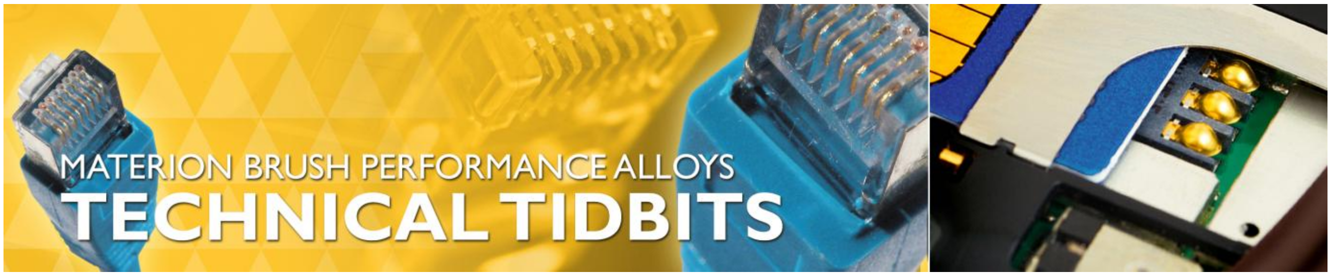

Issue No. 49 – January 2013 **Updated from Original July 2005 Publication**

No need for tension headaches – An in-depth discussion on the ultimate tensile strength and related properties.

- **Ultimate Tensile Strength**
- **Uniform Strain**
- **Non-uniform Strain**
- **Necking**
- **Total Strain**

The next issue of Technical Tidbits will discuss strain hardening.

Tensile Strength Considerations

(This issue of Technical Tidbits continues the materials science refresher series on basic concepts of material properties.) The **ultimate tensile strength**, often referred to simply as the tensile strength, is one of the most frequently cited material properties. This is in spite of the fact that it is almost an irrelevant property for some design engineers. Failure of electrical contacts would most likely occur by excessive permanent set, stress relaxation or fatigue at stress levels well below the tensile strength. Most designs that operate near the tensile strength would be virtually certain to fail by one of these mechanisms during the expected product lifetime (unless it is a onetime, permanent connection not subjected to elevated temperatures or cyclical loading.)

Unlike the yield strength, the tensile strength of a material is very easy to identify. Figure 1 shows a typical stress-strain curve for C17410 HT copper beryllium strip. (Astute readers will note that it has appeared in two of the last three additions of Technical Tidbits, albeit with different properties highlighted.) The tensile strength represented by the dot is the highest level of engineering stress experienced during the tensile test. Up to this point, the tensile specimen continues to uniformly elongate along the axis and uniformly contract in cross-sectional area. The strain associated with this uniform elongation is called **uniform strain**. Note that the uniform strain will have both elastic and plastic components.

After the tensile strength has been reached, the specimen will undergo **non-uniform strain**. Most of the remainder of the deformation will be highly localized in a phenomenon known as **necking** (Figure 2). The **total strain** experienced by the specimen will be the sum of the uniform and non-uniform strain. During non-uniform deformation, the minimum cross-sectional area decreases as the test proceeds, so the engineering stress (force divided by the original cross-sectional area) falls off as the strain increases. The engineering stress continues to decrease until the sudden fracture at the conclusion of the test. Note that on an engineering stress-strain curve, the fracture strength is actually lower than the tensile strength. On a true stress-strain curve, the stress will continue to increase to failure. However, unless the minimum cross-sectional area is continuously measured so that the true strain can be accurately calculated, the calculated true stress will have no meaning beyond the tensile strength.

In ductile materials, the necked- down region will look like two truncated cones stacked tip to tip, with side slopes of 45 degrees. This happens during non-uniform strain, when dislocations in the crystalline microstructure slide past other portions of the crystalline matrix in the direction of maximum shear stress, which happens to be 45 degrees from the direction of force under uniaxial tension. On the other hand, brittle materials will tend to fracture without (or with very little) plastic deformation. In that case, the elastic limit, tensile strength and fracture strength will be virtually identical. Brittle fractures will tend to be very rough and perpendicular to the axis of deformation. (See Figure 3)

