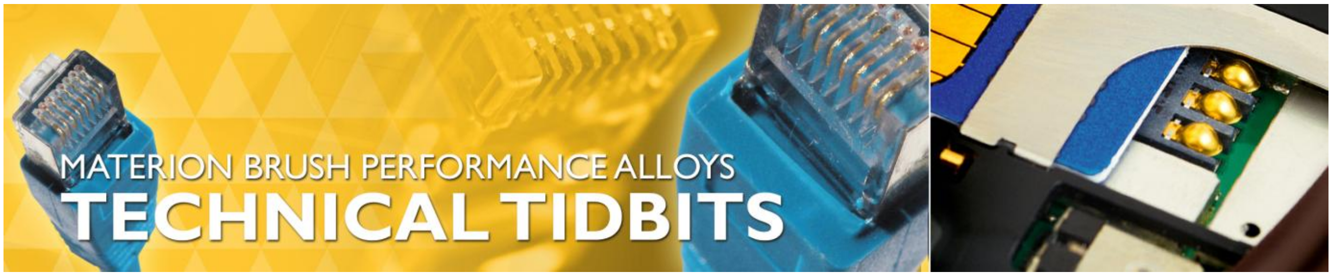


**Issue No. 63 – March 2014** **New Publication**

**That's one mean stress level you've got there. –** A discussion on how R=-1 fatigue data can be used to estimate fatigue life for parts under loading at other R Ratios.

- **Mean Stress**
- **Alternating Stress (Stress Amplitude)**
- **Goodman (Haigh) Diagram**

*The next issue of Technical Tidbits will continue the discussion on the Goodman diagram, and will introduce some alternatives as well.*

# Mean Stress and Alternating Stress

(This issue of Technical Tidbits continues the materials science refresher series on basic concepts of material properties.) The last few month's edition of Technical Tidbits discussed how to predict fatigue life for parts in simple loading based on stress life fatigue testing and modifying factors. This month we will discuss what to do if the loading is neither completely reversed nor perfectly unidirectional.

Cyclical loading can be thought of as a fully reversed **alternating stress** superimposed on a constant **mean stress** level. The **mean stress** is the arithmetic mean of the maximum stress and the minimum stress. The **alternating stress,** also known as the **stress amplitude** is then the difference between the peak stresses and the mean stress. Figure 1 below repeats the stress ratio diagrams from Issue 53 of Technical Tidbits, and adds the mean and alternating stress levels to the charts. The equations for calculating the mean stress and alternating stress are as follows:

$$\sigma_{mean} = \frac{\sigma_{max} + \sigma_{min}}{2} \qquad \sigma_{alternating} = \frac{\sigma_{max} - \sigma_{min}}{2}$$

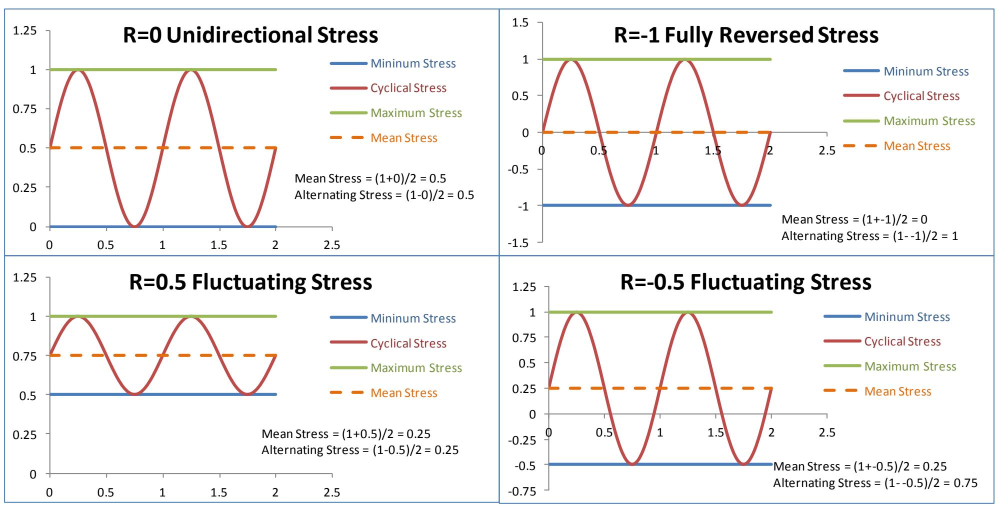


**Figure 1.** Alternating and Mean Stress Levels for Various Loading Conditions. The mean stress is calculated as by adding the maximum and minimum stress levels and dividing the result by two. The alternating stress is calculated by subtracting the minimum stress level from the maximum stress level and dividing the result by two. It is absolutely critical to use the appropriate sign (positive and/or negative) of the maximum and minimum stress levels.

