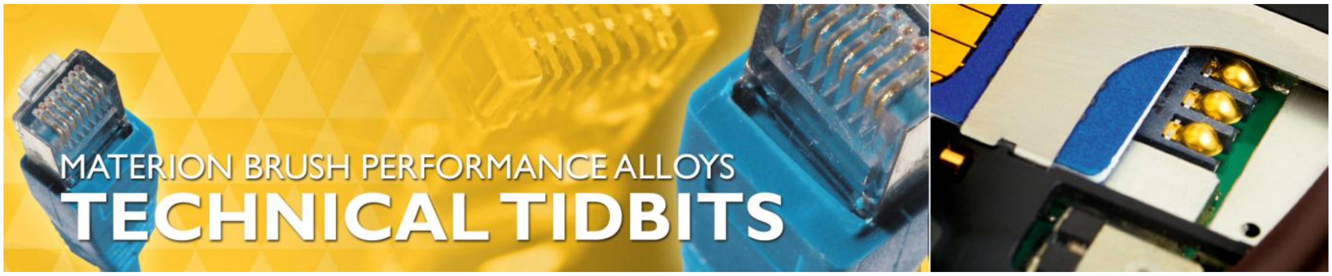

Issue No. 66 – June 2014 **New Publication**

A Second Chance at Life – A discussion on alternative means of calculating fatigue life, based on strain measurement techniques.

- **Stress Life**
- **Strain Life**
- **Strain Amplitude**
- **Number of Reversals to Failure**
- **Fatigue Strength Coefficient**
- **Fatigue Strength Exponent**
- **Fatigue Ductility Coefficient**
- **Fatigue Ductility Exponent**
- **Coffin-Manson Relationship**

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

Introduction to Strain Life

(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 various methods for estimating fatigue life at various R ratios based on limited data. This month introduces strain life techniques.

Issues 52 through 65 of Technical Tidbits provided some detailed discussion of fatigue, using **stress life** methods. Many methods exist for calculating expected life within statistical limits or computing maximum allowable stress levels if you want to achieve a given service life. In all these methods, expected stress in the designed is compared to a stress level in standard fatigue testing.

Another option is to use **strain life** techniques, where comparisons and predictions are based on strains as opposed to stresses. Strain life techniques can be used to estimate the fatigue behavior in the low cycle, high strain regime. (Recall that stress-life techniques were most useful in the high cycle, low stress regime, and tended to fall apart in low cycle regimes.) Furthermore, stress life techniques can be used when the loading is plastic (resulting in permanent set), whereas stress life techniques are only used when the cyclic stress is elastic. (Yes, every fatigue failure involves plastic strain localized at the crack tip. However, the bulk of the material in stress life testing only experiences elastic strain.)

Strain life testing is different than stress life testing. In strain life, a specimen is loaded in tension to a given strain level, and then the strain is fully reversed to an equal and opposite compressive strain. This cycling is repeated until fracture is obtained. The outputs of most interest are the **strain amplitude** (maximum strain-minimum strain)/2 and the **number of reversals to failure**, and not the number of cycles to failure as in stress life testing. Note that each cycle contains two reversals.

The strain amplitude is separated into two components, elastic strain amplitude and plastic strain amplitude. This means that each strain life fatigue test produces two data points, plastic strain amplitude vs. number of reversals to failure, and elastic strain amplitude vs. number of reversals to failure. (Recall that in stress life testing, each individual test generated only one data point, stress amplitude vs. cycles to failure).

The data points are plotted on a chart as shown below. The y axis consists of strain amplitude, and is drawn on a logarithmic scale. The x axis is the number of reversals to failure, also drawn on a logarithmic scale. A best fit straight line is drawn through the elastic data points and another through the plastic data points.

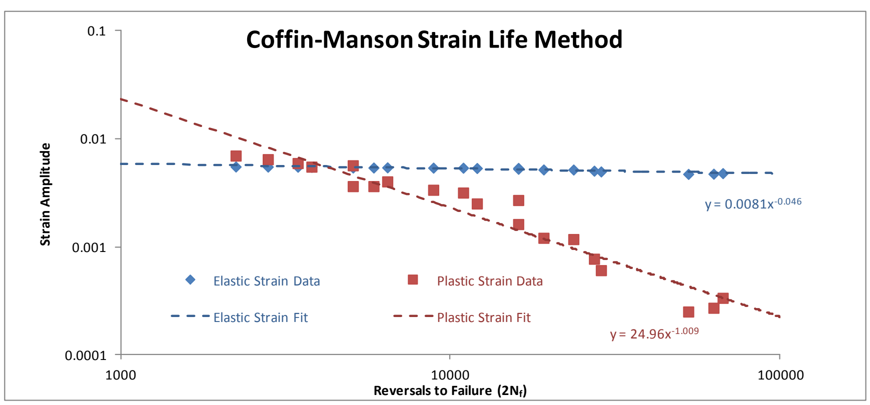

Figure 1. Initial Construction of the Strain Amplitude vs. Cycles to Failure Chart. The elastic strain data and plastic strain data are each curve fit with power law functions ($y=ax^b$), which appear as straight lines on a log-log chart. The intercept with the y axis at single reversal provides constant "a", and the apparent slope of the straight line provides the constant "b".

