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How Much Elastic Strain Energy can your Spring Contact Absorb? – A discussion of the importance of elastic resilience in spring contact design.

- **Resilience**
- **Modulus of Resilience**
- **Strain Energy Density**

The next issue of Technical Tidbits will discuss temperature rise in electronic connectors.

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.

The prior 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 four 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, T6 temper 7075 aluminum, 25 ½ HT temper copper beryllium, and 301 H temper stainless steel. As shown in Table 1, the phosphor bronze and stainless steel have nearly equal resilience. However, the steel alloy will create a higher force due to its greater elastic modulus. Resilience is generally best used to compare alloys with similar elastic moduli. Fortunately, the elastic moduli of copper alloys do not vary greatly. Note that the copper beryllium has the highest resilience, and the greatest maximum deflection and contact force.

Material	Alloy	Temper	Yield Strength psi	Elastic Modulus psi	Elastic Resilience -	Max Deflection (in)	Max Force (lbs)	Modulus of Resilience (psi)
Phos. Bronze	510	H	81.0E+3	16.0E+6	5.06E-03	0.34	0.68	205
Alumnimum	7075	T8	58.0E+3	10.3E+6	5.63E-03	0.38	0.48	163
Copper Beryllum	25	1/2 HT	177.5E+3	19.0E+6	9.34E-03	0.62	1.48	829
Stainless Steel	301	H	140.0E+3	28.0E+6	5.00E-03	0.33	1.17	350

Table 1. Property Comparison among Various Spring Materials.

$$d_{yield} = \frac{2 \cdot L^2}{3 \cdot E \cdot t} \cdot \sigma_{yield} \qquad F_{yield} = \frac{w \cdot t^2}{6 \cdot L} \cdot \sigma_{yield}$$

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:

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

Elastic Resilience (continued)

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. Note the values for modulus of resilience in the last column of Table 1. Copper beryllium provides the greatest deflection because of its high resilience value, and the highest contact force because of its modulus of resilience value.

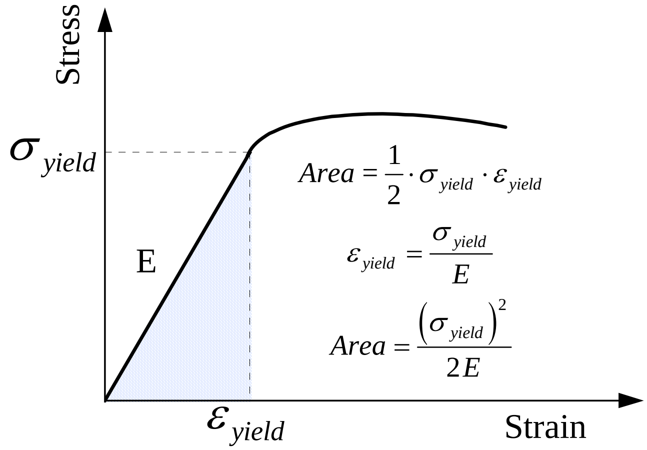

Figure 1. Derivation of the Elastic Resilience from a Stress-Strain Curve.

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.)

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

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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TECHNICAL TIDBITS

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Please contact your local sales representative for further information on resilience or other questions pertaining to Brush Wellman or our products.

Health and Safety

Handling copper beryllium in solid form poses no special health risk. Like many industrial materials, beryllium-containing materials may pose a health risk if recommended safe handling practices are not followed. Inhalation of airborne beryllium may cause a serious lung disorder in susceptible individuals. The Occupational Safety and Health Administration (OSHA) has set mandatory limits on occupational respiratory exposures. Read and follow the guidance in the Material Safety Data Sheet (MSDS) before working with this material. For additional information on safe handling practices or technical data on copper beryllium, contact Brush Wellman Inc.