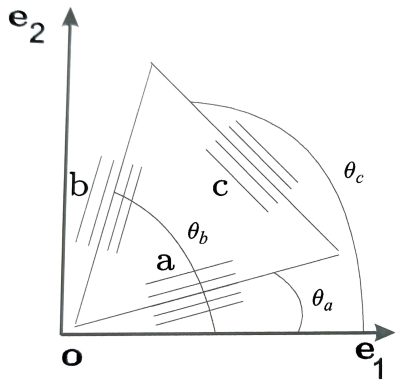

Figure 1: Schematic representation of a 60° strain-gauge rosette.

   (a) Let $\{\boldsymbol{e}_a, \boldsymbol{e}_b, \boldsymbol{e}_c\}$ denote three non-collinear unit vectors which represent the directions in which the three strain gauges in a rosette are arranged, and let

$$E_{aa} = \boldsymbol{e}_a \cdot \boldsymbol{E}\boldsymbol{e}_a, \qquad E_{bb} = \boldsymbol{e}_b \cdot \boldsymbol{E}\boldsymbol{e}_b, \qquad E_{cc} = \boldsymbol{e}_c \cdot \boldsymbol{E}\boldsymbol{e}_c,$$

   denote the components of the strain measured in the directions $\{\boldsymbol{e}_a, \boldsymbol{e}_b, \boldsymbol{e}_c\}$. Determine a general expression for the components of strain, $\boldsymbol{E}$, (i.e E_{11}, E_{22}, $E_{12} = E_{21}$) with respect to the basis $\{\boldsymbol{e}_1, \boldsymbol{e}_2\}$, as functions of ($E_{aa}$, E_{bb}, E_{cc}) and the orientations $(\theta_a, \theta_b, \theta_c)$.

   (b) Evaluate E_{11}, E_{22} and E_{12} for $\theta_a = 0°$, $\theta_b = 60°$, and $\theta_c = 120°$.

3. Stress is not a directly measurable quantity for most materials and is usually computed from the strain measurements in a complex engineering system. A common method for measuring the state of strain is

to use *strain gauges* which are simple electrical devices that can measure only the normal strain along its length.

A strain rosette having three strain gauges a, b and c is installed on a block as shown in Fig.2. During a static test of the block in plane strain ($\epsilon_{zz} = 0, \gamma_{xz} = 0$ and $\gamma_{yz} = 0$), the strain rosettes read $\epsilon_a = 0.003$, $\epsilon_b = 0.001$ and $\epsilon_c = 0.001$.

1) Calculate the shear strain γ_{xy} for an element oriented along the xy plane (Round your answer to 4 decimal points). Note that for a strain gauge oriented at an angle of θ to the x-axis , the gauge reading ϵ_θ can be expressed as:

$$\epsilon_\theta = \epsilon_{xx} \cos^2(\theta) + \epsilon_{yy} \sin^2(\theta) + \gamma_{xy} \sin(\theta) \cos(\theta)$$

2) If the block is made of a material with elastic modulus $E = 100$ GPa and Poisson's ratio $\nu = 0.3$, use Hooke's law to find the stress components in the $x - y$ plane.

3) Determine the principal stresses in the block.

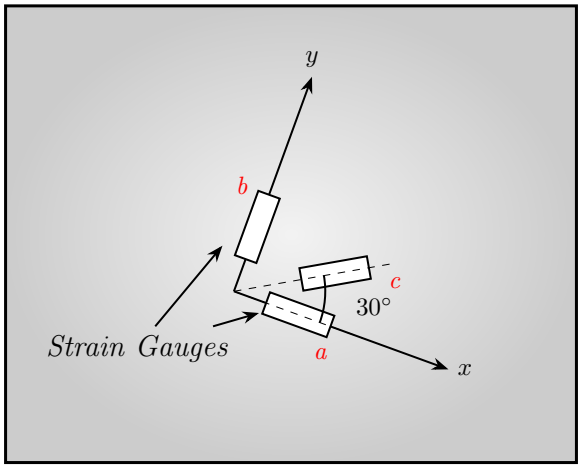

Figure 2: Strain Gauges

4. A rectangular strain rosette (0-90 degrees) is used to measure strains on an aluminum surface. The readings are $\epsilon_{11} = 200\,\mu$m/m and $\epsilon_{22} = 100\,\mu$m/m. Determine the strain measured by a 45-degree gauge.

5. A rectangular strain rosette is attached to a steel plate with gauge angles of 0°, 45°, and 90°. If the measured strains are $1000\,\mu\varepsilon$, $800\,\mu\varepsilon$, and $1200\,\mu\varepsilon$, respectively, calculate the principal strains and stresses.

6. A delta strain rosette with gauge angles of 0°, 60°, and 120° measures strains of $500\,\mu\varepsilon$, $700\,\mu\varepsilon$, and $900\,\mu\varepsilon$. Determine the principal strains, principal stresses, and maximum shear stress.

7. A strain gauge rosette is used to measure the strain on a machine component. If the measured strains are $2000\,\mu\varepsilon$, $1500\,\mu\varepsilon$, and $2500\,\mu\varepsilon$ at angles of 0°, 45°, and 90°, calculate the normal strain in the x-direction, normal strain in the y-direction, and shear strain in $x - y$ plane.

8. A material with a Young's modulus of 200 GPa and Poisson's ratio of 0.3 is subjected to a strain gauge rosette measurement. If the principal strains are 1500 $\mu\varepsilon$ and 800 $\mu\varepsilon$, calculate the principal stresses and maximum shear stress.

9. A steel plate with a Young's modulus of 210 GPa and Poisson's ratio of 0.29 is subjected to a load. If the measured strains using a strain gauge rosette are 1000 $\mu\varepsilon$, 600 $\mu\varepsilon$, and 1200 $\mu\varepsilon$ at angles of 0°, 60°, and 120°, calculate the principal stresses and maximum shear stress.

10. A machine component is subjected to a complex loading condition. If the strain gauge rosette measurements are 2500 $\mu\varepsilon$, 1800 $\mu\varepsilon$, and 3000 $\mu\varepsilon$ at angles of 0°, 45°, and 90°, calculate the principal strains, principal stresses, and von Mises stress.