2. Spring Material

The spring material generates a strain when external force is applied. When force is exerted to a spring material, it causes a strain, and the resistance value of the strain gauge bonded to the spring material will change. The spring material converts force into an electrical output by utilizing the same principle. In order to enhance the performance of a load cell, the characteristics of the spring material are very important. The following characteristics are required for a spring material:

1. Creep should be small. Creep is defined as the phenomenon that occurs when the deformation of an object caused by external force becomes larger with time.
2. The material should have a high proportional limit, which guarantees a wide range of linearity.
3. The secular change of the material should be small and there should be no variation of shape due to the remaining stress.
4. The resistance to impact should be high.
5. It should have good workability.

Generally, nickel-chrome-molybdenum steel, stainless steel, and aluminum steel are considered to be materials that meet the above requirements.

2.1. How the Strain Occurs

An object changes its shape when acted upon by an external force. If an object is deformed by an external force, a molecular force works between each molecule that constitutes the object, generating an internal force that tries to prevent the deformation by the external force. When the external force that the object receives is balanced with the internal force generated inside the object, the deformation of the object will cease. At this moment, the internal force per unit area that is generated on the cross section of the object is called the “stress.”

See Figure 2.4.

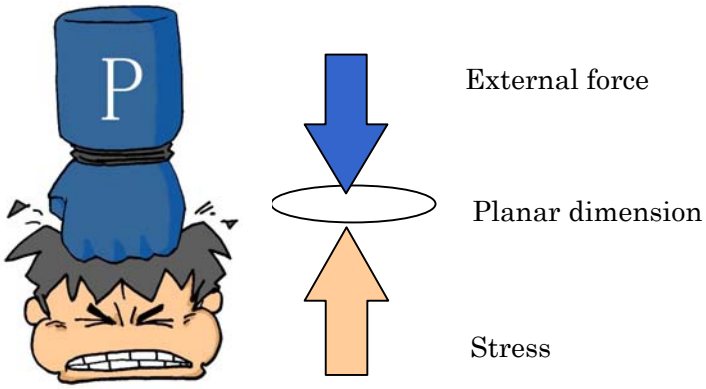


Figure 2.4

He has received a punch on the head

The fist represents an external force and the head is an object. Stress will be generated in the head in response to the external force created when the fist punches the head. When the external force of the fist is **P(N)** and the planar dimension of the head is **A(m²)**, the stress σ (sigma) is calculated as follows:

$$\sigma = \frac{P(N)}{A(m^2)} = \frac{P}{A}(Pa)$$ (Pascal)

2.2. Strain

When an object changes its form after being acted upon by an external force, the changed portion from the original dimensions expressed per unit length is called the "strain." In the dictionary, strain is defined as the proportion of change, such as elongation, contraction, contortion, etc. that occurs when an external force is applied to an object.

See Figure 2.5.

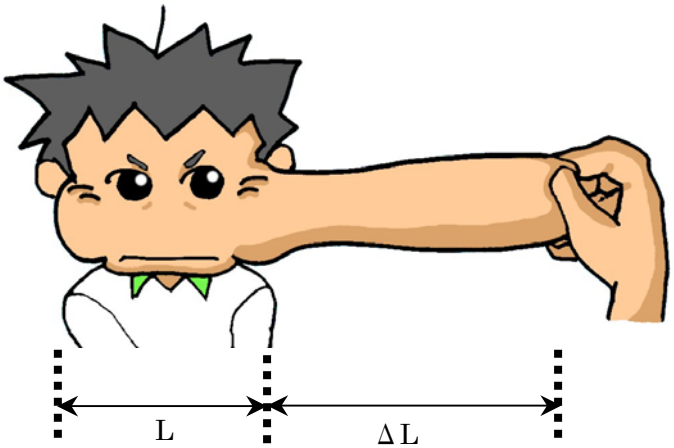


Figure 2.5

He is being pulled by the cheek.

If the original length of the cheek is **L**, and the increased length when pulled is **ΔL**, the strain **ε** (epsilon) will be expressed as follows:

$$\varepsilon = \frac{\Delta l}{l} \qquad \frac{\text{Increased length}}{\text{Original length}}$$

Strain is defined as the ratio between the original length and the increased length. Strain cannot be expressed as a unit.

2.3. Poisson Ratio

An object becomes thinner and longer when stretched. The strain in the same direction as the external force is called the "longitudinal strain" **(ε1)**, the strain at the right angle is called the "transverse strain" **(ε2)**, and the ratio between these two values, the "poisson ratio" **ν (Nu)**. Many materials have a poisson ratio of approximately 0.3.

$$\nu = \left| \frac{\varepsilon_2}{\varepsilon_1} \right| \cong 0.3$$

The elongation, which is longitudinal to the external force, is negative (+), and the contraction, which is transverse to the external force is positive (−).

2.4. Relationship between Stress and Strain

As the external force being applied to an object gets larger, first the strain increases linearly with the stress generated in the object. However, when the stress exceeds a certain limit, the linear relationship will no longer be true. This limit is known as the "proportional limit," the "elastic limit," or the "yield point." As the stress-strain relationship is linear while the stress is below the proportional limit, we can immediately determine the amount of stress based on the strain.

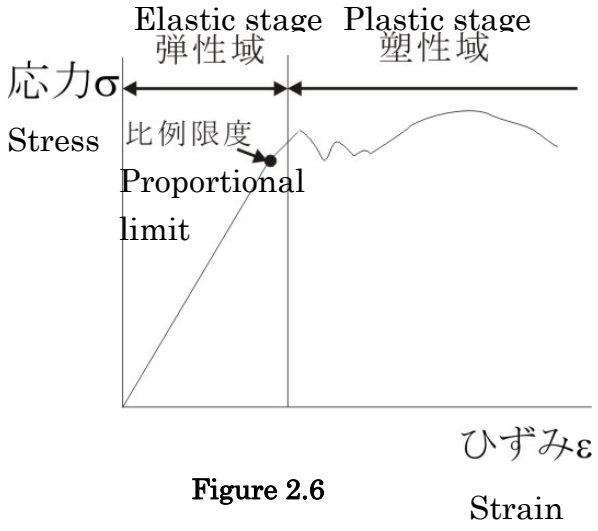
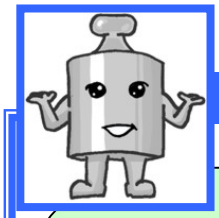


Figure 2.6

“Hooke’s law” can be used to explain the linear relationship between stress and strain below the proportional limit. The range where Hooke’s law is valid is called the “elastic stage,” whereas the range where it is not valid is called the “plastic stage.” At the plastic stage, the object will not return to its original shape even after removing the external force and the strain will remain. The remaining strain is called the “permanent strain,” or the “residual strain.”



A load cell engineer says

1. What is “creep?”
Creep refers to the phenomenon that occurs when a plastic deformation of an object increases with time under constant stress. The deformation accelerates as the temperature increases or as the stress gets larger. Creep is a salient feature of polymeric materials such as plastics.
2. What is “secular variation?”
This is the change in an object that occurs as time lapses.

Mr. K