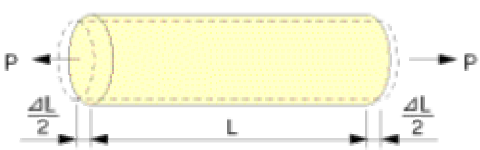
Strain...

External force applied to an elastic material generates stress, which subsequently generates deformation of the material. At this time, the length L of the material extends to L+ΔL if applied force is a tensile force. The ratio of ΔL to L, that is ΔL/L, is called strain. (Precisely, this is called normal strain or longitudinal strain.) On the other hand, if compressive force is applied, the length L is reduced to L- ΔL. Strain at this time is (- ΔL)/L. Strain is usually represented as ε.
Supposing the cross sectional area of the material to be A and the applied force to be P, stress σ will be P/A, since a stress is a force working on a definite cross sectional area. In a simple uniaxial stress field as illustrated below, strain ε is proportional to stress σ, thus an equation $\sigma = E \times \varepsilon$ is satisfied, provided that the stress σ does not exceed the elastic limit of the material. "E" in the equation is the elastic modulus (Young's modulus) of the material.



$$\varepsilon = \frac{\Delta L}{L}$$

ε = ΔL/L
ε : Strain
L : Original length
: Change due to force P

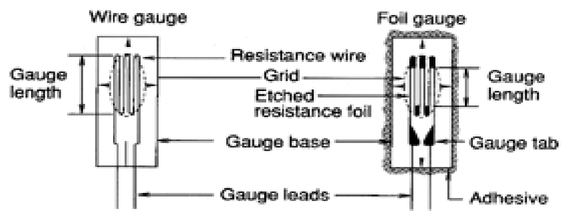
Because a strain is a ratio between length of two parts, it is a quantity having no dimension. Usually it is represented in a unit of $1\text{x}10^{-6}$, since the ratio of deformation is often very small. For example, supposing L to be 100mm and ΔL to be 0.1mm, strain ε is indicated as $1000\text{x}10^{-6}$strain, because "$0.1\text{mm}/100\text{mm}=0.001=1\text{x}10^{-3}=1000\text{x}10^{-6}$". To indicate comparatively large strain, "% strain" is also used. In this case, 1% strain equals to $10000\text{x}10^{-6}$strain.

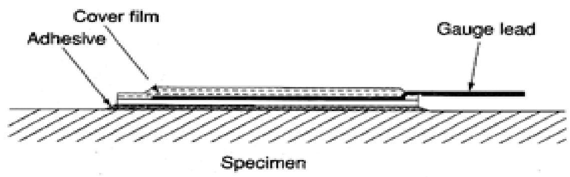
Strain and resistance change...

When a metal (resistor) is expanded or contracted by external force, it experiences a change of electrical resistance. By bonding a metal (resistor) on the surface of a specimen with an electrical insulator between them, the metal changes its dimension according to the expansion or contraction of the specimen, thus resulting a change of its resistance. Strain gauge (electrical resistance strain gauge) is a sensor to detect the strain of a specimen by this resistance change.

Strain gauge...

Strain gauge is constructed by bonding a fine electric resistance wire or photographically etched metallic resistance foil to an electrical insulation base(backing), and attaching gauge leads. Strain gauge is used for strain measurement by bonding it on the surface of the specimen with specified adhesive.





The strain generated in the specimen is transmitted to the resistor(foil or wire) through the gauge base (backing), where expansion or contraction occurs. As a result, the resistor experiences a variation in resistance. This variation is proportional to the strain as indicated in the following equation.

$$\varepsilon = \frac{\Delta L}{L} = \frac{\Delta R / R}{K}$$

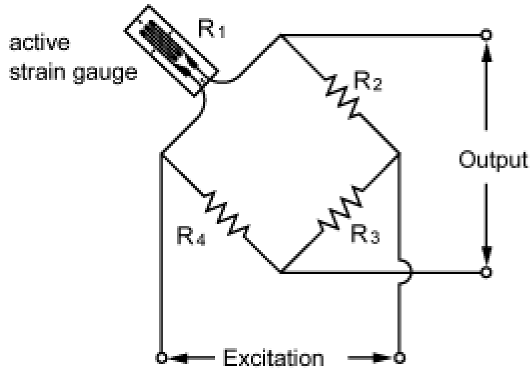
ε : Strain
R : Gauge resistance
: Resistance change due to strain
K : Gauge factor as shown on the package

Features of a strain gauge

Strain gauges are provided with many convenient features as follows.
· Simple construction with a small mass and volume so as not to interfere with the stresses on the specimen
· Small gauge length for evaluation of localized stress
· Good frequency response for tracking rapid fluctuations in stress
· Simultaneous measurement of multiple points and remote points.
· Electrical output for easy data processing
However, each strain gauge has its limitations in terms of temperature, the amount of strain, fatigue and the measurement environment. These limitations must be examined before using a strain gauge.

Strain measurement using a Wheatstone bridge circuit

Resistance of a strain gauge changes proportionally to the received strain. To measure strain is to measure this resistance change. Since this resistance change is very small in usual case, it requires a Wheatstone bridge circuit to convert the resistance change into voltage output.



The output voltage of a bridge circuit is given as follows.

$$e = \frac{R_1R_3 - R_2R_4}{(R_1 + R_2)(R_3 + R_4)}E$$

e :Voltage output
E :Exciting voltage
R_1 :Gauge resistance
R_2~R_4 :Resistance of fixed resistors

Assuming the value R as $R=R_1=R_2=R_3=R_4$, and the strain gauge resistance varies to $R+\Delta R$ due to strain, the output voltage Δe(variation) due to the strain is given as follows.

$$\Delta e = \frac{\Delta R}{4R + 2\Delta R}E$$

When $\Delta R \ll R$ this is approximated to. $\Delta e = \frac{\Delta R}{4R}E = \frac{E}{4}K\varepsilon$

The strain gauge is connected to a strain meter, which provides Wheatstone bridge circuit and exciting input voltage. The strain (ε) is measured on a digital or analog display of the strain meter.