MATERION

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TECH BRIEFS

Tensile Testing High Performance Copper Alloy Strip

The mechanical properties of Materion Brush Performance Alloy wrought products are most frequently measured by the simple uniaxial tensile test. The test provides information that can be used in component design. Tensile test information is also used in materials acceptance and in the process control of operations such as stamping, bending, rolling, machining, drawing and slitting. The test itself is relatively simple, but interpretation and use of the test data for these alloys require a thorough understanding of both the test procedure and the alloy's behavior during testing.

THE TENSILE TEST

Depending upon the sample configuration and the test equipment available, a wide range of test fixtures, grips, and stress and strain measuring devices can be used. Materion Brush Performance Alloys uses the test procedure described in ASTM E 8 (Standard Test Methods of Tension Testing Metallic Materials) for measurement and certification of tensile properties on all wrought alloy shipments. This test procedure allows wide latitude in selection of test conditions, equipment, and sample configurations.

Copper beryllium's properties are moderately strain rate sensitive for test speeds in the strain rate range of 0.005-0.2 min-1. The test is conducted at a constant speed or strain rate, although the speed may be step increased after the sample reaches the yield stress in order to minimize testing time for high elongation alloys.

For testing of strip, reduced section ("dog bone") test pieces are most often used, but straight sided strip samples are also acceptable. The test sample axis is oriented along the longitudinal or the rolling direction of the strip. Any sample preparation technique that produces a smooth, stress free edge can be used. The edges should be lightly polished with emery cloth to remove nicks or burrs that can cause premature and inaccurate test results. Materion Brush Performance Alloys' testing of strip products uses a 0.5 inch (12.5 mm) wide test sample with a 2 inch (50 mm) gauge length.

For heavy gauge or bulk products, tensile test bars are machined to either a 0.35 inch (9 mm) diameter by 1.40 inch (36 mm) long gauge section or 0.5 inch diameter by 2 inch gauge section. As with strip samples, ASTM E 8 requires a gauge length that is at least four times the gauge diameter. Tensile bar machining is done to a 63 microinch (1.5 μm) maximum rms surface finish, with at least 0.003 inch (0.08 mm) depth cut on the final machining pass to minimize surface stress in the bar.

The output from the tensile test is the engineering stress strain curve shown schematically in Figure 1. Stress, on the vertical axis, is the test load divided by the cross sectional area of the sample. Stress is expressed in units of pounds/in^2 (psi or lbf/in^2), thousands of pounds/in2 (ksi) or, in SI units of Newton's/mm^2 (N/mm^2) or megapascals (MPa). A megapascal is defined as 1 N/mm2. Less frequently, metric stress is given in kilograms/mm2 (kg/mm2 or kgf/mm2). Table 1 lists conversions for stress units.

psi	x 1000	= ksi
ksi	x 6.895	= N/mm^2
ksi	x 6.895	= MPa
ksi	x 0.703	= kg/mm^2
kg/mm^2	x 9.807	= MPa
MPa	x 1	= N/mm^2
MPa	x 0.102	= kg/mm^2
MPa	x 0.145	= ksi
N/mm^2	x 0.145	= ksi
kg/mm^2	x 1.422	= ksi

Table 1. Conversion Factors for Stress Units

Strain, on the horizontal axis of the stress strain curve, is the elongation of the test sample divided by the length of the gauge section. Since the units of strain are inch/inch or mm/mm, strain is expressed either as a dimensionless decimal or as a percentage. Sometimes the gauge length is provided with the strain units such as "% in 2 inches".

Analysis of the stress strain curve allows the determination of yield strengths, tensile strength, elastic (Young's) modulus, uniform strain, and total strain. Reduction in area measurements, when required for round test samples, are made from the test specimens after completion of the test.