The first method to discuss is the simplest (and therefore naturally least accurate) method of all, the Goodman method. While falling out of favor do to oversimplification and general lack of accuracy, it nonetheless serves as a reasonable introduction to the subject, as it was the first attempt to predict fatigue behavior at stress ratios other than 0 or -1 from existing data.

The **Goodman (Haig) diagram** (Figure 2) is drawn by plotting alternating stress on the y axis and mean stress on the x axis. A straight line is then drawn between the R= -1 fatigue strength of interest on the y axis, and the ultimate tensile strength on the x axis. This forms a triangle, with one corner as the origin of the graph. Any combination of mean and alternating stress within the triangle is considered safe, while combinations outside the triangle would be expected to fracture before the desired number of cycles.

## Mean Stress and Alternating Stress (continued)

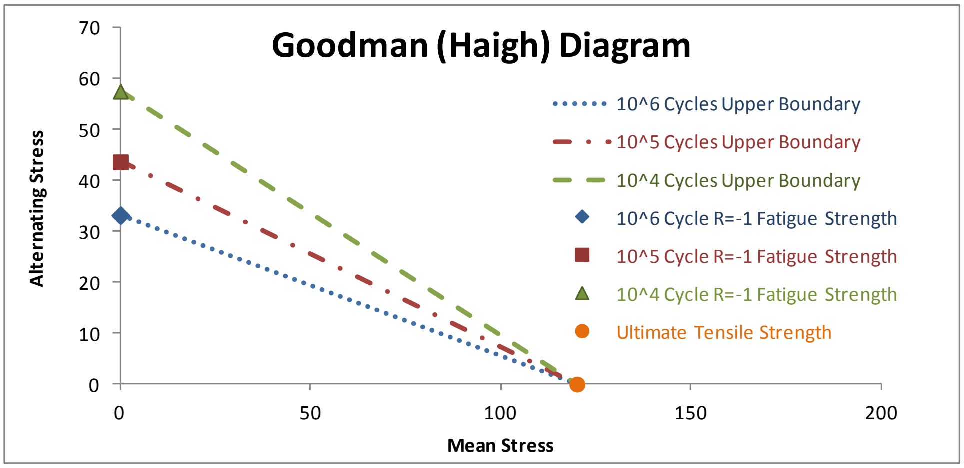


**Figure 2.** Example Goodman (Haigh) Diagram.
Points inside the triangle formed by the origin, the ultimate tensile strength, and the particular fatigue strength of interest would theoretically be expected to last the desired number of cycles, while those points outside the triangle would be expected to fail.

For any safety factor at all, the fatigue strength on the y axis should be the statistically derived number for the desired failure rate, and not the best fit value. It is also important to note that the diagram works better for low mean stress and high alternating stress than vice versa. For a detailed discussion why this is so, and some of the other shortcomings of the Goodman method, see the blog "Why the Goodman Diagram is Not so Good", by Dave Palmer, P.E. posted May 30, 2014 on designnews.com (the website for Design News magazine).

The aforementioned blog also references another paper worthy of a look, "Mean Stress Effects and the Walker Equation", by N.E. Dowling, C.A. Calhoun, and A. Arcari, available for purchase from the SAE website at store.sae.org. At the time of this writing, a search on the term "fatigue" in the SAE store finds nearly 13,000 different publications on the subject. Several useful papers from this site will be listed in the references in the next edition of Technical Tidbits.

In spite of its shortcomings, we will continue the discussion on the Goodman (Haigh) diagram since it serves as a foundation for some more accurate techniques, in the same way that the planetary model of the atom paves the way for an understanding of the quantum mechanical model.

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