4. The Shapes of Spring Materials and How Strains Occur

Spring materials have various shapes and each shape has different characteristics. The five most commonly used spring materials are the column, Roberval, shear, ring, and diaphragm types. Let's examine the distinctive characteristics of these five types of spring materials and the ways in which strains occur when a force is applied.

4.1. Column Type

Figure 2.7 shows a conventional column load cell. When the column is compressed by a force (F), strain gauge 1 contracts while strain gauge 2 stretches. Now, when the strain of strain gauge 1 is **ε1** and that of strain gauge 2 is **ε2**, the relationship between the two gauges is expressed as **ε2 = με1** (**μ**: Poisson ratio).

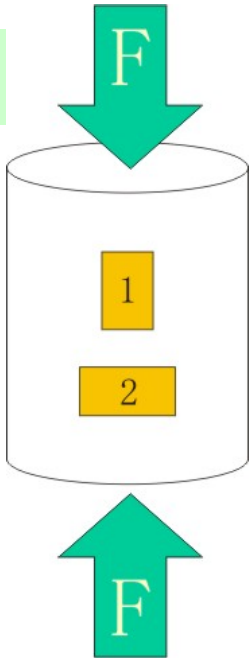

Figure 2.7 Column load cell

Since

$$\varepsilon_1 = \frac{\sigma}{E} (\sigma : \text{Stress, E : Young's modulus})$$

and

$$\sigma = \frac{F}{A} = \frac{F}{\pi R^2} (A : \text{Planar dimension}, R : \text{Radius})$$

therefore the strain that occurs in the strain gauge 1 is:

$$\varepsilon_1 = \frac{\text{F}}{\pi \text{R}^2 E}$$

$$\varepsilon_2 = \frac{\mu \times F}{\pi R^2 E}$$

The column structure is simple and this makes it possible to downsize the load cell even when the capacity is large. On the other hand, this structure is not suitable for a small capacity. Generally, the measurement range for the structure is between 2t and 300t. It can be used for both tension and compression measurements.

4.2. Roberval Type (Double-beam Type, Parallel-beam Type)

Figure 2.8 shows a conventional Roberval-type load cell.

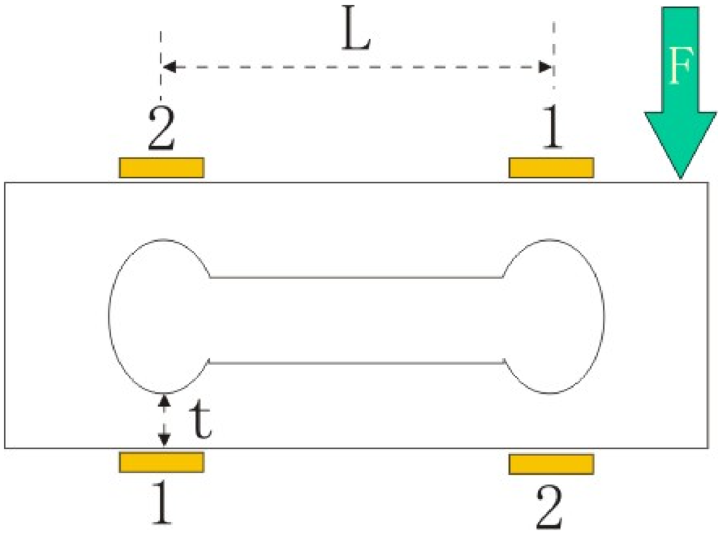

Figure 2.8. Roberval-type load cell

When a force (F) is applied to the Roberval-type load cell, strain gauge 1 contracts while the strain gauge 2 stretches.

Since

$$\varepsilon_1 = \frac{\sigma}{E}$$

and

$$\sigma = \frac{M}{Z}$$

M is the moment in the bonding area of the strain gauge

Z is the unifacial factor in the bonding area of the strain

As a result:

$$M = \frac{F \times L}{4}$$

$$Z = \frac{b \times t^2}{6} \qquad (b: \text{Thickness of the spring material})$$

The formula above is valid and therefore the strain that occurs in the strain gauge 1 will be:

$$\varepsilon_1 = \frac{3 \times F \times L}{2 \times b \times t^2 \times E}$$

$$\varepsilon_2 = -\varepsilon_1$$

This structure is suitable for high-precision load cells. The most remarkable feature of this structure is that it can make a scale with no four-corner errors without using the scale mechanism. Roberval-type load cells are used for such scales as value-weighing scales and platform scales. The measurement range is generally between 1kg and 1ton, and not suitable for large capacities.

