Unit II : Transducers
Module Name : Strain Gauges
Module No : 09

Strain Gauges

The strain gauge is an example of a passive transducer that uses the variation in electrical resistance in wires to sense the strain produced by a force on the wires.
It is well known that stress (force/unit area) and strain (elongation or compression/unit length) in a member or portion of any object under pressure is directly related to the modulus of elasticity.
If a metal conductor is stretched or compressed, its resistance changes on account of the fact that both the length and diameter of the conductor changes. Also, there is a change in the value of the resistivity of the conductor when subjected to strain, a property called the piezo-resistive effect. Therefore, resistance strain gauges are also known as piezo resistive gauges.
When a gauge is subjected to a positive stress, its length increases while its area of cross-section decreases. Since the resistance of a conductor is directly proportional to its length and inversely proportional to its area of cross-section, the resistance of the gauge increases with positive strain. The change in resistance value of a conductor under strain is more than for an increase in resistance due to its dimensional changes. This property is called the piezo-resistive effect.

The following types of strain gauges are the most important.
1. Wire strain gauges
2. Foil strain gauges
3. Semiconductor strain gauges

Resistance Wire Gauge

Resistance wire gauges are used in two basic forms, the unbonded type, and the bonded type.

1. Unbonded Resistance Wire Strain Gauge.

An unbonded strain gauge consists of a wire stretched between two points in an insulating medium, such as air. The wires are kept under tension so that there is no sag and no free vibration. Unbonded strain gauges are usually connected in a bridge circuit. The bridge is balanced with no load applied as shown in Fig. 1.

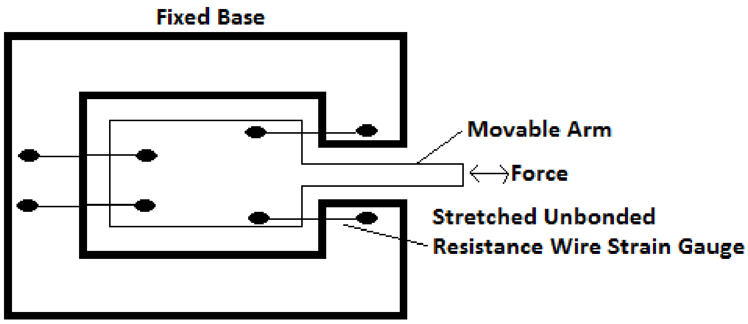

Fig 1. Unbonded Wire Strain Gauge

When an external load is applied, the resistance of the strain gauge changes, causing an unbalance of the bridge circuit resulting in an output voltage. This voltage is proportional to the strain

2. Bonded Resistance Wire Strain Gauges

A metallic bonded strain gauge is shown in Fig. 2. A fine wire element looped back and forth on a carrier (base) or mounting plate, which is usually cemented to the member undergoing stress. The grid of fine wire is cemented on a carrier which may be a thin sheet of paper, bakelite, or teflon. The wire is covered on the top with a thin material. The carrier is then bonded or cemented to the member being studied. This permits a good transfer of strain from carrier to wire.

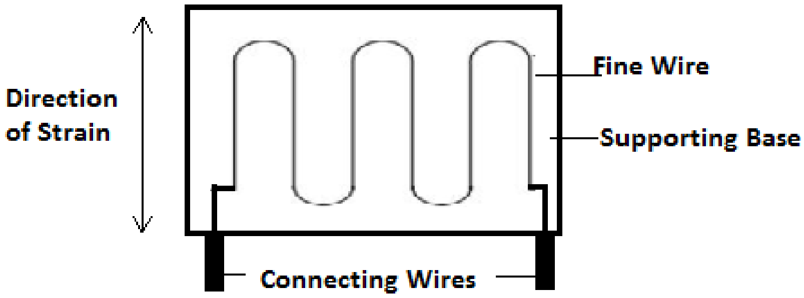

Fig 2 Bonded Wire Strain Gauge

The measurement of the sensitivity of a material to strain is called the gauge factor (GF). It is the ratio of the change in resistance Δ R/R to the change in the length Δ L/L
where K = gauge factor
Δ R = the change in the initial resistance in W's
R = the initial resistance in W (without strain)
ΔL = the change in the length in m
L = the initial length in m (without strain)
Since strain is defined as the change in length divided by the original length,

