[Strain Measurement]

Strain in a body subjected to direct tensile or compressive force is defined as ratio of change in length to original length.
The transducers used for measurement of strain are known as strain gauges.

Types of strain Gauges :

Strain Gauge
- Mechanical Strain Gauge
- Optical Strain Gauge
- Electrical Strain Gauge

Mechanical Strain Gauge :

In these gauges, change in length is magnified mechanically using gears or levers. These gauges are generally large in size.

Optical Strain Gauge :

These are similar to mechanical gauges the difference being that magnification of change in dimension is achieved with multiple reflectors using mirrors or prism.

Electrical Strain Gauge :

These are based on measurement of change in resistance or inductance or capacitance.
Strain gauges based on change in resistance is most commonly used.

Working Principle of Resistance Strain Gauges :

When axial load is applied on a metallic bar in outward direction, it leads to increase in length of bar and decrease in area of cross section.

We know that Resistance,

$$R = \frac{\rho l}{A}$$

where ρ is resistivity, l is length of conductor and A is area of cross section.

from above expression we see that when A will change, 'l' will change and hence R will also change. This is the working principle of operation of strain gauges based on resistance.

Types of Resistance Strain Gauges :

These gauge are classified as follows.

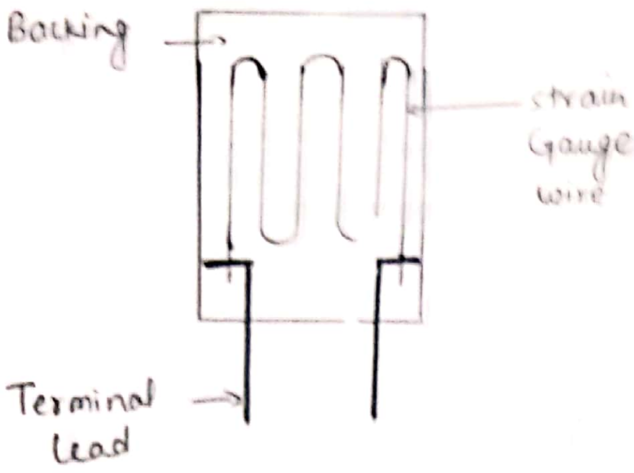
(i) Wire wound type
(ii) Foil type
(iii) Semiconductor Gauges
(iv) Thin film strain gauges

Wire Wound Gauges :

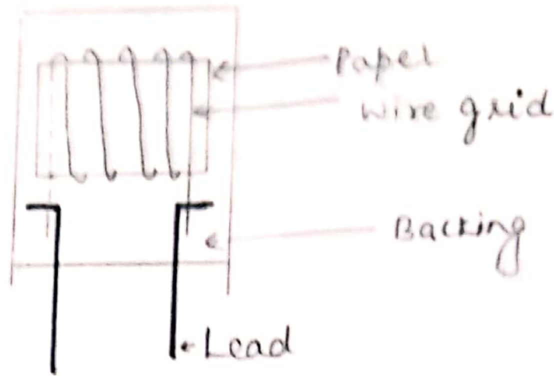
Wire wound gauges are of two types.

(a) Bonded Strain Gauges
(b) Unbonded Strain Gauges

Bonded strain gauges are bonded directly to the surface of specimen being examined with thin layer of adhesive cement. Depending upon the requirement, bonded strain gauges can have various structures.

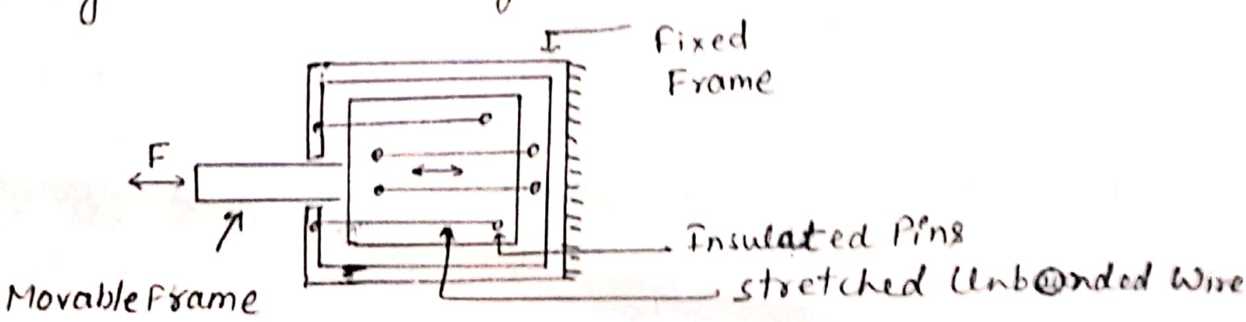


(Flat Grid Type)



(Wrap around type)

