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Internal Assessment Test 1 – March. 2019

Sub:	Experimental Stress Analysis				Sub Code:	15ME832	Branch:	Mech
Date:	6.03.19	Duration:	90 min's	Max Marks: 50	Sem / Sec:	VIII/A&B		OBE

Answer any FOUR FULL Questions (Each question carries 12.5 marks)

		MARKS	CO	RBT
1a)	Define Gauge factor and derive the expression for gauge factor.	[4]	CO1	L2
b)	List the desirable characteristics of an adhesive used to mount the strain gauge and explain strain gauge mounting techniques.	[4.5]		
c)	Explain the method of strain measurement using electrical resistance strain gauge.	[4]		
2a)	Mention any 3 properties of ideal strain gauge material and explain the working of strain gauge with a neat sketch.	[6.5]	CO1	L2
b)	With a neat sketch, explain the working of potentiometer circuit strain gauge under constant voltage conditions.	[6]	CO1	L2
3 a)	Derive the expression for three element delta rosette.	[6.5]	CO1	L2
b)	Explain different strain rosette configurations.	[6]		

(Please Turn over)

4\. a) Three strain gauges are applied to a point, gauge A is along x axis; gauge B at 30° from x axis; C at 75° from x axis. Calculate principal stresses, Principal strains and directions. [6.5] CO2 L2

Gauge	A	B	C
Strain (μm/m)	-600	300	500

b) Derive an expression for plane shear gauge. [6]

5a) Explain the basic concepts in Dynamic measurement and Experimental errors. [6] CO2 L2

b) Briefly explain system response, distortion impedance matching, Causes and types of experimental errors. [6.5]

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Solutions Key

Q.No	Solution
1.a)	

Strain Sensitivity in Metallic Alloys :-

Gauge factor:- Kelvin noted that resistance of wires increased with increasing strain and decreased with decreasing strain.

Analysis:- The resistance R of a uniform conductor with length 'L' cross-section area A, specific resistance 'ρ' is given by:

$$R = \rho \frac{L}{A} = \frac{\rho L}{CD^2} \quad \ldots\ldots (1)$$

CD^2 is area of c/s of wire,

D is sectional Dimension

C is Proportionality Constant : $C = 1$ & $\frac{\pi}{4}$ for Square & Circular c/s.

$$\log R = \log \rho + \log L - \log C - 2\log D \quad \ldots\ldots (2)$$

When wire is strained axially each of variable in eqn (2) may change

Differentiate eqn (2):- $dR/R = \frac{d\rho}{\rho} + \frac{dL}{L} - 2\log\frac{dD}{D} \quad \ldots (a)$

÷ by $\frac{dL}{L}$ on b.s of (a)

$$\frac{dR/R}{dL/L} = \frac{\frac{d\rho}{\rho}}{dL/L} + 1 - 2\,\frac{dD/D}{dL/L} \qquad \epsilon = \frac{dL}{L}, \quad \nu = \frac{-dD/D}{dL/L}$$

$$\frac{dR/R}{\epsilon} = \frac{d\rho/\rho}{\epsilon} + (1+2\nu)$$

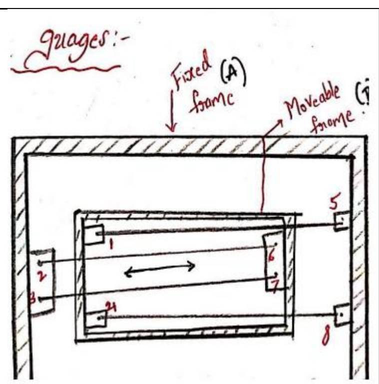
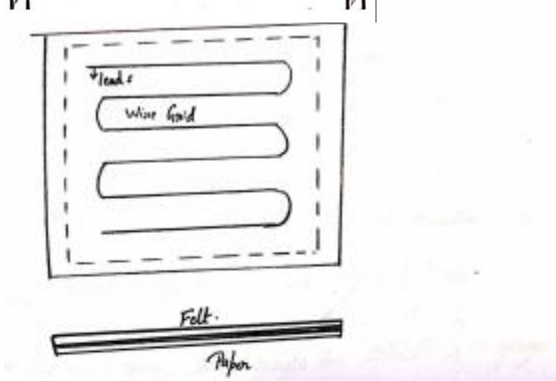
This may be written as:

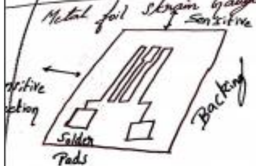
Sensitivity of metallic alloys $S_A = \frac{dR/R}{\epsilon} = (1+2\nu) + \frac{d\rho/\rho}{\epsilon} \quad \ldots\ldots (3)$

This equation shows strain sensitivity of any alloy is due to 2 factors

Change in dimensions of conductor & change in specific resistance.