Foil Strain Gauge
This class of strain gauges is an extension of the resistance wire strain gauge. The strain is sensed with the help of a metal foil. The metals and alloys used for the foil and wire are nichrome, constantan (Ni + Cu), isoelastic (Ni + Cr + Mo), nickel and platinum.
Foil gauges have a much greater dissipation capacity than wire wound gauges, on account of their larger surface area for the same volume. For this reason, they can be used for a higher operating temperature range. Also, the large surface area of foil gauges leads to better bonding.
Foil type strain gauges have similar characteristics to wire strain gauges. Their gauge factors are typically the same.

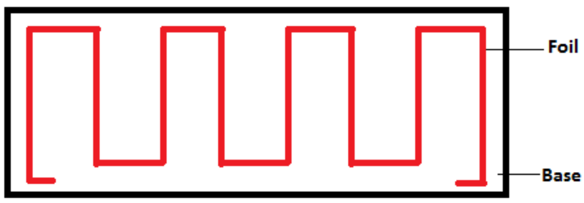

Fig 3. Foil Strain Gauge.

The advantage of foil type strain gauges is that they can be fabricated on a large scale, and in any shape. The foil can also be etched on a carrier.
Etched foil gauge construction consists of first bonding a layer of strain sensitive material to a thin sheet of paper or bakelite. The portion of the metal to be used as the wire element is covered with appropriate masking material, and an etching solution is applied to the unit. The solution removes that portion of the metal which is not masked, leaving the desired grid structure intact.

Semiconductor Strain Gauge

To have a high sensitivity, a high value of gauge factor is desirable. A high gauge factor means relatively higher change in resistance, which can be easily measured with a good degree of accuracy.
Semiconductor strain gauges are used when a very high gauge factor is required. They have a gauge factor 50 times as high as wire strain gauges. The resistance of the semiconductor changes with change in applied strain. Semiconductor strain gauges depend for their action upon the piezo resistive effect, i.e. change in value of the resistance due to change in resistivity, unlike metallic gauges where change in resistance is mainly due to the change in dimension when strained. Semiconductor materials such as germanium and silicon are used as resistive materials.
Gold leads are generally used for making contacts. These strain gauges can be fabricated along with an IC Op Amp which can act as a pressure sensitive transducer. The large gauge factor is accompanied by a thermal rate of change of resistance approximately 50 times higher than that for resistive gauges. Hence, a semiconductor strain gauge is as stable as the metallic type, but has a much higher output.

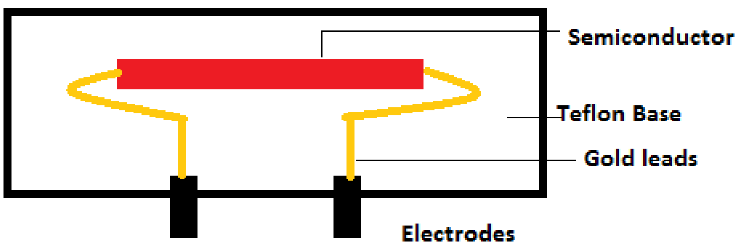

Fig 3. Semiconductor Strain Gauge

Advantages of Semiconductor Strain Gauge

1. Semiconductor strain gauges have a high gauge factor of about + 130.
2. This allows measurement of very small strains, of the order of 0.01 micro strain.
3. Hysteresis characteristics of semiconductor strain gauges are excellent,i.e. less than 0.05%.
4. Life in excess of 10 ¥ 106 operations and a frequency response of 10^{12} Hz.
5. Semiconductor strain gauges can be very small in size, ranging in length from 0.7 to 7.0 mm.

Disadvantages

1. They are very sensitive to changes in temperature.
2. Linearity of semiconductor strain gauges is poor.
3. They are more expensive.