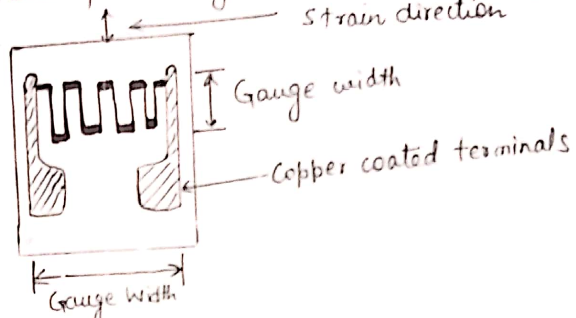
Unbonded metal wire strain gauge doesnot having backing material, so the strain is transferred to the resistance wire directly. The wires are wound between two insulated pins one of which is fixed on a stationary frame while the other to a movable frame as shown in figure below. The gauge employs a set of unbonded metal wires which are preloaded and connected to a wheatstone bridge. All the wires are kept equally tight and so the wheatstone bridge is initially balanced. When force acts on the movable frame, tension in two wires increase while tension in two wires decreases. This changes the resistance of the wires which leads to



unbalanced bridge condition. The output voltage so generated is proportional to input displacement and can be calibrated in terms of strain.

Foil strain Gauge :

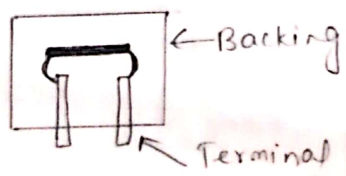
It is an extension of wire strain gauge but instead of wires, it makes use of thin sheets or foils as sensing elements. The foil with thickness less than 5 μm is made from tungsten platinum alloy



(Foil strain Gauge)

Semiconductor Strain Gauge :

Semiconductor materials have a unique property called piezoresistivity, that is, when these materials are stressed, they undergo a change in their resistivity. This gauge is made of wafers of 150 μm thickness. The bonding techniques used are similar to that used for wire or foil strain gauges but in this case greater care must be taken because of their brittleness.



(Semi conductor Gauge)

Temperature Compensation :

When strain measurement is carried out over a long period of time, the gauge may get subjected to change in the ambient temperature. At the same time, differential expansion of the gauge and the specimen to which it is bonded may induce some strain in the gauge wires.

Change in resistance of gauge wires resulting from change in resistivity due to change in temp is given by,

$$\Delta R_1 = \beta R \Delta T$$

Change in resistance of gauge wires resulting from differential expansion due to change in ambient temp.

$$\Delta R_2 = (\alpha_s - \alpha_g) G_f R \Delta T$$

where $\beta \rightarrow$ coefficient of resistivity of gauge material

$\alpha_s \rightarrow$ co-efficient of linear expansion of specimen

$\alpha_g \rightarrow$ coefficient of linear expansion of gauge material

$G_f \rightarrow$ Gauge Factor

$R \rightarrow$ original resistance of gauge wires.

$\Delta T \rightarrow$ change in ambient temp.

So Net change in resistance,

$$\Delta R = \Delta R_1 + \Delta R_2 = \left[\beta + (\alpha_s - \alpha_g) G_f\right] R \Delta T$$

$$\Rightarrow (\Delta R / R) = \left[\beta + (\alpha_s - \alpha_g) G_f\right] \Delta T$$

Such errors can be reduced by using specially designed temp- compensated strain gauge. Such a gauge consists of two elements of different materials such as constantan and Nickel. The dimensions of each material is so chosen that change in resistance of the two materials due to change in temp. are with opposite sign, hence nullify each other

Strain Gauge Rosettes :

For uniaxial strain measurement, single gauges are employed. When strain direction is known, the gauge is bonded to the test specimen which may be subjected to tensile, compressive or bending load. Strain induced can be easily calculated when the member is stressed axially.

$$\frac{\text{Stress}}{\text{Strain}} = \text{Modulus of elasticity.}$$

But in practice when any member is stressed in one direction, laterial strain also gets developed. For measuring the strain in such cases, a set of strain gauges is required which is generally called strain gauge rosette.

Strain Gauge Rosettes are of three types.

(1) Rectangular Rosette
(2) Delta Rosette
(3) T-delta Rosette.

Strain gauge rosettes are generally used when stress conditions are unknown.

Gauge Factor :

$$\text{Gauge factor } (G_f) = \frac{\Delta R/R}{\Delta l/l} = \frac{\Delta R/R}{\epsilon}$$

Backing Material : It is the portion of the strain gauge to which wire or foil grid structure is attached. Commonly used strain gauge backing materials are paper, fibre glass, or bakelite etc.

Bonding Cement : It is the adhesive used to fix the strain gauge onto the test specimen. Commonly used adhesives are epoxy cement, bakelite cement, etc.