THE STRESS-STRAIN CURVE

The initial portion of the stress strain curve (Figure 1) is linear and the numerical value of the slope (stress divided by strain) of the linear portion is the Elastic Modulus of the material. The elastic modulus, also called Young's Modulus, measures the resistance of the material to small deformations and is a measure of the stiffness of the material. The greater the elastic modulus, the smaller the strain resulting from the application of a given stress. The traditional dimensional units of elastic modulus for metals are millions of psi (msi), thousands of ksi or, in metric units, gigapascals (GPa).

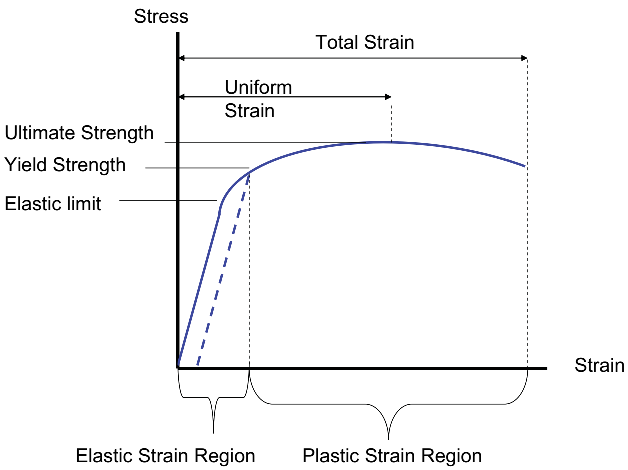

Figure 1. Stress Strain Curve

An alternative stiffness measurement, the secant modulus, is sometimes used in design as an indication of apparent stiffness when the test sample is strained beyond the elastic limit, as shown in Figure 2. Calculation of the secant modulus requires an accurate stress strain curve and a specific strain value. The secant modulus is not a pure materials property in that a design element (the strain value) influences the value of the secant modulus. The secant modulus will always be less than or equal to the elastic modulus.

The initial linear portion of the stress strain curve is elastic. When the load is removed, the sample will exhibit no permanent set. Deformation beyond the elastic region and into the plastic strain region will always result in some permanent set or strain when the load is removed and the elastic deformation is recovered.

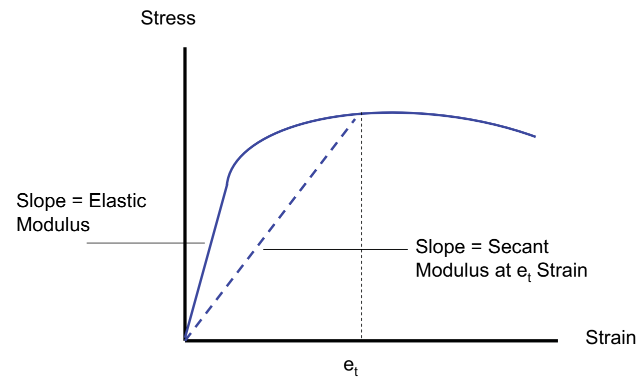

Figure 2. Elastic Modulus and Secant Modulus

The Yield Strength of the material is defined as the stress required to generate a given permanent set in the test sample. To be unambiguous, the yield strength should be specified with its numerical strain or permanent set value, such as 0.01%, 0.2%, or 0.5%. The 0.2% yield strength (also called 0.2% offset yield) is the most frequently measured yield strength, and when the numerical strain value is omitted, it is assumed to be 0.2%. Prior to computerized tensile test equipment, the yield strength was determined graphically from the stress strain curve by constructing a line parallel to the elastic deformation line, and offset to the right of the origin by the appropriate strain value. The intersection of the construction line with the stress-strain curve is the yield strength. The yield strength measurements are influenced by the accuracy of this construction whether it is performed by a computer or done graphically.

The transition point between the elastic and plastic regions (the 0% yield strength) is termed the Elastic Limit. For many nonferrous alloys, the transition between elastic and plastic behavior is very gradual. The elastic limit, or any low offset yield strength measurement, is difficult to precisely determine without highly sensitive equipment. Computer generated elastic modulus and elastic limit measurements are provided by newer test equipment, but their accuracy can be significantly influenced by inaccurately determined slopes in the elastic region. Inaccurate slope measurements can be caused by failure to compensate for flexure of the test machine or by the early onset of plastic deformation in the test sample. The precision elastic limit test measures the yield strength at 0.0001% offset (1 microstrain or 1 microinch strain per inch of gauge).

