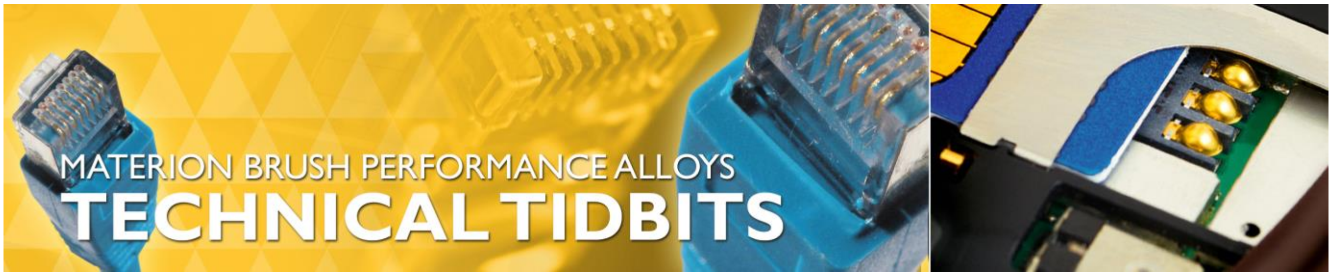

Issue No. 81 – September 2015 **New Publication**

The spring of springs. – This is what most people picture when they think of springs.

- **Coil Spring**
- **Extension Spring**
- **Compression Spring**
- **Pitch**
- **Open End (Plain End)**
- **Closed End**
- **Ground End**
- **Active Coil**

The next issue of Technical Tidbits will continue the discussion on spring types, focusing on bellows and diaphragms.

Spring Types Part 6 – Coil Springs

This series of six or so (now up to eight or so) editions of Technical Tidbits will discuss various types of springs used in electrical contacts or sensors, and group them into six broad categories of similar function (cantilever beams, simply supported beams, torsion bars, Belleville washers, coil springs, and bellows & diaphragms). This month we will focus on coil springs.

If you ask any random person on the street to picture a spring, odds are pretty good that they will not be thinking about cantilever beams, torsion bars or Belleville washers. Instead, they will probably picture a **coil spring.** If you are reading this article, you will likely need no description of the appearance or function of these springs, but we will do it anyway, since coil springs are fun to draw in CAD programs.

Coil springs come in two varieties, **compression springs** and **extension springs**. (Figure 1). The only real difference is that compression springs may have flattened (closed) or ground ends that press up against the components to be kept apart, while extension springs typically have hooked ends which grab onto the two components to be held together. Otherwise, they are functionally identical.

Figure 1. Coil Springs. The open-ended spring on the left is about as generic as a coil spring can get. The same spring is shown as a compression spring with closed ends in the middle, with the addition of flat, non-active coils at its top and bottom. On the right is the same spring as an extension spring, with hooks added to its top and bottom.

Table 1 below shows the possible end conditions for compression springs. If the **pitch** (distance between the centers of successive coils) of the spring is constant all the way to the end of the spring, then it is an open end. If the last coil is flattened and its end is allowed to touch the neighboring interior coil, then it is considered a closed end. If the spring end must be flat to better mate with a flat surface, the end may be ground flat. This can be done with either open or closed end springs.

	Open End	Closed End
Unground End		
Ground End		

Table 1. End Types. Ends may be either open or closed, and may also be ground.

Coil Springs (continued)

The material that makes up a cantilever beam in bending has a bending stress state. Torsion bars that are loaded in pure torsion have stress states that are pure torsion. In these cases, the stress state in the material intuitively matches the loading mechanism. So, do extensions springs exist in a state of tensile stress while compression springs exist in a state of compressive stress? The answer is no. In both loading cases, the wire in compression and extension coil springs is actually loaded in torsion, so the primary stresses are shear stresses and not normal stresses, unlike the other springs discussed in previous editions.

For a spring made of round wire, the equations for contact force (P) and maximum shear stress (τ) as a function of deflection (δ) are as follows (G = modulus of rigidity, D = mean diameter of the helix, d = diameter of the wire coiled into the spring, and N_A= number of active coils):

$$P = \frac{G\cdot d^4}{8\cdot D^3\cdot N_A}\delta, \quad \text{and} \quad \tau = \left[\frac{4(D/d)-1}{4(D/d)-4} + \frac{0.615}{(D/d)}\right]\cdot\frac{8\cdot D}{\pi\cdot d^3}P = \left[\frac{4(D/d)-1}{4(D/d)-4} + \frac{0.615}{(D/d)}\right]\cdot\frac{G\cdot d}{\pi\cdot D^2\cdot N_A}\delta$$

Figure 2. Various Types of Coil Springs. The boring spring on the far left is straight-sided and has constant pitch. The three constant-pitch springs in the middle are tapered into conical, barrel, and hourglass shapes, respectively. The spring on the far right is straight sided, but has variable pitch. Variable pitch springs may also be tapered, if required.

The above equations, valid for both compression and extension springs, contain only 3 geometric variables. Namely, input wire diameter, mean diameter of the spring, and number of **active coils**. (other equations describe the behavior of coil springs made out of square or rectangular wire, instead of round, and are not published here.) Active coils are the coils that are free to move when the spring is compressed or extended. In extension springs, it is all the coils. In straight sided compression springs, it is all the coils except those that are part of a closed end. If a compression spring is sufficiently tapered such that each successive coil can nest within the previous coil, then all the coils are active.

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