4. 3. Shear Type

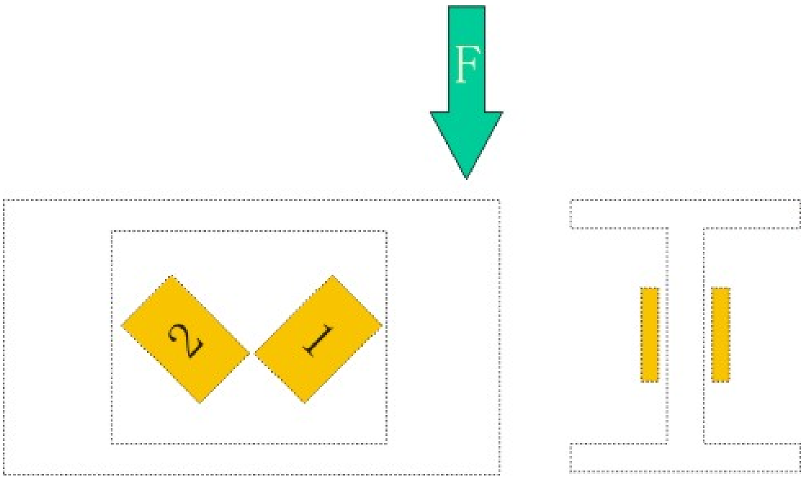

Figure 2.9. Shear type load cell

Figure 2.9 Shows a typical shear-type load cell.

Strain gauges are bonded at a 45° angle on the neutral axis of the load cell.

$$\varepsilon_1 = -\varepsilon_2$$

The above formula is valid and judging only from the results, the strain that occurs can be expressed as follows:

$$\varepsilon_1 = \varepsilon_2 = \frac{Sx}{2GIb}\int_0^{\frac{h}{2}} ydA$$

$$\int_0^{\frac{h}{2}} ydA = \frac{th_1^2}{8} + \frac{b}{2} \times (\frac{h^2}{4} - \frac{h_1^2}{4})$$

A particular characteristic of shear-type load cells is that they can be made smaller than Roberval-type load cells with the same capacity. In addition, shear-type load cells are strongly resistant to transverse loading and it is easy to make them highly precise. The measurement range is generally between 100kg and 20t.

4.4. Ring Type (Annular Type)

The shape of the spring material is shown in Figure 2.10 on the right. The ring load cell is a high precision load cell and primarily has an intermediate capacity, ranging from 500kg to 20ton.

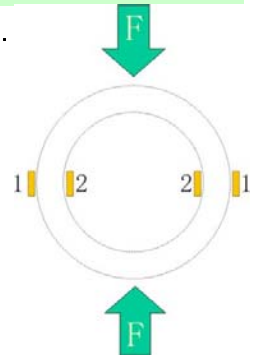

Figure 2.10 Ring load cell

4.5. Diaphragm Type

The diaphragm-type load cell has a round shape. A cross section of the diaphragm-type is shown in Figure 2.11 below. The primary advantage of using a diaphragm-type load cell is that its height can be lowered and it is resistant to transverse loading. However, the precision is approximately 1/100 at best.

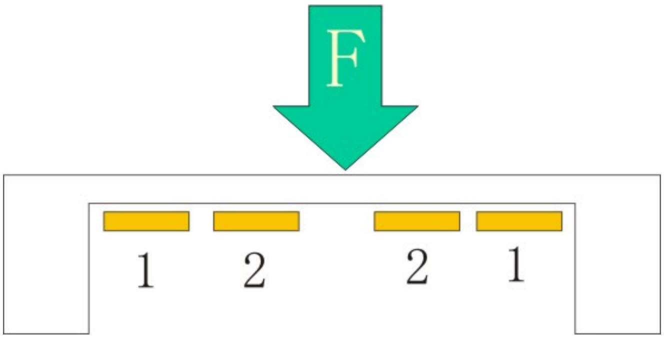

Figure 2.11. Diaphragm type load cell