



Indian Institute of Technology Bhubaneswar
School of Infrastructure

Subject Name : Solid Mechanics

Subject Code: CE2L001

Tutorial No. 6

Date: October 30, 2023

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 $\epsilon_a = 100 \mu\text{m/m}$, $\epsilon_b = 400 \mu\text{m/m}$, and $\epsilon_c = 900 \mu\text{m/m}$. 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.

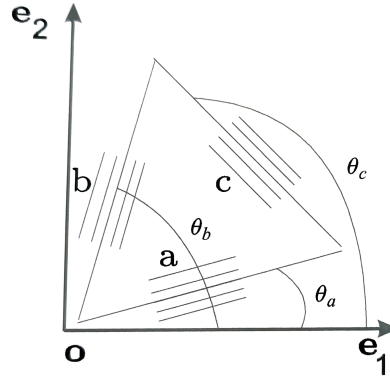


Figure 1: Schematic representation of a 60° strain-gauge rosette.

- (a) Let $\{e_a, e_b, e_c\}$ denote three non-collinear unit vectors which represent the directions in which the three strain gauges in a rosette are arranged, and let

$$E_{aa} = e_a \cdot \mathbf{E} e_a, \quad E_{bb} = e_b \cdot \mathbf{E} e_b, \quad E_{cc} = e_c \cdot \mathbf{E} e_c,$$

denote the components of the strain measured in the directions $\{e_a, e_b, e_c\}$. Determine a general expression for the components of strain, \mathbf{E} , (i.e $E_{11}, E_{22}, E_{12} = E_{21}$) with respect to the basis $\{e_1, e_2\}$, 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 $\theta_a = 0^\circ$, $\theta_b = 60^\circ$, and $\theta_c = 120^\circ$.
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.

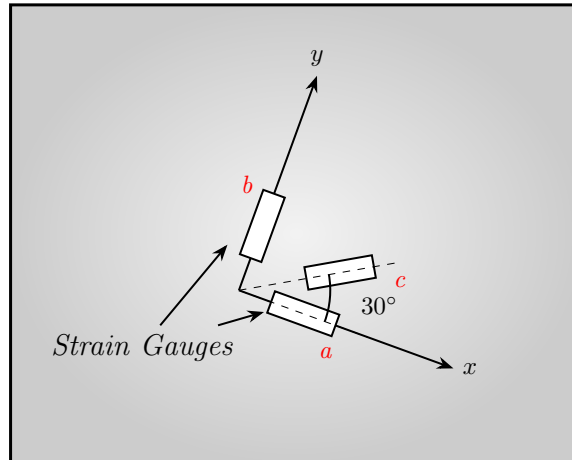


Figure 2: Strain Gauges

4. A rectangular strain rosette (0-90 degrees) is used to measure strains on an aluminum surface. The readings are $\epsilon_{11} = 200 \mu\text{m/m}$ and $\epsilon_{22} = 100 \mu\text{m/m}$. 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 $1000 \mu\epsilon$, $800 \mu\epsilon$, and $1200 \mu\epsilon$, respectively, calculate the principal strains and stresses.
6. A delta strain rosette with gauge angles of 0° , 60° , and 120° measures strains of $500 \mu\epsilon$, $700 \mu\epsilon$, and $900 \mu\epsilon$. 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 $2000 \mu\epsilon$, $1500 \mu\epsilon$, and $2500 \mu\epsilon$ 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 $1500 \mu\epsilon$ and $800 \mu\epsilon$, 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 $1000 \mu\epsilon$, $600 \mu\epsilon$, and $1200 \mu\epsilon$ 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 $2500 \mu\epsilon$, $1800 \mu\epsilon$, and $3000 \mu\epsilon$ at angles of 0° , 45° , and 90° , calculate the principal strains, principal stresses, and von Mises stress.