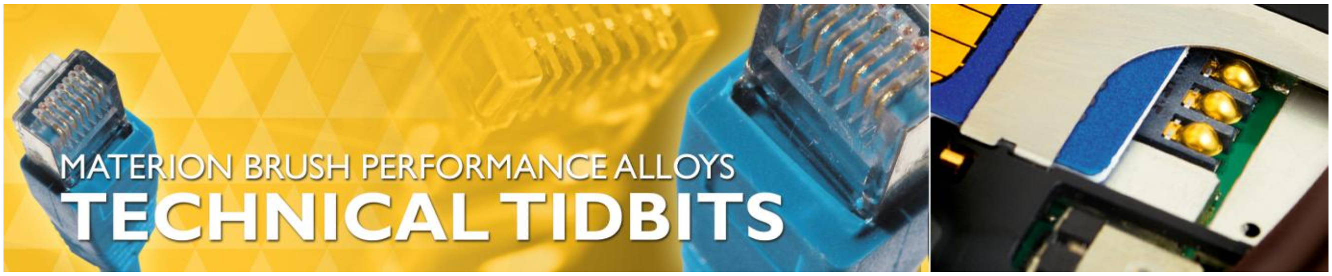

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Fatigue Strength Modifying Factors - Part 3

(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 modify the fatigue strength of a material to account for elevated (or depressed) temperatures. This month discusses modification factors for loading condition, size, and geometry.

There are a number of other factors that can be used to modify fatigue behavior. For example, in certain steel alloys, there are factors that can be used to account for case hardening operations (carburizing, nitriding, etc.) Since copper alloys cannot be case hardened (and yes, that question does come up often) we will only mention these factors in passing. If you are working with steel alloys, any mechanical engineering handbook or textbook should have these factors.

The loading condition all comes into play. The loading can be applied in tension, flexure, torsion/shear, or some combination thereof. For a material tested at the same peak stress level, the fatigue life would be greatest in bending, slightly lower in axial loading (tension), and lowest in shear or torsion. For data generated in flexure, the **loading factors** would be as follows: $k_{axial} = 0.9$, $k_{torsion/shear} = 0.577$. Some readers will recognize the 0.577 ($1/\sqrt{3}$) factor as the relationship between the shear strength and yield strength of a ductile metal predicted by the distortion energy theory. So, this relationship holds for both yield strength and fatigue strength.

The next important modifying factor to consider is the **size factor**. This is used to compensate for how the size and shape of the real life component is different from the simple geometry test specimen used. Larger size specimens have greater surface area and volume than smaller size specimens. This means that bigger parts have a greater potential for defects on the surface or within the volume, which makes earlier fatigue crack initiation and propagation more likely. (See Figure 1.) This size relationship holds true for all cases of loading (axial, bending, and torsional).

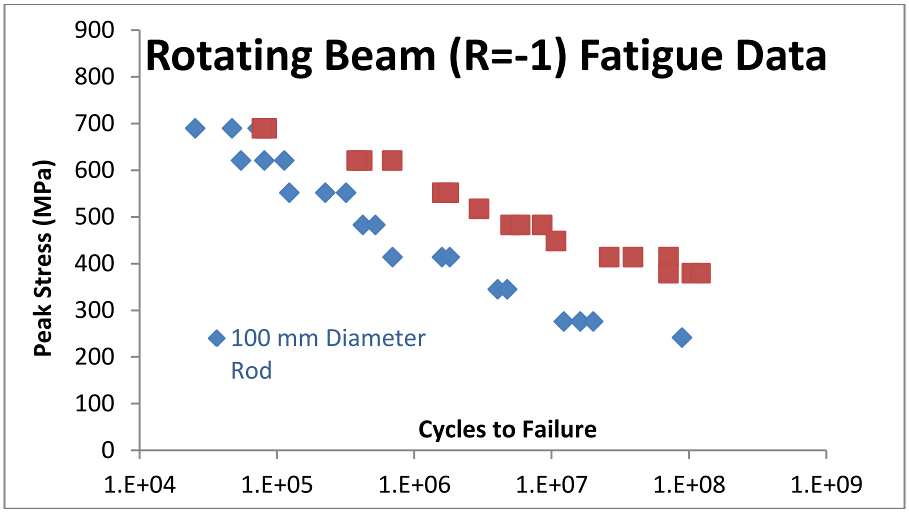

Figure 1. Effect of Size on the Rotating Beam (R=-1) Fatigue Strength of a Plastic Mold Tooling Alloy. Larger diameter rod has a greater volume under stress, which means a greater chance of microscopic defects to initiate fatigue cracks. Therefore, the smaller size would have greater fatigue strength than the larger size. Note also that the spread in the data increases as the number of cycles increases.

Size (and Shape) Does Matter – Continuation of the discussion on how to modify the calculated fatigue strength value to account for real-world conditions.

- **Modification Factor**
- **Loading Factor**
- **Size Factor**
- **Effective Diameter**

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

Fatigue Strength Modifying Factors - Part 3 (continued) Fatigue data are generated using test specimens of ideal geometry (rectangular or round cross sections.) Often, the part that you are designing will have a cross section completely different from that used to generate the fatigue data. The size can also be used to account for this difference. So, it is used to account for differences in geometry (both size and shape) between your part and the test specimen.

Of course, different sources provide different equations and relationships to calculate the size factor when using non-equivalent geometry. All of them, however, involve finding the area of the cross section which has a stress level above 95% of the maximum value (**at any point in the cycle**). An effective diameter is then found that has an equivalent cross sectional area above 95% of the maximum stress value. This effective diameter is then used to calculate the size factor. (These calculations will vary slightly depending upon which reference book you choose, but typically the modifying factor can be expressed as follows: $k_{size} = C_1 \times \varnothing_e^{C_2}$, where C_1 and C_2 are constants and $\varnothing_e$ is the effective diameter of an equivalent round rotating beam specimen.

Note also that the area will vary depending upon the loading condition. For unidirectional bending, this will be an area on the tensile side of the bend. For fully reversed bending, this area will be on both the top and the bottom of the beam. For tensile loading, the stress is uniform across the cross section, so there is no size factor. This is why it is always best to use fatigue data in the generated with a specimen of the same cross section and loading mode as the part you are designing, so you do not have to calculate equivalent areas.

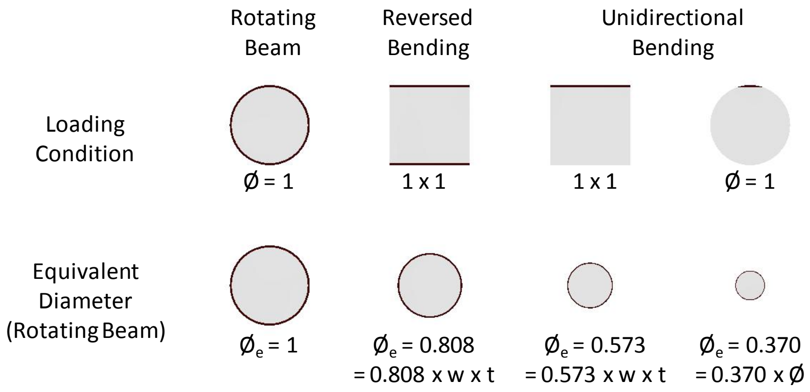

Figure 2. Effect of specimen geometry and cross section on effective diameter. The gray section represents the cross section, and the red section is the area stressed to 95% of the maximum value. The loading conditions across the top row result in progressively smaller equivalent diameters on the bottom row.

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