Because of the measurement difficulties, elastic limit and very low offset (below 0.2%) yield strengths are not routinely reported for wrought products. Information is available from Materion Brush Performance Alloys' Customer Technical Service Department.

As the stress strain curve moves further into the plastic region, the stress required to accommodate the elongation of the test sample continues to increase until it reaches a maximum. The maximum is called the Tensile Strength or ultimate tensile strength (UTS). Up to this point in the tensile test, the test sample has elongated (and reduced its cross section) uniformly along the gauge length. At the maximum strength or tensile strength, the tensile test piece becomes dimensionally unstable and additional deformation is nonuniform and very localized. The test piece begins to neck down at the point where it will eventually fracture. This is reflected in the stress strain curve by the decrease in stress for strain values above the ultimate tensile strength. Because of the necking of the test piece, the points of maximum stress and maximum strain are not coincident.

Strain or Elongation measurements from the tensile test provide an indication of the alloy's ductility or formability. Total strain is the value most frequently reported, and as shown in Figure 1. It is the strain recorded at the conclusion of the test when the test sample fails. Total strain includes the elastic strain, the uniform strain and the nonuniform strain during the necking of the test sample after the material reached the ultimate tensile stress. In component design work, the uniform strain value is of greater importance than the total strain since it measures only the "usable" deformation, to the point of the ultimate tensile stress, the maximum allowable design stress. On the other hand, in materials characterization for metal processing operations such as machining, stamping, or slitting, where the metal deformation leads to fracture, total strain is more meaningful than uniform strain.

INTERPRETATION OF TEST DATA

For each shipment of its copper beryllium product, Materion Brush Performance Alloys will certify the following standard tensile properties: ultimate tensile strength, 0.2% offset yield strength, and elongation. While these measurements will, for most applications, characterize the alloy's performance, component performance in some applications may be affected by the alloys near elastic properties (low offset yield strength) for which the standard tensile test is insensitive. When alloy samples, showing identical tensile test certifications, perform differently in service, more sensitive tensile testing or additional materials characterization may be required to identify the problem.

Tensile test data will accurately reflect performance when the use conditions closely approximate the actual test conditions. This rarely occurs since most use environments impose stress conditions which are more complex than the uniaxial tensile test. While tensile test data may provide indications of performance under conditions of compression, bending, or plane strain, additional information is required to accurately predict performance under non tensile conditions.

Hardness testing provides an indication of material strength, but since it does not measure the alloy's strength, it cannot be used as a substitute for tensile test data. The hardness test evaluates a relatively small volume of metal, and can be influenced by a microstructure which is not homogeneous. The tensile test, because of the size of the test piece, is less sensitive to variations in structure.

For heavily cold or hot worked products, tensile properties are not isotropic. The relationship of the off axis tensile properties to the properties reported in the longitudinal direction depends upon the property (modulus, strength, elongation), the alloy, the microstructure, and the degree of deformation in the material. In cold worked strip, the transverse elastic modulus is slightly higher and elongation slightly lower than measured in the longitudinal direction.

Tensile test ranges for all tempers of copper beryllium, copper nickel tin, and other alloy products are provided in the publication, "Guide to Materion Brush Performance Alloys".

Unless otherwise specified, tensile properties are measured at room temperature. Near room temperature, 100-300°F (70-150°C), the alloys' tensile properties are temperature insensitive. Tensile data at elevated and cryogenic temperatures for selected products are available from

Materion Brush Performance Alloys.

SAFE HANDLING OF COPPER BERYLLIUM

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, contact Materion Brush Performance Alloys, Technical Service Department at 1-800-375-4205.

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