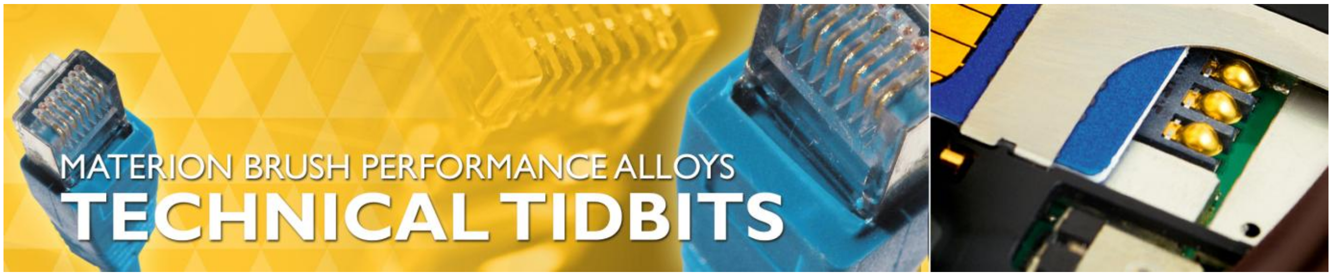

Issue No. 54 – June 2013 **New Publication**

Spin Doctors – An in-depth discussion on how fatigue data is generated.

- **Rotating Beam (R=-1) Testing**
- **Torsional Testing**
- **Flexure (Bend) Testing**
- **Axial (Tension-Tension Testing)**
- **High Cycle Fatigue**
- **Runout**
- **S-N Diagram**

The next issue of Technical Tidbits will continue the discussion on Fatigue.

Characterization of Fatigue Behavior

(This issue of Technical Tidbits continues the materials science refresher series on basic concepts of material properties.) Last month's edition of Technical Tidbits discussed the stress ratio (R ratio) of fatigue test specimens and of parts experiencing fatigue in the field. This month, we will discuss how the fatigue test is conducted.

For proper fatigue characterization of a material for a given application, it is necessary to obtain data in a test whose loading mimics the expected cyclical loading that will be experienced by the material in the application. This means that if the part will experience cyclical uniaxial tension, then the test data should be generated in uniaxial tension. For expected bending or torsional stresses, the test data should be generated in bending or torsion, respectively. Strip may be tested in tension or bending, rod may be tested in torsion, bending, or tension. (See figure below displaying typical specimens used for testing.) To test other forms of materials such as thick plate or tube, additional machining is required to obtain one of the specimen configurations below.

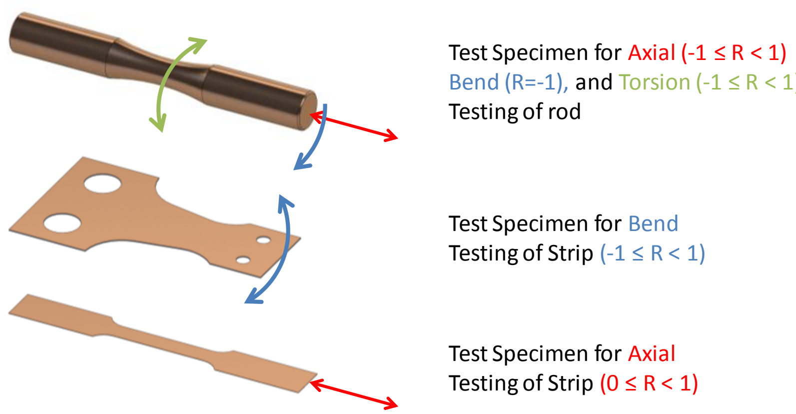

Figure 1. Configurations of Various Fatigue Test Specimens

The fatigue test samples would be treated to remove burrs or other stress risers on the strip edges or the rod surface. This will reduce the effect of the edge/surface condition on the fatigue test. The taper in the test zone of the strip bending specimen varies the moment of inertia of the cross section, so that the maximum stress in the beam is spread out down the length of the beam, as opposed to being concentrated at the base.