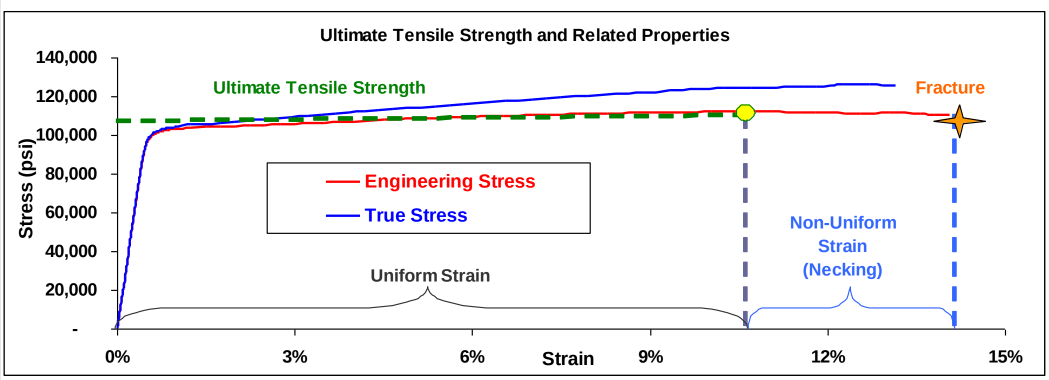

Figure 1. Stress-strain properties near failure

Tensile Strength Considerations (continued)

The safety factor of a design is usually defined as a function of the yield strength of a material. In most cases, 75% of the 0.2% offset yield strength is considered an acceptable maximum stress level. This ensures that the stress relaxation behavior of the material is within acceptable limits and that there will be little, if any, permanent set. However, some specifications, particularly US military specifications, define the maximum allowable stress as a percentage of the tensile strength, such as 50%. (This is typically the case when there are a large number of expected cycles and fatigue failures can be an issue.) A maximum allowable stress level that low would virtually guarantee that the behavior of the material would be entirely elastic, since the maximum allowable stress is likely to be no more than 60% of the yield strength (at least in copper alloys). This is demonstrated in Table 1 below. For any industry other than aerospace, however, such a design criterion would most likely be overly conservative, resulting in over-designed parts and unnecessary costs. (However, applications that would be expected to experience a high number of cycles without fatigue failure may indeed require stress levels significantly below the yield strength in order to ensure that the part does not fail in fatigue.)

Tensile strength is an easily defined material property, although it has limited practical applications. The 0.2% offset yield strength will usually provide a better indication of material success or failure. High strength materials like copper beryllium will usually provide a robust design that is unlikely to fail by yielding, overload fracturing or fatigue.

Alloy	Temper	UTS	YS	UTS/2 YS		Alloy	Temper	UTS	YS	UTS/2 YS
C17200 (25)	TH04	205	185	55%		C70250	TM03	113	108	52%
C17200 (190)	TM08	183	165	55%		C18080	TM08	83	80	52%
C17460 (390)	TH04	174	144	60%		C19210	H10	72	70	51%
C17410 (174)	TH04	120	110	54%		C52100	H06	106	79.8	66%

Table 1. Tensile Properties and Safety Factor (in ksi) as a Percentage of the Yield Strength for CuBe (left) and Other Common Connector Materials (Right)

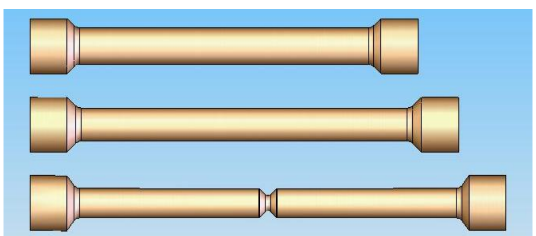

Figure 2. Undeformed (Top), Uniformly Deformed (Middle), and Non-Uniformly Deformed/Necked (Bottom) Tensile Samples

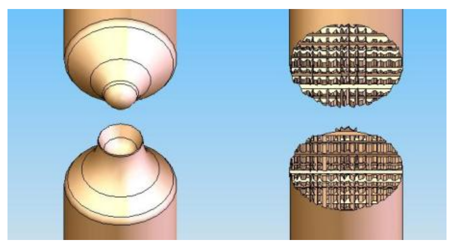

Figure 3. Exaggerated Representation of Ductile (Left) and Brittle (Right) Fractures of Tensile Samples

Written by Mike Gedeon of Materion Brush Performance Alloys Customer Technical Service Department. Mr. Gedeon's primary focus is on electronic strip for the telecommunications and computer markets with emphasis on Finite Element Analysis (FEA) and material selection.

TECHNICAL TIDBITS

Materion Brush Performance Alloys
6070 Parkland Blvd.
Mayfield Heights, OH 44124
(216) 486-4200
(216) 383-4005 Fax
(800) 375-4205 Technical Service

MATERION

References:

Technical Tidbits Issue #1 "Why Good Designs Fail"

Technical Tidbits Issue #27 "Tensile Testing"

ASTM E8

ASTM E6

Please contact your local sales representative for further information on tensile strength or other questions pertaining to Materion 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,