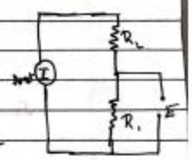
Experimental results show S_A varies about -12.1 to 6.1 for metallic alloys.

1.b)	**Adhesives:** The bondable strain gauges are attached to the test specimen by some form of cement or adhesives. A number of bonding cements are available which require various detailed techniques for their use. The following are the desirable characteristics of the bonding cements: ➢ High mechanical strength ➢ High creep resistance ➢ High dielectric strength ➢ Minimum temperature resistance ➢ Good adherence giving shear strength of 10.5 to $14 N/mm^2$ ➢ Minimum moisture absorption ➢ Ease of application. ➢ Low setting time.
c)	 

	> It Consists of strain sensitive Conductor (wire) Mounted on small Piece of Paper. > The 2 layers of wire and 3 layers of Paper results in guage which is approx 0.006inch thick. > In flat type after attaching lead wires to ends of grids, a second piece of Paper is Cemented over wire as Cover. > This guage is Prefered because of better Current carrying Capacity. hysteresis. Creep. elevated temperature.
2.a)	Metal foil strain Gauge:-  > It has foil grid made up of thin strain Sensitive foil. > The width of foil is very large as compared to thickness so large area of guage is for Cementing. > The metal foil gauges are usually mounted on thin epoxy Carrier which is approx 0.001 inch thick & flexible > The metal film strain guages are available in guage lengths ranging from 1/64 to 1 inch & 60 to 1,000 Ω

2.b)

Potentiometer Circuit (Constant Current)



$E = IR_1$

When Resistance R_1 & R_2 changes by ΔR_1 & ΔR_2 output Voltage becomes

$E + \Delta E = I(R_1 + \Delta R_1)$

Circuit sensitivity

$S_c = \frac{\Delta E}{\epsilon} = IR_g F$

It can be

Sum Circuit

$\Delta E = I(R_1 + \Delta R_1) - IR_1$

$\underline{IR_1 + I \cdot \Delta R_1 - IR_1}$

$\Delta E = I\Delta R_1$

$\times \underline{R_1}$ on both sides

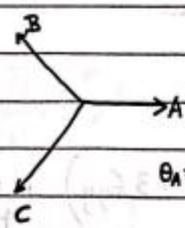
$\Delta E = I \cdot \Delta R_1 \times \frac{R_1}{R_1}$

$\boxed{\Delta E = IR_1 \cdot \frac{\Delta R_1}{R_1}}$

3.a)

Three-element Delta Rosettes

The angular position is $0°$, $120°$ & $240°$.



$\theta_A = 0°$; $\theta_B = 120°$; $\theta_C = 240°$

$\epsilon_A = \epsilon_{xx} \cos^2\theta_A + \epsilon_{yy} \sin^2\theta_A + \gamma_{xy} \sin\theta_A \cdot \cos\theta_A$

$\theta = 0$ so $\underline{\epsilon_A = \epsilon_{xx}} \rightarrow (1)$

$\epsilon_B = \frac{1}{4}\left(\epsilon_{xx} + 3\epsilon_{yy} - \sqrt{3}\,\gamma_{xy}\right)$

When $\theta = 120°$

$\cos 120° = -\frac{1}{2}$

-0.5

$\sin 120 = \frac{\sqrt{3}}{2}$

$\epsilon_B = \epsilon_{xx} \cos^2 120 + \epsilon_{yy} \sin^2 120 + \gamma_{xy} \sin 120 \cdot \cos 120$

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$\epsilon_{xx} \cdot \left(-\frac{1}{2}\right)^2 + \epsilon_{yy} \left(\frac{\sqrt{3}}{2}\right)^2 + \gamma_{xy} \cdot \left(-\frac{1}{2}\right)\left(\frac{\sqrt{3}}{2}\right)$

$\epsilon_3 = \frac{1}{4}\left(\epsilon_{xx} + 3\epsilon_{yy} - \sqrt{3}\,\gamma_{xy}\right) \rightarrow (2)$

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<tr><td></td><td></td></tr>
<tr><td>3.b)</td><td>

Two element rectangular rosettes:

This rosette is suitable only when the directions of principal strain are known. The gage a is arranged along the maximum strain direction chosen along the x-axis so that $\theta_A = 0$ and the gage b is set along the minimum strain direction so that $\theta_B = 90^o$