For rod, material, bending data would be generated by loading the specimen in the machine, then applying a deflection on one end to generate the desired stress level in bending. The specimen would then be rotated about the cylindrical axis, so that each point on the circumference in the test zone would cyclically pass through peak tensile stress and an equal and opposite compressive stress. This is known as **rotating beam fatigue testing**, and can only produce an R=-1 stress ratio. Alternatively, one end can be fixed and the other rotated about the long axis, producing cyclical **torsional** (shear) stress. (While the torsional stress is always positive, the direction of the stress can change to produce R=-1 curves.) Similarly, the sample can be alternately pulled in tension and compressed (**axial testing**) in the long direction.

For **flexure (bend) testing** of strip, the back end would be held in a fixture, and the other end would be flexed up and down to the desired stress level. This is usually accomplished by using a cam attached to a rotating shaft to provide the required deflection. This way, the cyclic frequency is only limited by the rotational speed of the shaft. Strip material can also be cyclically tested in tension (**tension-tension testing**), but not in compression. Therefore, the most severe stress state for axial testing of strip is R=0.

Characterization of Fatigue Behavior (continued) A counter on the test fixtures will record the number of cycles experienced, and will stop counting once the force load on the samples falls below a predetermined value. (This drop will indicate fracture of the specimen.) Because they are driven by a rotating shaft, the rotating beam and strip flexure tests can be run at high RPM's, so that a large number of cycles can be quickly generated. Table 1 below indicates the amount of time it takes to reach a given number of cycles for some typical test frequencies.

Number of Cycles	1200 RPM 20 cycles per second	3000 RPM 50 cycles per second	10 000 RPM 166.7 cycles per second
1.0E+00	.05 sec.	.02 sec.	.006 sec.
1.0E+01	.5 sec.	.2 sec.	.06 sec.
1.0E+02	5 sec.	2 sec.	.6 sec.
1.0E+03	50 sec.	20 sec.	6 sec.
1.0E+04	8.3 min.	3.3 min.	1 min.
1.0E+05	83 min.	33 min.	10 min.
1.0E+06	14 hr.	6 hr.	100 min.
1.0E+07	139 hr.	56 hr.	16.7 hr
1.0E+08	58 days	23.1 days	6.9 days
1.0E+09	579 days	231 days	69.4 days
1.0E+10	15.8 years	6.3 years	1.90 years

Table 1. Time to Complete Fatigue Testing at Various Test Speeds

Most S-N curves are run in the **high cycle fatigue** regime (more than 10 000 cycles.) Here, the stresses are well below the yield strength of the material, so there is no plastic deformation anywhere other than the tip of the fatigue crack. Fatigue tests are typically stopped after 10^8 (100 million) cycles, and the result is designated as a **runout**. (This means that the sample did not fail after the required amount of cycles). For strip bend testing, up to 4 samples can be mounted simultaneously in one fixture. For the other tests, only one sample can be loaded at a time. Therefore, the time listed in the table above is the time it takes to generate a *single data point*. To completely characterize the fatigue behavior of a given material, (i.e. generate an **S-N *curve*** of multiple data points), it would typically take a minimum of 3 samples at each stress level of interest (in order to obtain statistically meaningful data.) More data points may be required for greater accuracy, or if a problem occurs with the test operation. Although extremely useful, fatigue characterization is the one of the most time consuming of all mechanical tests. Unlike tensile testing, which can be routinely done on all production material, fatigue testing is only done on representative samples, and only if the material is to be used in cyclical applications.

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TECHNICAL TIDBITS

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References:

ASTM B593: Standard Test Method for Bending Fatigue Testing for Copper-Alloy Spring Materials

ASTM E466: Standard Practice for Conducting Force-Controlled Constant Amplitude Axial Fatigue Tests of Metallic Materials

ASTM E468: Standard Practice for Presentation of Constant Amplitude Fatigue Test Results for Metallic Materials

ASTM E606: Standard Practice for Strain-Controlled Fatigue Testing

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