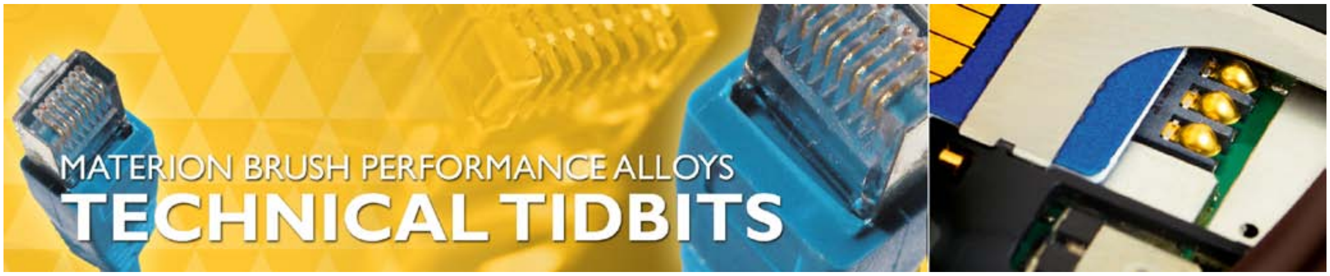

Issue No. 45 – September 2012 Updated from Original May 2004 Publication

As if life weren't stressful enough! – A discussion that goes back to the basics with an in-depth discussion of stress and strain concepts.

- **Engineering Stress & Strain**
- **Elastic Modulus**
- **Elastic Limit**
- **Elastic & Plastic Strain**
- **Permanent Set**
- **Yield Strength**

The next issue of Technical Tidbits will continue the discussion on stress and strain concepts.

Stress-Strain Concepts Revisited – Part 1

(A number of requests came in 2004 for Technical Tidbits to revisit and reinforce some basic concepts on material properties. In response to this, Technical Tidbits is supplying a refresher on basic materials science for design engineers.) The uniaxial tensile test may very well be the most useful material characterization test available. It works simply by continuously measuring the force required to elongate a test specimen by increasing increments until it fractures. The test measures a number of important material properties as illustrated below. Most importantly, it generates stress-strain curves, which are the unique identifiers of each material tested (each material's DNA, so to speak).

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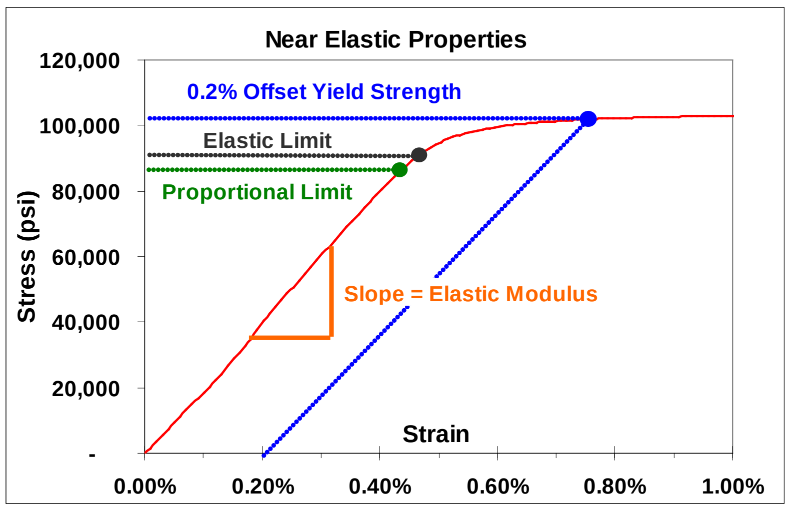

Figure 1. Stress-Strain Curve in the Near-Elastic Region.

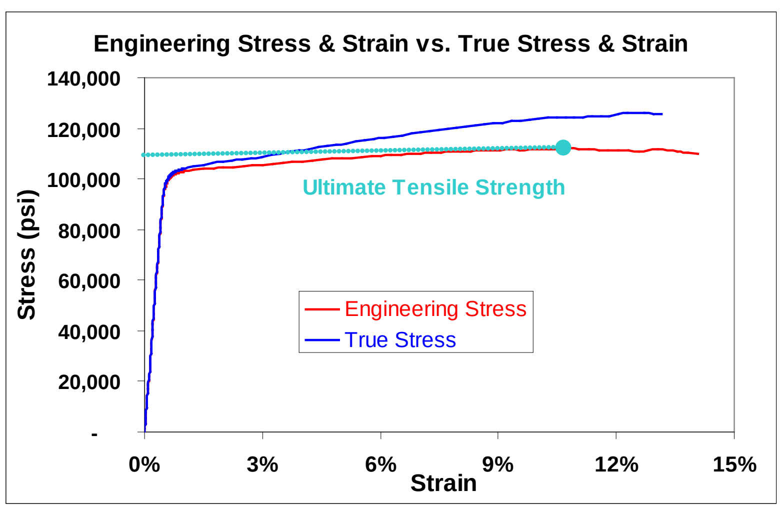

Figure 2. Alloy 17410 HT True and Engineering Stress-Strain Curves

Stress-Strain Concepts Revisited (continued)

Engineering stress is defined simply as instantaneous force divided by the original cross-sectional area of the test specimen. **Engineering strain** is simply the change in test specimen length divided by the original length, usually specified as a percentage. As the test proceeds, the force required to elongate the specimen increases linearly (for most materials) up to a point known as the proportional limit, as shown in green in Figure 1. The slope of the curve up to this point is known variously as the **elastic modulus**, Young's modulus, or modulus of elasticity.

If one lightly strains (deforms) an object, it will usually return to its original, undeformed shape when the load is removed. This is referred to as elastic behavior. However, if the stress is high enough, the object will permanently deform. This is referred to as plastic behavior. The **elastic limit** on a stress-strain curve is the point where the behavior of the material switches from elastic to plastic. If the stress (and therefore strain) applied to a material is lower than the elastic limit, both the stress and strain will return to zero (recover) when the load is removed. If, however, the elastic limit is exceeded, only the **elastic strain** will be recovered, and the **plastic strain** will remain as **permanent set**. The stress in the material will unload along a path parallel to the elastic modulus.

Since it is usually undesirable to experience permanent set in a component, engineers would like to design parts so that the expected service stress is less than the elastic limit by some reasonable factor of safety. However, the elastic limit cannot be accurately determined by a tensile test. Instead, it is found by the much more time consuming precision elastic limit test. However, it is easy to determine an **offset yield strength** from the stress-strain curve generated by a tensile test. For this reason, the yield strength of a material is more often specified than the elastic limit. The yield strength is determined by finding the stress corresponding to a specified amount of permanent set, usually 0.2% strain for strip (or 0.5% extension under load for low strength rod and wire). The 0.2% offset yield strength is found by drawing a line parallel to the elastic modulus from the 0.2% mark on the strain axis through its intercept with the stress-strain curve. (This is demonstrated by the dotted blue line in Figure 1.) Together, the yield strength, elastic limit and **proportional** limit are known as the near-elastic properties.

There are additional properties that can be obtained from the stress-strain curve. These will be covered in Part 2 of this edition of Technical Tidbits. Future editions of Technical Tidbits will focus on these properties in detail.

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References:

Technical Tidbits Issue #27 "Tensile Testing"

Technical Tidbits Issue #1 "Why Good Designs Fail"

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