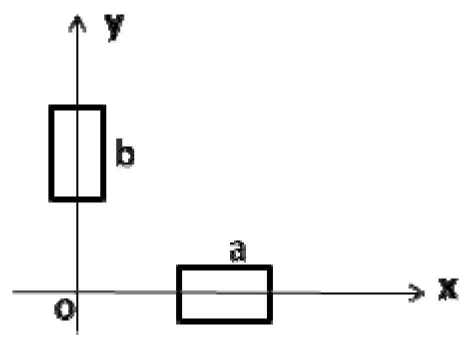

Fig: Two gage rosette

The strain along these directions A, B is

$$\therefore \quad \epsilon_A = \epsilon_{xx}$$

$$\epsilon_B = \epsilon_{yy}$$

Hence, $\epsilon_1 = \epsilon_A$, $\epsilon_2 = \epsilon_B$, $\gamma_{max} = (\epsilon_A - \epsilon_B)$
The principal stress σ_1 and σ_2 can be

$$\sigma_1 = (\epsilon_A + \vartheta\, \epsilon_B) * \frac{E}{(1-\vartheta^2)}$$

$$\sigma_2 = (\epsilon_B + \vartheta\, \epsilon_A) * \frac{E}{(1-\vartheta^2)}$$

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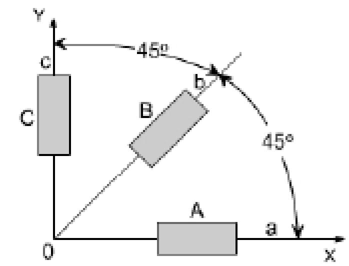
	Three element rectangular rosettes:



In this rosette the three gage are laid out so that the axis of gauges B and C are at 45° and 90 ° respectively to the axis of gage A. taking the OA axis to be coincident with the O x-axis, the angles corresponding to the gauges A, B and C in the three- element rectangular rosette are

$$\theta_A = 0 \ \theta_B = 45^0 \ \theta_C = 90^o$$

Than

$$\therefore \quad \epsilon_A = \epsilon_{xx} \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$\epsilon_B = \frac{1}{2}(\epsilon_{xx} + \epsilon_{yy} + \gamma_{xy}) \ldots\ldots\ldots\ldots (2)$$

$$\epsilon_C = \epsilon_{yy} \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

We can rewrite these eq in terms of ϵ_{xx}, ϵ_{yy}, γ_{xy} are obtained as

$$\therefore \quad \epsilon_{xx} = \epsilon_A$$

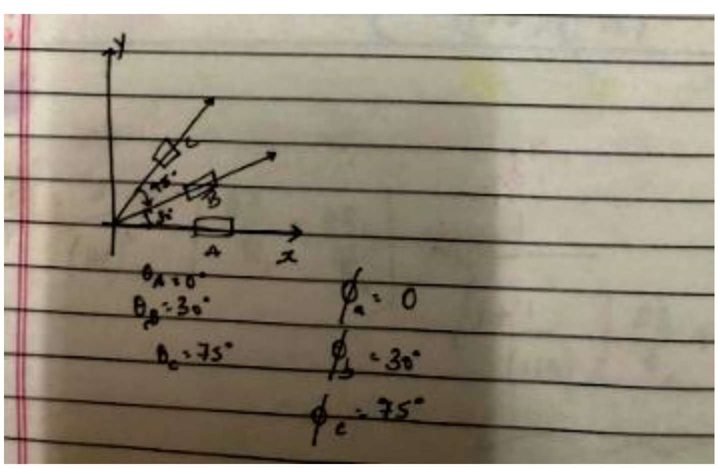
$$\epsilon_{yy} = \epsilon_C$$

$$\gamma_{xy} = 2\,\epsilon_B - (\epsilon_A + \epsilon_C) \ldots\ldots\ldots\ldots (4)$$

The principal strains are given by

$$\epsilon_1 = \frac{1}{2}(\epsilon_{xx} + \epsilon_{yy}) + \frac{1}{2}\left((\epsilon_{xx} - \epsilon_{yy})^2 + \gamma_{xy}{}^2\right)^{1/2}$$

$$\epsilon_1 = \frac{1}{2}(\epsilon_A + \epsilon_C) + \frac{1}{2}\left((\epsilon_A - \epsilon_C)^2 + \left(2\,\epsilon_B - (\epsilon_A + \epsilon_C)\right)^2\right)^{1/2}$$



Generally :-

$$\epsilon_\phi = \frac{\epsilon_x + \epsilon_y}{2} + \frac{1}{2}(\epsilon_x - \epsilon_y)\cos 2\phi + \frac{\gamma_{xy}}{2}\sin\phi$$

