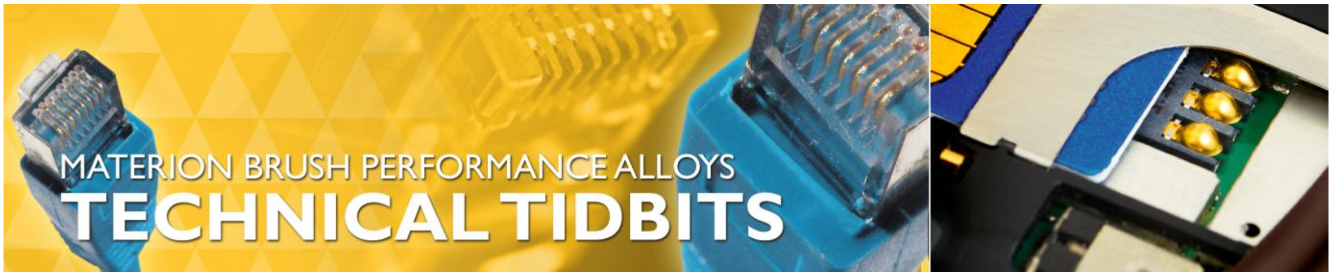

Issue No. 65 – May 2014 **New Publication**

Stressed out over fatigue yet? – A discussion of alternative methods of predicting fatigue life from R=-1 data.

- **Goodman Equation**
- **Gerber Equation**
- **Morrow Equation**
- **Soderberg Equation**
- **Smith Watson Topper Equation**
- **Walker Equation**
- **Stress Ratio**
- **Fatigue Strength**
- **Endurance Limit**
- **S-N Diagram**
- **Modification Factor**
- **Mean Stress**
- **Stress Life**
- **Strain Life**
- **Fracture Mechanics**

The next issue of Technical Tidbits will introduce strain-life methods.

Final Comments on Stress Life Methods

(This issue of Technical Tidbits continues the materials science refresher series on basic concepts of material properties.) Last month's edition of Technical Tidbits introduced several methods of estimating fatigue life at various stress ratios based on limited data and some material parameters. This month will discuss those various methods, and offer some final comments on stress life methods.

Figure 1 below repeats the chart from the previous issue introducing the 6 methods. (Note that this is not based on any particular material, and the property values were chosen to make the math easy.) No comment was made then regarding the accuracy or utility of these methods. Also note that there are other methods not listed below, but those listed have all been popular at one time or another.

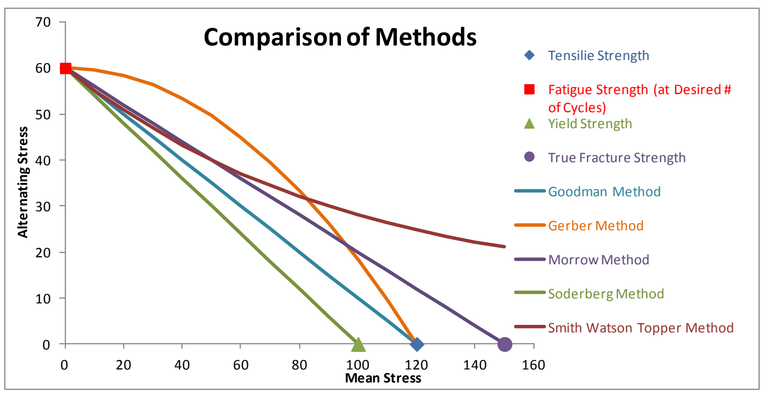

Figure 1. Comparison of Stress-Life Mean Stress Methods for Estimating Fatigue Behavior. The Goodman, Gerber, Morrow, and Soderberg equations attempt to predict fatigue performance based on fully reversed fatigue test data and other unrelated mechanical properties. The Smith Watson Topper method and the Walker method (not depicted) use only fatigue data.

The **Goodman equation** was the first attempt at coming up with a relationship between fatigue and material properties, using the tensile strength. This was followed by a the slightly more accurate **Gerber equation**, also using the tensile strength, and the slightly less accurate **Soderberg equation**, using the yield strength. The **Morrow equation** improves the accuracy more by using the true fracture stress instead of the tensile strength. For all these methods, accuracy is better on the left edge of the graph and decreases as you get closer to the right edge, since there is no universal correlation between for fatigue strength and yield, tensile, or fracture strength that applies to all metals.

The **Smith Watson Topper equation** does not try to correlate with any other material properties and increases the accuracy. The **Walker equation** is the most accurate, as it is derived by curve fitting actual fatigue data. The downside is that more testing is required for this method than for any other in order to come up with a good curve fit. Note that some of these methods may be more or less accurate depending on the fatigue behavior of the particular material or material family being modeled. In a reasonable attempt at ascending order of accuracy, the methods would be ranked as follows:

- Solderberg Method
- Goodman Method
- Gerber Method
- Morrow Method
- Smith Waston Topper
- Walker Method

Final Comments on Stress Life Methods (continued)

The first four methods are overly simplistic, but may work for some materials. The last method requires more data than any other and the relationships must be uniquely derived for every individual material tested. In any case, it is always best to have as much fatigue data as possible, and to have a feel for how the particular material behaves in fatigue, so that you would know which model to use.

In summary, the prior 15 issues presented quite a bit of information about stress life fatigue calculations:

- Definition and calculation of **stress ratios**
- How materials are tested to generate fatigue data
- What **fatigue strength** for a given number of cycles means (as opposed to **endurance limit**)
- How to statistically analyze fatigue test data to make meaningful predictions
- How to construct and appropriately use an **S-N diagram**
- How to us **modification factors** to account for edge and surface condition, temperature, part geometry, stress concentration, loading, residual stresses, environmental conditions, directionality, etc.
- How to use appropriate **mean stress** techniques to predict fatigue behavior when the stress ratio is something other than 0 or -1

Another point to remember is that the referenced calculations should be made with respect to 1st principle tensile stress. Von Mises equivalent stress may include compressive components, which may cause an underestimation of the peak tensile stress in a component. Fatigue is a series of progressive fracturing, which only occurs in tension. However, this is not the same as saying that only tensile loading causes fatigue. Even a part that is loaded in compression, unless such loading is isostatic, will experience some tensile stress component somewhere. For example, a cylinder under axial compression will bulge around the middle, due to tensile hoop stress. It is easy to picture how such a part, loaded purely in compression, can experience tensile fractures or fatigue failure.

The popularity of stress life methods lie mainly within the ease of calculations. Note that all of the fatigue strength modifying factors previously discussed are designed for use with **stress life** calculations only. Many have no corresponding **strain life** equivalents. For example, there are calculated and tabulated stress concentrations factors galore, but no such factors exist for strain concentration. Therefore, most strain life based calculations would require the assistance of finite element analysis.

The last approach to consider would be **fracture mechanics**. This method analyzes fatigue behavior on the microscopic scale, as opposed to the macro scale in stress life and strain life methods. Testing is conducted to evaluate how rapidly fatigue cracks grow under cyclic loading. This method is often favored by engineers working in the oil and gas exploration and completion industries, as well as those working in the aerospace industry.

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