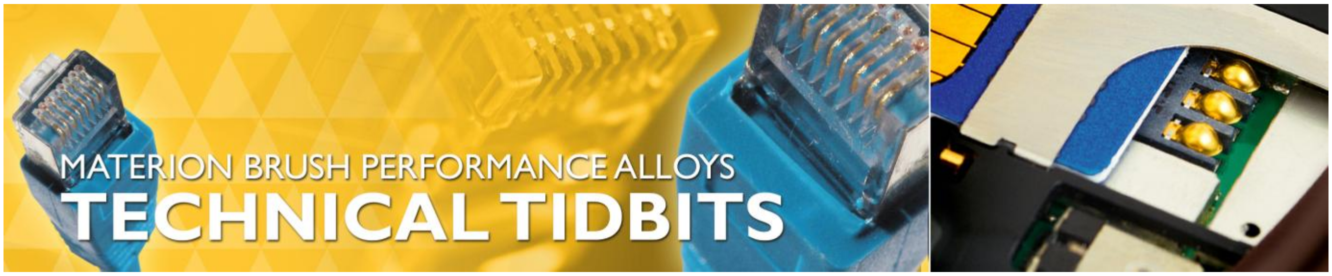

Issue No. 72 – December 2014 **New Publication**

Tired of Fatigue Yet? – A summary and listing of caveats to add to the fatigue discussion going on for several months now.

- **Corrosion Fatigue**

The next issue of Technical Tidbits will initiate a discussion on friction.

Some Final Thoughts on Fatigue

(This issue of Technical Tidbits continues the materials science refresher series on basic concepts of material properties.) So far we have learned what fatigue is, how to generate and statistically analyze appropriate test data, several different methods for estimating fatigue life, and how to diagnose fatigue failures. This month will finally complete the long discussion on fatigue.

So, now we know all that there is to know about fatigue life prediction, correct? Well, not quite. The first caveat is that most fatigue test data is for ideal conditions of pure bending, torsion, tension, etc. The peak stress occurs in a carefully controlled location. In real parts, loading is often complex. The actual loading may be some combination of bending, tension, compression, torsion, shear, etc.

Fatigue tests are usually performed under ideal conditions, where care is taken to minimize burrs or other stress risers on the test samples. The same care is often not found in real manufacturing conditions, and actual parts may have burrs, tool marks, rough edges, etc. that function as stress risers, leading to fatigue crack initiation in much less time than in the ideal test environment.

Depending on the alloy and the environment, the part may also experience corrosion induced cracking that could result in rapid progression to failure. Corrosion initiate cracking, as areas in tensile stress are highly vulnerable. Furthermore, corrosion product can build up in the crack, wedge the surfaces apart, and help to drive the tip forward much more rapidly than stress alone. This synergistic effect, called **corrosion fatigue**, cause failure in much less time than either fatigue or corrosion alone.

In connectors, the high stress areas are typically areas that have been formed (bent) into position. The stress and strain states in these areas are complex, and completely different from the virgin material used to conduct fatigue testing.

Another important point to note is that the all sources of stress will factor into the fatigue performance of a component. This includes the design stress from mechanical sources (applied forces, pressures, or deflections), thermal stresses (elevated environmental temperatures or internally generated by joule heating), vibration, impact, and even residual stresses from forming or machining operations. Many of these sources are highly variable and unpredictable. This is why it is important to include safety factors in fatigue analysis.

To summarize the series, fatigue strength is influenced by:

- Stress state (fatigue ratio, stress concentration, applied static load)
- Strain rate
- Geometry (both part size and shape)
- Stress concentration (holes, cracks, notches, pits, sharp corners and transitions, burr, fillets, tool marks, scratches, welds, corrosion)
- Loading condition as well as order and magnitude of cycles
- Environment (corrosion)
- Material orientation (anisotropy)
- Operating temperature (ambient + ohmic heating temperature rise)
- Surface condition
- Metallurgical characteristics (grain size, aging condition)
- Processing characteristics (residual stress, surface roughness)

Remember that fatigue is an ongoing process. One means to guard against failure in parts susceptible to fatigue would be to ensure that it is removed from service before the estimated fatigue life (minus a factor of safety) is used up.

Some Final Thoughts on Fatigue (continued)

Fatigue loading may even come from unexpected sources. Processes such as ultrasonic cleaning or welding can induce fatigue failures, if the driving frequency is at or near one of the natural frequencies of the component. Undamped oscillations at the natural frequency quickly build to high magnitudes relative to the strength of the material. Furthermore, vibration at an ultrasonic frequency of 20 kHz would result in one million cycles in just 50 seconds. At 250 kHz, one million cycles are reached in only 4 seconds!

Yes, the preceding paragraph contained a sweeping generalization. The amplitude of the induced loading relative to the fatigue strength would certainly depend on the driving force, material, and geometry of the part. If you are to be conducting any ultrasonic processing on your parts, it might be a good idea to run a modal analysis in FEA to determine if there is a resonant frequency near the driving frequency. If this will be a problem, change the driving frequency of the ultrasonic process. Similarly, if intact parts are going into your ultrasonic process and coming out cracked, then change the frequency.

One of the best ways to extend the life of your parts would be to design them to resist fatigue. To do so:

- Ensure a smooth surface (Ra < .25 µm, 10 µ")
- Ensure a burr-free edge with no notches, cracks, tool damage, etc.
- Use abrasive tumbling to deburr & smooth rough edges and polish the surface
- Minimize stress concentrations effects (location, shape)
- Use material with sufficient ductility to avoid roughness (heavy orange peel or incipient cracking) at bend location
- Avoid corrosion (use protective coatings, hermetic enclosures)
- Avoid high stress platings that can initiate fatigue cracks
- Stress relieve to removes residual stress
- Use material with uniform (consistent) grain size

Remember, fatigue life can only be approximated, it can never be precisely calculated. Even under the controlled conditions of a fatigue test, there is still substantial scatter in the data. This is because every bit of material is unique. Every piece of strip, rod, wire, plate, forging, etc. produced has its own unique microstructure. Every component made from these will see slightly different manufacturing conditions. Each and every part will thus have uniquely shaped and oriented fractures initiating at slightly different locations in the microstructure, and will propagate at different rates to failure along unique microstructural features.

This is why statistical approaches to fatigue failure and reliability are most useful. This way you can estimate the percentage of parts that will exceed a given lifetime. It is certainly better to have failures occur due to six sigma defects than to have half of your parts fail.

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