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Technical Tidbits

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How much energy can your connector absorb ? This issue of Technical Tidbits discusses the importance of elastic resilience in a material.

- Resilience
- Modulus of Resilience
- Strain Energy Density

The next issue of Technical Tidbits will discuss Connector Temperature Rise.

Elastic Resilience

Those involved in the design of electronic connectors must make many choices. They choose what form of connector to use. They select a size and shape of the contacts. They determine what materials to use at the contact interface, and what normal force is required. They also select a base metal for the spring material. For the latter, they need a quick and easy way to compare base metals.

Last month's edition of Technical Tidbits introduced the concept of a material's **resilience**; the ratio of a material's yield strength to its elastic modulus. It can be used to predict the comparative performance of different materials. A highly resilient material is able to withstand greater deflections and generates higher forces than a less resilient material. Resilience is also non-dimensional. This material property will have the same value in any system of units, which makes it easy to compare specifications of different materials, even if their respective data sheets consist of different units.

Resilience does have some drawbacks. A low strength material with a very low modulus will have a high resilience. In some cases, a lower resilience material will create a higher force. For example, let us compare the performance of two different materials used in the same cantilever beam. Let us set the length as 1.0 inch, the width as 0.5 inches, and the thickness as 0.010 inches. We will compare 1/2 H temper 510 phosphor bronze with T6 temper 7075 aluminum. As shown in Table 1, the aluminum alloy has a higher resilience. However, the phosphor bronze alloy will create a higher force due to its greater yield strength. Resilience is generally best used to compare alloys with similar elastic moduli. Fortunately, the elastic moduli of copper alloys do not vary greatly.

$$d_{yield} = \frac{2 \cdot L^2}{3 \cdot E \cdot t} \cdot \sigma_{yield}$$

$$F_{yield} = \frac{w \cdot t^2}{6 \cdot L} \cdot \sigma_{yield}$$

	Yield Strength (psi)	Elastic Modulus (psi)	Resilience	Max. Def. (in)	Max. Force (lb)
Ph. Bronze	81,000	16.0E+6	0.0051	0.34	0.68
Aluminum	58,000	10.3E+6	0.0056	0.38	0.48

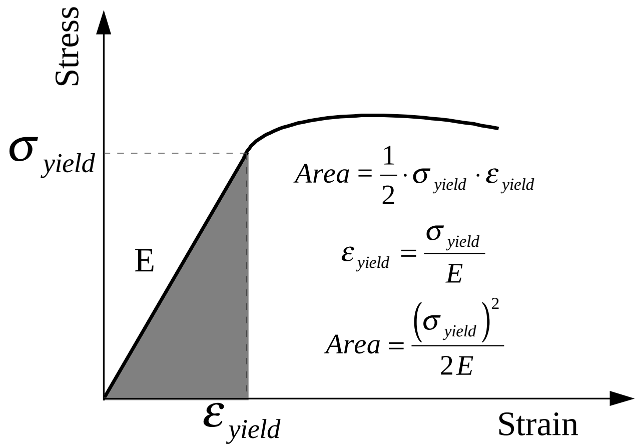
Table 1. Property Comparison Phosphor Bronze vs. Aluminum.

However, there is a related parameter that probably gives a better indication of the performance of a spring material. Take another look at the equations for the maximum allowable force and deflection of a cantilever beam. Notice that the deflection at yield depends on the resilience, and the force at yield depends on the yield strength. For the best performance, we want high allowable deflection and high force. Therefore, we would like the product of these two terms to be as high as possible. All those who remember physics know that a force multiplied a distance results in work, which is equivalent to energy. Therefore, the product of the force and deflection gives the energy required to deflect the beam. The equation below derives the maximum strain energy absorbed by the beam before it yields.

$$Energy_{max} = Work_{max} = F_{max} \times d_{max} = \frac{2 \cdot L^2}{3 \cdot E \cdot t} \sigma_{yield} \times \frac{w \cdot t^2}{6 \cdot L} \cdot \sigma_{yield} = \frac{2}{9} \cdot (w \cdot L \cdot t) \cdot \frac{(\sigma_{yield})^2}{2 \cdot E}$$

Notice that the twos in the numerator and denominator have not been cancelled by each other. The reason is that the term on the far right of the equation is a special quantity, known as the **modulus of resilience**. This is a quantity that can be derived from a material's stress-strain curve, as shown in figure 1. The area under the curve at any point is the **strain energy density** (strain energy per unit volume) required to stress the material to that point on the curve. The modulus of resilience is the area under the curve up to the yield strength. Therefore, The modulus of resilience is the strain energy density required to stress the material to its yield strength.

Let us re-examine the equation for the energy absorbed by a cantilever beam deflected up to its yield point. The term on the far right is the strain energy per unit volume at the yield point. The center term is the volume. These two multiplied together give the total strain energy. The 2/9 term is merely a shape factor for the cantilever beam. (In this case, it is a straight cantilever beam with a rectangular cross section.)



$$Energy_{\max} = \frac{2}{9}\cdot(w\cdot L\cdot t)\cdot\frac{(\sigma_{yield})^2}{2\cdot E}$$

Figure 1. Derivation of the modulus of resilience using a stress-strain curve.

This strain energy is entirely elastic, which means that it will want to recover when the load is removed. Until the load is removed, all of the strain energy works to maintain a normal force at the point of contact. Higher strain energy means better contact force. Therefore, the modulus of resilience gives an indication of the ability of the material to perform in a contact spring under load.

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