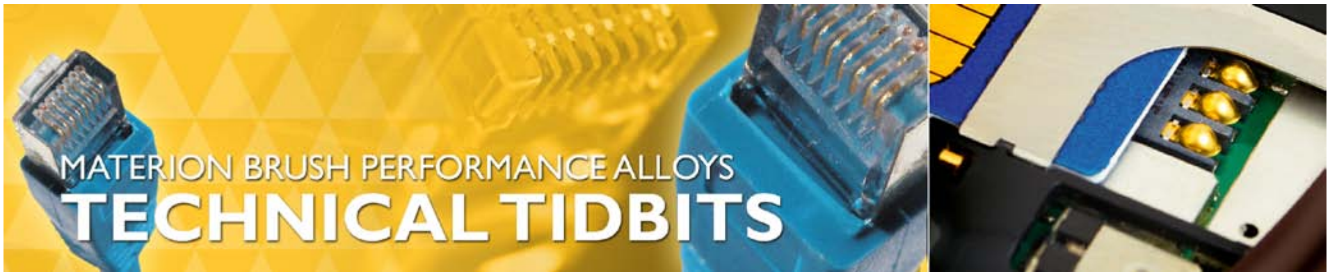

Issue No. 47 – November 2012 **Updated from Original January 2005 Publication**

Good designs yield to no one! – An in-depth discussion on yield strength and related properties.

- **Proof Strength**
- **Proportional Limit**
- **Elastic Limit**
- **0.2% Offset Yield Strength**
- **0.5% Extension Under Load Yield Strength**
- **Safety Factor**
- **Spring Bend Limit**

The next issue of Technical Tidbits will discuss the elastic modulus.

Yield Strength and Other Near-Elastic Properties

(This issue of Technical Tidbits continues the materials science refresher series on basic concepts of material properties.) The yield strength (also known as the **proof strength**) may be the most important material property to consider when designing electronic and electrical contacts and connectors. However, in most cases it is actually a derived property, and not a well-defined point on the stress-strain curve where material behavior changes. In fact, there are several types of yield strengths, each with its own definition.

As was stated in the previous edition of Technical Tidbits, the stress and strain in the first portion of a material's stress-strain curve are linearly proportional to each other. This forms a straight line on the stress-strain diagram, with a slope know as the elastic modulus of the material. The stress level at which the stress-strain response first begins to deviate from linear behavior is known as the **proportional limit**, shown below as the green line in Figure 1.

The name yield strength seems to imply that it is the level of stress at which a material under load ceases to behave elastically and begins to yield. This is not the case. The point at which the material first begins to experience permanent set is known as the **elastic limit** (shown as the black line in Figure 1 below.) Material that is loaded to a stress level below the elastic limit will completely return to its original size and shape, if the load is released immediately. Conversely, material that is loaded to a stress level greater than the elastic limit will have experienced some degree of permanent set. The yield strength is defined as the level of stress that produces a specific amount of permanent set. This means that by the time the yield strength is reached, the base material has already yielded (undergone permanent set) by definition.

The **0.2% offset yield strength** (0.2% OYS, 0.2% proof stress, $R_{P0.2}$, $R_{P0,2}$) is defined as the amount of stress that will result in a plastic strain of 0.2%. This is illustrated by the blue line in Figure 1 below. This is the yield strength that is most often quoted by material suppliers and used by design engineers. If a different permanent set is specified, then there will be a different yield strength associated with that strain level. For example, the orange line in the figure below would represent the 0.01% offset yield strength. In some cases, particularly with low strength rod or wire, it is difficult to accurately measure the plastic strain. In this case, the total strain is measured, and the **0.5% extension under load yield strength** (0.5% EUL, RT0.5) is listed instead.

