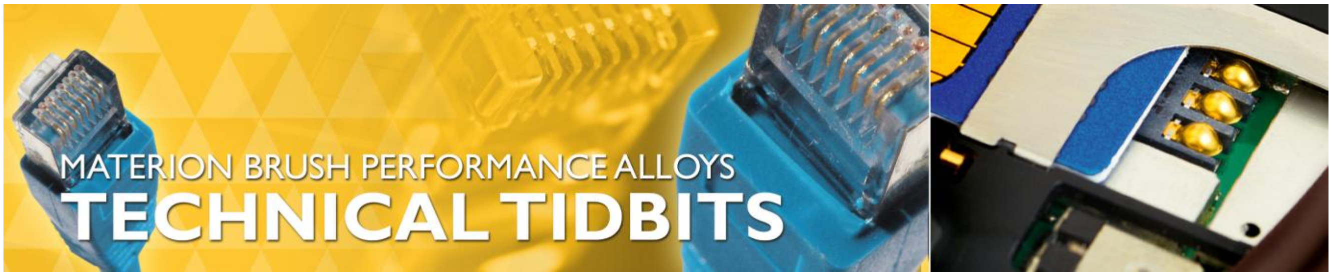

Issue No. 57 – September 2013 **New Publication**

Now that it's clear, let's change it – A discussion on how to modify the calculated fatigue strength value to account for real-world conditions.

- **Modification Factor**
- **Surface Factor**

The next issue of Technical Tidbits will continue the discussion on fatigue strength modification factors.

Fatigue Strength Modifying Factors - Part 1

(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 how to obtain statistically derived fatigue strength form S-N data. This week we will discuss how to take that idealized information and modify it for real life engineering.

Up to this point in our discussion, we have described how fatigue data is obtained in testing. We would require this data for the material we are using, in the orientation that we are using it, under the type of loading (bending, torsion, tension, etc.) we are applying, and at the appropriate stress ratio (fully reversed, unidirectional, etc.). We have seen how to present this information on an S-N chart, and have learned how to statistically analyze this data to determine the relationship among the 3 key variables: number of cycles to failure, peak stress level per cycle, and failure rate. Specifically, when provided with any two of these variables, we can reasonably well predict the third.

So far, this all seems pretty straightforward. However, in engineering, there is always a catch. Fatigue tests are usually run under ideal conditions, using samples that have simple, ideal shapes, nice surfaces and smooth edges, at room temperature, without plating, and without corrosive agents present in the environment. Just like the real parts that you design. What's that? The parts you design have complicated shapes with potential stress risers, are made with rough edges or surfaces, might be operating at elevated temperatures, could be plated, and may be exposed to corrosive agents during operation? So, how do we use these ideal results to predict component life under real world conditions?

The way this is accounted for is by using a series of **modifying factors**, one derived for each non-ideal condition. You can multiply the maximum permissible stress level obtained above by these factors to obtain a lower, but more accurate value. Or, you can use similar factors to reduce the predicted number of cycles to a more accurate number. Note that you cannot use the same factor for both methods.

A common means to estimate the modified fatigue strength is as follows:

$$\sigma_{max} = k_1 \cdot k_2 \cdot k_3 \cdot \ldots \cdot k_n \cdot \sigma'_{max}$$

Here σ'_{max} is the minimum, statistically-derived fatigue strength at the desired number of cycles, under ideal conditions. σ_{max} is the fatigue strength adjusted for the adverse conditions. Each constant corresponds to a modification factor that accounts for a particular means in which the material is less than ideal. Each constant is generally ≥ 0 and ≤ 1. Common modifying factors account for:

- Surface condition (smooth, rough, brushed, machined, corroded, etc.)
- Temperature
- Part size and shape (relative to original fatigue test specimen size and shape)
- Stress concentration (notches or cracks)
- Loading condition (torsional, axial, bending, shear, or some combination.)
- Residual stresses
- Platings/coatings
- Environmental conditions
- Other effects which may be relevant to your application

The first modification factor regards surface condition. Most of the original work in this area was done on high strength steel alloys. Additional testing over the years confirms its applicability to most steel alloys. (Fortunately, high strength copper beryllium alloys tend to show similar trends in fatigue behavior to high strength steels.) Figure 1 on the next page shows a representation of this data, which you can find in any textbook or handbook on fatigue. Note that this data should be used in the high cycle regime only.

Fatigue Strength Modifying Factors - Part 1 (continued)

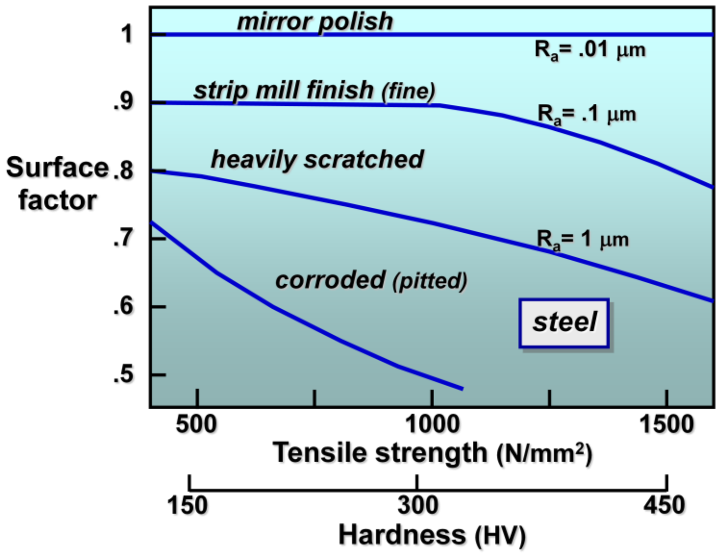

Figure 1. Effect of Surface Finish on Fatigue Life. Ideal fatigue life is obtained in perfectly smooth surfaces (no stress risers or flaws that can initiate cracks). As the surface condition deteriorates, more sites are available to initiate fractures, and fatigue life drops.

Note that the surface effect is less pronounced on weaker, more ductile steels, and more pronounced on harder, stronger steels since fatigue crack propagation takes longer in more ductile materials.

This is just a representative sample of a small number of surface conditions. Many more such charts exist in various handbooks on mechanical design. There are even surface modification factors for various machining operations. Note again this data is derived for steels, but has some limited applicability to high strength copper beryllium.

This is the first of several modification factors to be discussed in future editions of Technical Tidbits.

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