@ $\phi_1 = 0$; $\epsilon_1 = -600 \times 10^{-6}$

$$-600\times10^{-6} = \frac{1}{2}(\epsilon_x + 0) + \frac{1}{2}(0\epsilon_x - 0)\cos 2\phi + \frac{\gamma_{xy}}{2}\sin\phi$$

$$= \frac{\epsilon_x}{2} + \frac{\epsilon_x}{2}$$

$$\boxed{-600\times10^{-6} = \epsilon_x} \quad -(1)$$

@ $\phi_2 = 30°$;

$$300\times10^{-6} = \frac{1}{2}(\epsilon_x + \epsilon_y) + \frac{1}{2}(\epsilon_x - \epsilon_y)\cos 60° + \frac{\gamma_{xy}}{2}\sin 60°$$

$$= \frac{\epsilon_x}{2} + \frac{\epsilon_y}{2} + \frac{\epsilon_x}{2}\cos 60 - \frac{\epsilon_y}{2}\cos 60° + \frac{\gamma_{xy}}{2}\sin 60°$$

$$300\times10^{-6} = 0.5\epsilon_y + 0.5\epsilon_x + 0.25\epsilon_x - 0.25\epsilon_y + \frac{0.866}{2}\gamma_{xy}$$

$$300\times10^{-6} = 0.75\epsilon_x + 0.25\epsilon_y + 0.433\gamma_{xy} \quad -(2)$$

At $\phi_3 = 75°$; $\epsilon_\phi = \epsilon_3$

$$400\times10^{-6} = \frac{1}{2}(\epsilon_x + \epsilon_y) + \frac{1}{2}(\epsilon_x - \epsilon_y)\cos(150) + \frac{\gamma_{xy}}{2}\sin 150°$$

$$= 0.5\epsilon_x + 0.5\epsilon_y - 0.433\epsilon_x + 0.433\epsilon_y + 0.25\gamma_{xy}$$

$$400\times10^{-6} = 0.067\epsilon_x + 0.933\epsilon_y + 0.25\gamma_{xy} \rightarrow (3)$$

Solving (1), (2), (3)

$\epsilon_x = -600\times10^{-6}$
$\epsilon_y = 9.1132\times10^{-6}$
$\gamma_{xy} = 1726.8\times10^{-6}$

Principle strain

$$\epsilon_{1,2} = \frac{1}{2}(\epsilon_x + \epsilon_y) \pm \frac{1}{2}\sqrt{(\epsilon_x - \epsilon_y)^2 + \gamma_{xy}^2}$$

$$= \frac{1}{2}(-600 + 9.1132)\times10^{-6} \pm \frac{1}{2}\times10^{-6}\sqrt{(-600 - 9.1132)^2 + (1726.8)^2}$$

$\epsilon_1 = 620.12\times10^{-6}$
$\epsilon_2 = -1211\times10^{-6}$

$$\tan 2\phi = \frac{\gamma_{xy}}{\epsilon_x - \epsilon_y} = \frac{1726.84}{-600 - 9.1132} = -2.835$$

$$2\phi = \tan^{-1}(-2.835)$$

-2.835

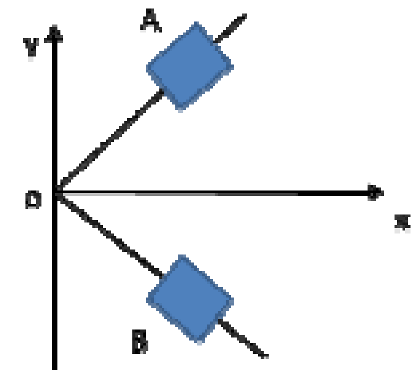
$$\phi = -35.29$$

$$\phi_1 = 144.71°$$

$$\phi_2 = 234.71$$

4.b)

Shear strain gauges:



Strain gauges do not respond to shear strains. However the relationship between shear and normal strains can be utilized to obtain from a strain rosette an output directly proportional to the shear strain in the surface.