Introduction to Strain Life (continued)

The two lines are added together to get the total strain curve, which is the strain-life equivalent of the fit curve on the S-N diagram, as shown in the green line of figure 2. The intercept of the elastic strain amplitude curve fit with the y axis at 1 reversal generates the quantity σ'_F/E, which is the **fatigue strength coefficient (σ'_F)** divided by the elastic modulus (E). The slope of the line generates the **fatigue strength exponent (b)**. Similary, the plastic strain amplitude curve fit generates the **fatigue ductility coefficient (ε'_F)** and the **fatigue ductility exponent (c)**. When the elastic strain and plastic strain amplitude are added together to get the total strain amplitude, you have obtained the **Coffin-Manson relationship** for the material, shown in the green box.

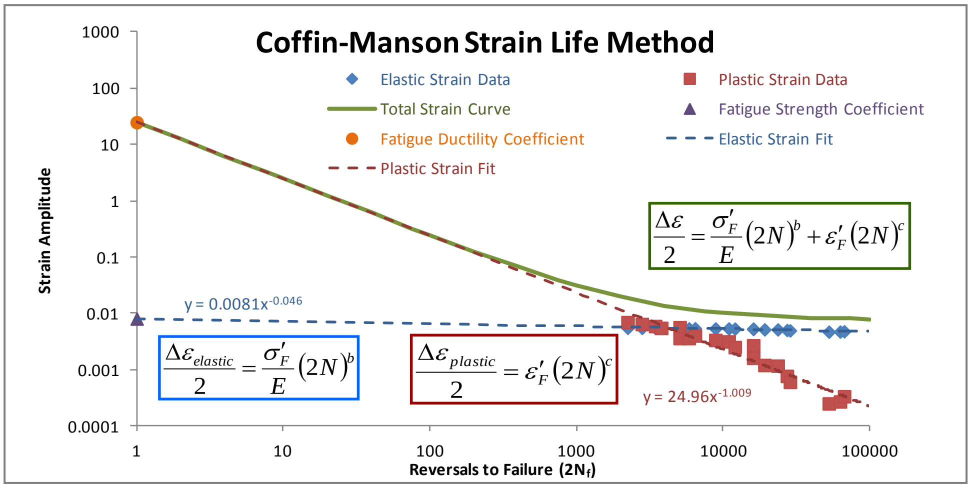

Figure 2. Completion of the Coffin-Manson Relationship. Here, σ'_F is the Fatigue Strength Coefficient, b is the Fatigue Strength Exponent, ε'_F is the Fatigue Ductility Coefficient, and c is the Fatigue Ductility Exponent. Ideally, there would be more data points to use in the high plastic strain region. However, the data work for illustrative purposes.

Now we know how to test the material and how to use the resulting data to generate the Coffin-Manson relationship. Now, what do we do with this knowlege? As it turns out, a number of the methods used for stress life fatigue strength estimation have strain life counterparts. Instead of the simple terms used in stress life equations such as tensile strength, yield strength, fatigue strength, etc., they will use the more complicated terms on the right side of the Coffin-Manson relationship. We will discuss these in the next edition of Tidbits. Since the math can get daunting, and finite element simulations of fatigue life are readily available, we will only briefly discuss.

Written by Mike Gedeon of Materion Brush Performance Alloys Marketing Department. Mr. Gedeon's primary focus is on electronic strip for the automotive, telecom, and computer markets with emphasis on application development.

TECHNICAL TIDBITS

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

MATERION

References:

Landgraf, R.W.
"Fundamentals of Fatigue Analysis"
SAE International 1982

Dowling, N.E.
"A Discussion of Methods for Estimating Fatigue Life"
SAE International 1982

Dowling, N.E.
"A Review of Fatigue Life Prediction Methods"
SAE International 1987

Khosrovaneh, Abolhassan; Pattu, Ravi; Schnaidt, William
"Discussion of Fatigue Analysis Techniques in Automotive Applications"
SAE International 2004

Dowling, Norman E.
"Mean Stress Effects in Stress-Life and Strain-Life Fatigue"
SAE International 2004

Dowling, N. E.; Calhoun, C.A. and Arcari, A.
"Mean Stress Effects in Stress-Life and Strain-Life Fatigue"
Blackwell Publishing Ltd 2009

Please contact your local sales representative for further information on the fatigue 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, contact Materion Brush Performance Alloys or your local representative.