Issue No. 30 – June 2011 **Updated from Original December 2001 Publication**

Squaring the circle! – A continued discussion on the relative merits of strip or flat wire versus round wire for use in electronic connectors.

- **Cantilever Beam Equations**
- **"Free" Contact Force**

The next issue of Technical Tidbits will introduce coating options for electrical contacts.

Round vs. Rectangular Cross Sections

Electrical and electronic connectors are complete systems encompassing contacts that are typically formed from a copper alloy base metal, plated with precious or non-precious metal, and then molded or inserted into a plastic housing. The last edition of Technical Tidbits focused on how the form of the base metal can be just as important as the alloy and temper in determining the characteristics of the contact spring. This issue will present a brief discussion of the advantages of contact springs with rectangular cross sections over those with round cross sections. Future editions will focus on the appropriate types and amounts of plating in connector applications.

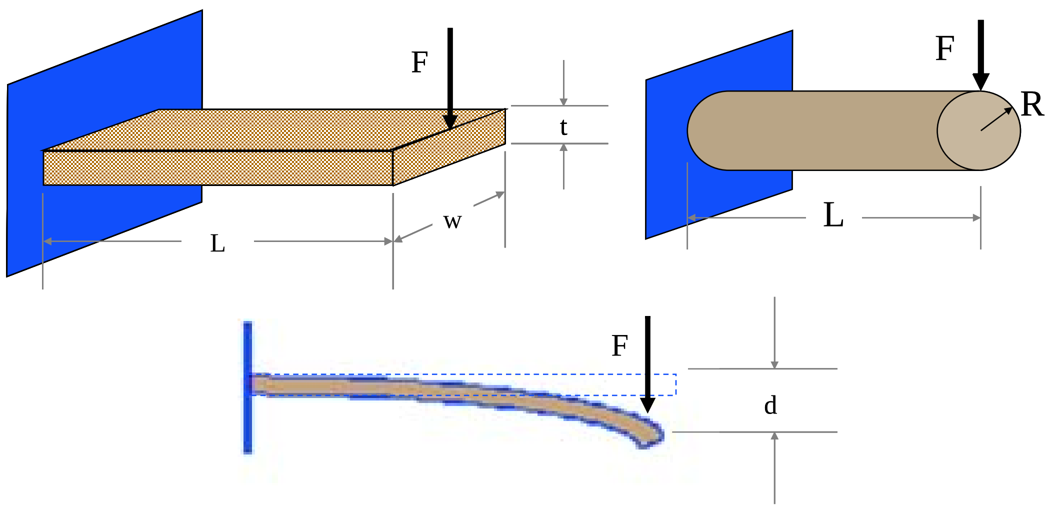

Figure 1. Nomenclature used in cantilever beam discussion.

This discussion will start with a quick review of **cantilever beam equations**, which lie at the heart of contact spring design. Figure 1 above defines the terms used in the following discussion. The equations that calculate the maximum surface stress of round and rectangular cantilever beams are shown in figure 2. Here, E is the elastic modulus of the material, L is the length, d is the deflection, t is the thickness of the rectangular strip, and D is the diameter of the round wire. Note that the equations are very similar, and the only difference is the thickness/diameter term. Image a round and a rectangular cantilever beam that have the same length, are made of materials with identical moduli of elasticity, and are subjected to the same deflection. If the thickness of the strip is equal to the diameter of the wire, the two beams will experience the same maximum surface stress. If the thickness and diameter are different, then the stress ratio of the stresses will be equal to the ratio of the thickness and diameter.

$$\sigma_{\text{rectangular}} = \frac{3 \cdot E \cdot t}{2 \cdot L^2} d \qquad \sigma_{\text{round}} = \frac{3 \cdot E \cdot D}{2 \cdot L^2} d \qquad \frac{\sigma_{\text{rectangular}}}{\sigma_{\text{round}}} = \frac{t}{D}$$

Figure 2. Maximum stress equations for cantilever beams with round and rectangular cross sections.

Round vs. Rectangular Cross Sections (continued)

The equations that calculate the contact force of cantilever beams are slightly more complicated. They are shown below in figure 3. The contact force is directly proportional to the area moment of inertia, I, of the cross section. Imagine the pair of spring beams from the example in the previous paragraph, where the thickness and diameters are the same. If the width of the strip is the same as the thickness, giving a square cross section, then the contact force of the beam with the square cross section will be 70% greater than the beam with the circular cross section. If the width is further increased, then the rectangular cross section will have an even greater advantage in contact force, without the penalty of any additional stress. *Square or rectangular cross sections will always have an advantage over round cross sections of the same thickness, as long as the width of the rectangle is at least 58.9% of the thickness.*

$$I_{\text{rectangular}} = \frac{w \cdot t^3}{12} \qquad I_{\text{round}} = \frac{\pi \cdot D^4}{64} \qquad F = \frac{3 \cdot E \cdot I}{L^3} d$$

$$F_{\text{rectangular}} = \frac{E \cdot w \cdot t^3}{4 \cdot L^3} d \qquad F_{\text{round}} = \frac{3 \cdot \pi \cdot E \cdot D^4}{64 \cdot L^3} d \qquad \frac{F_{\text{rectangular}}}{F_{\text{round}}} = \frac{16 \cdot w \cdot t^3}{3 \cdot \pi \cdot D^4}$$

Figure 3. Contact force equations for cantilever beams with round and rectangular cross sections.

An increase in the width of a contact can almost be described as **"free" contact force**, in the sense that one does not have to pay for the increased force with any additional stress. (There will be a penalty of increased space required for the contact, however.) To increase contact force with round wire, one would have to increase the diameter, which also increases the stress. However, the increase in contact force would be 4 times as great as the increase in stress, so all is not lost.

Round wire will in most cases be less expensive to process than strip material. For example, round wire would not have to be slit to the appropriate width, as would be the case with strip. The use of round wire would eliminate much of the scrap generated by stamping contacts from strip. Thus, wire should not be ruled out of the question entirely, if it can provide acceptable performance. If an engineer were to design a contact with a constant cross section, (such as a modular data jack contact) round wire may be the optimum choice, if the force requirements were not too stringent. However, very few designs would actually meet the necessary requirements for the use of wire. In all other cases, strip would be the appropriate choice for base material, with all of the advantages in contact force provided by its rectangular cross section.

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TECHNICAL TIDBITS

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