In order to ensure that a designed connector does not yield in service, a safety factor should be used when calculating the design stress. A maximum stress level of 75% of the yield strength (corresponding to a **safety factor** of 1.0 / 0.75 = 1.33) has historically been used. Recently, the predictive capability of finite

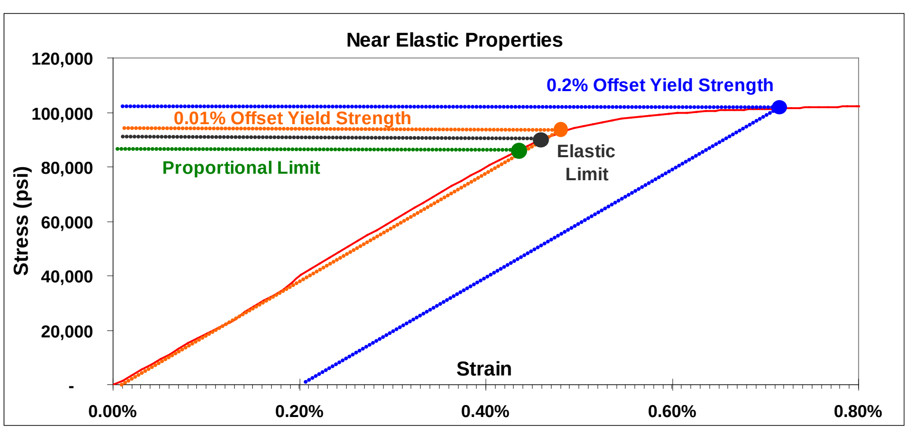

Figure 1. Stress-strain curve in the near elastic region.

Yield Strength and Other Near Elastic Properties (continued)

element analysis has allowed designs to proceed with safety factors approaching or even descending below 1.0, if a minor amount of permanent set is not detrimental and can be tolerated.

Another popular property that is often specified by material suppliers and designers, especially those in Asia, is **the spring bend limit**. This is not a property that is determined by the uniaxial tension test, but must be determined by its own specific spring bend limit test. In this test, a small sample of strip is repeatedly loaded and unloaded in bending by small increments until permanent set is observed. (This is similar to how the precision elastic limit is determined in tension.) There are several spring bend limit tests in use today. Interestingly, there appears to be no general correlation between the results from different spring bend limit tests, nor between the results from any spring bend limit test and the precision elastic limit test. Additionally, the spring bend limit is sensitive to the orientation of the sample (i.e., coilset-up or coilset-down orientations).

Typically, when designing a contact, materials with greater yield strengths will provide greater design flexibility by allowing for higher stress levels. However, since formability generally tends to decrease as yield strength increases, higher strength tempers of a given material will offer less design flexibility than the lower strength tempers. Therefore, it is imperative to find the material with the highest strength that also meets the formability requirements of the design. Figure 2 below shows the 0.2% offset yield strength as a function of formability for copper alloys commonly used in connector applications. The copper beryllium alloys shown in blue offer the greatest yield strength for a given formability level, and vice versa. These alloys will provide designers with the greatest amount of flexibility for a given strength level.

Although there are many ways to define it, the yield strength is probably the most important material property to consider when selecting a material for a design application.

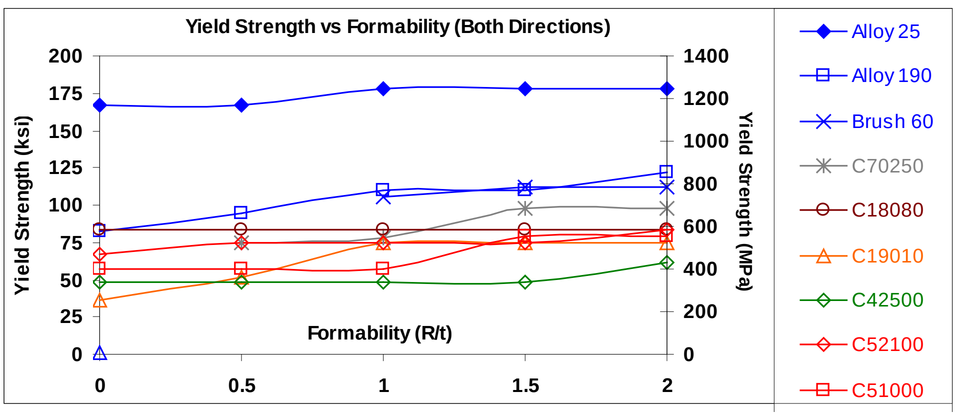

Figure 2. Yield strength vs. formability for common copper-based connector alloys.

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ASTM E8

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