The two strain gauges a and b oriented so that the x axis bisects the angle between the gage axes. Strain along two gage axes is

$$\epsilon_A = \frac{\epsilon_{xx}+\epsilon_{yy}}{2} + \frac{\epsilon_{xx}-\epsilon_{yy}}{2}\cos 2\theta + \frac{\gamma_{xy}}{2}\sin 2\theta$$

$$\epsilon_B = \frac{\epsilon_{xx}+\epsilon_{yy}}{2} + \frac{\epsilon_{xx}-\epsilon_{yy}}{2}\cos 2\theta - \frac{\gamma_{xy}}{2}\sin 2\theta$$

From the above eq. The shear strain γ_{xy} is

$$\gamma_{xy} = \frac{\epsilon_A - \epsilon_B}{\sin 2\theta}$$

From above eq the difference in the normal strain sensed by any two arbitrarily oriented gauges in a uniform strain field is directly proportional to the shear strain along an axis bisecting the included angle between the strain gage axes. When the included angle is 90^0, i.e. the rosette is a two-element rectangular rosette, above eq can be reduced to

$$\gamma_{xy} = \epsilon_A - \epsilon_B$$

Hence by orienting a two-element rectangular rosette such that the x-axis bisects the 90^0 angle between the gage elements and connecting the gage elements in the adjacent arm of a Wheatstone bridge, an output from the rosette equal to the shear strain γ_{xy} can be obtained directly.

A quantity is called dynamic when its value at one time instant depends on its values at previous time instants. That is, in contrast to static measurements where a single value or a (small) set of values is measured, dynamic measurements consider continuous functions of time

Dynamic measurements can be found in many areas of metrology and industry, such as, for instance, in applications where mechanical quantities, electrical pulses or temperature curves are measured.

A quantity is called dynamic when its value at one time instant depends on its values at previous time instants That is, in contrast to static measurements where a single value or a (small) set of values is measured, dynamic measurements consider continuous functions of time. Since the analysis of dynamic measurements requires different approaches than the analysis of static measurements this part of metrology is often called "Dynamic Metrology". The mathematical modeling of dynamic measurements typically utilizes methodologies and concepts from digital signal processing. In the language of metrology a signal denotes a dynamic quantity, and a system a measurement device whose input and/or output are signals. The output signal of a system is thus the indication value of the measurement device for a corresponding input signal.

In mathematical terms the signals are continuous time dependent functions x(t) and y(t). In most metrological applications the measurement system can be considered time-invariant and linear with respect to its inputs:

$$H(a_1x_1(t)+a_2x_2(t))=a_1H(x_1(t))+a_2H(x_2(t))$$

Such systems are called linear time-invariant (LTI) and are fully represented by their impulse response function h(t), equivalently by their transfer function H(s) or frequency response function H(f). The relation between input and output signal is then given mathematically as a convolution

Impedance matching

In electronics, impedance matching is the practice of designing the input impedance of an electrical load or the output impedance of its corresponding signal source to maximize the power transfer or minimize signal reflection from the load.

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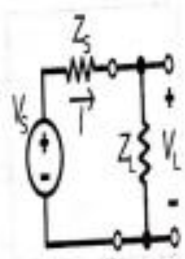
In the case of a complex source impedance Z_S and load impedance Z_L, maximum power transfer is obtained when

$$Z_S = Z_L^*$$

where the asterisk indicates the complex conjugate of the variable. Where Z_S represents the characteristic impedance of a transmission line, minimum reflection is obtained when

$$Z_S = Z_L$$



Source and load circuit impedance

The concept of impedance matching found first applications in electrical engineering, but is relevant in other applications in which a form of energy, not necessarily electrical, is transferred between a source and a load. An alternative to impedance matching is impedance bridging, in which the load impedance is chosen to be much larger than the source impedance and maximizing voltage transfer, rather than power, is the goal.

Impedance is the opposition by a system to the flow of energy from a source. For constant signals, this impedance can also be constant. For varying signals, it usually changes with frequency. The energy involved can be electrical, mechanical, acoustic, magnetic, or thermal. The concept of electrical impedance is perhaps the most commonly known. Electrical impedance, like electrical resistance, is measured in ohms. In general, impedance has a complex value; this means that loads generally have a resistance component (symbol: R) which forms the real part of Z and a reactance component (symbol: X) which forms the imaginary part of Z.

	CAUSES OF EXPERIMENTAL ERRORS **Errors** that may occur in the execution of a statistical **experiment** design. Types of **experimental error** include human **error**, or **mistakes** in data entry; systematic **error**, or **mistakes** in the design of the **experiment** itself; or random **error**, **caused** by environmental conditions or other unpredictable factors. **There are two kinds of experimental errors.** **Random Errors** These errors are unpredictable. They are chance variations in the measurements over which you as experimenter have little or no control. There is just as great a chance that the measurement is too big as that it is too small. Since the errors are equally likely to be high as low, averaging a sufficiently large number of results will, in principle, reduce their effect. **Systematic Errors** These are errors caused by the way in which the experiment was conducted. In other words, they are caused by the design of the system. Systematic errors can not be eliminated by averaging In principle, they *can* always be eliminated by changing the way in which the experiment was done. In actual fact though, you may not even know that the error exists.