MATERION

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TECHNICAL TIDBITS

MATERION PERFORMANCE ALLOYS

Ch-ch-ch-ch-changes! – How to predict the long-term effect of temperature on material properties.

▲ **Larson-Miller Parameter**

The next issue of Technical Tidbits will discuss accelerated testing.

PREDICTION OF TEMPERATURE-DEPENDENT CHANGE

In 1952, Frank Miller and J. Larson proposed a **method of estimating unknown stress relaxation behavior** by interpolation and extrapolation of existing data.

The Larson-Miller plotting method remained popular until the 1990's, when mathematical calculation and simulation software allowed for fast and easy data interpretation and extrapolation. Other parameters have been introduced over time, but the Larson-Miller method was the most widely used before desktop computers changed everything.

This technique can be used to plot stress relaxation, creep, stress-rupture, or any other behavior that depends on both time and temperature. It uses the Larson-Miller parameter, which combines exposure time and temperature into one variable:

Larson Miller Parameter = $T \times (C + \log_{10} t)$

Here, T is the absolute temperature in either °R or K, C is a constant usually between 20 and 25, and t is the time in hours. To estimate behavior at a given time and temperature, you would calculate the Larson-Miller parameter for the combination of interest and find the data in the set that has the same parameter.

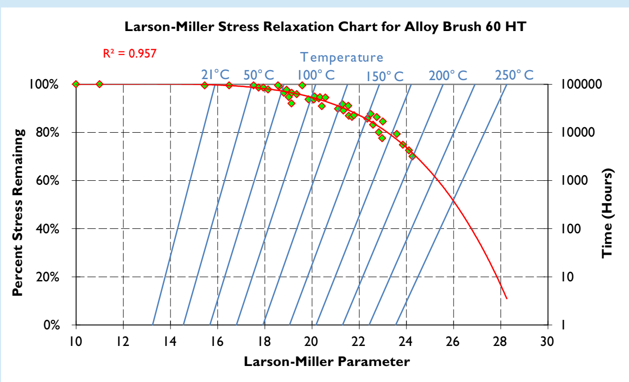

Figure 1. Example Larson-Miller Chart.
To read a Larson-Miller chart, 1) Locate the required time on the right axis. 2) Extend a horizontal line to the left until it intersects the diagonal temperature line (blue) of interest. 3) Extend a vertical line from this intersection to the Larson-Miller curve (red). 4) Extend a horizontal line from this point to the left. It will intersect the left axis at the remaining stress level. Note that you can reverse this procedure to estimate the expected time at a given temperature for which a component will retain stress greater than a given percentage.

Figure 1 shows an example of a Larson-Miller chart. In this case it is the stress relaxation behavior of Alloy Brush 60 HT. Note how there is scatter in the data and that different time-temperature combinations with the same Larson-Miller parameter have similar, but not necessarily identical, behavior. This could generate some significant error in interpolation, especially when considering that the right axis (time) uses a logarithmic scale.

PREDICTION OF **TEMPERATURE-DEPENDENT CHANGE** (CONTINUED)

The underlying assumption of the technique is that if two different time and temperature combinations had the same Larson-Miller parameter, then the amount of stress relaxation would be the same. The technique generally has good agreement with experimental data as long as:

1. Both the time and temperature of interest fall within the range of the existing data.
2. The two temperatures differ by no more than 25°C.

As the gap in temperature widens, this method becomes less reliable. This method is also best suited for interpolation within the existing data set, and not for extrapolation outside the data set. For example, the Maillard reaction that occurs when baking a cake is another time- and temperature-dependent reaction. You would not get the same reaction when baking a cake for 2.75 hours at 325°F (163°C) as you would when baking for 45 minutes at 350°F (177°C), or 0.25 seconds at 500°F (260°C). This is despite the fact that all 3 time and temperature combinations have the same Larson-Miller parameter.

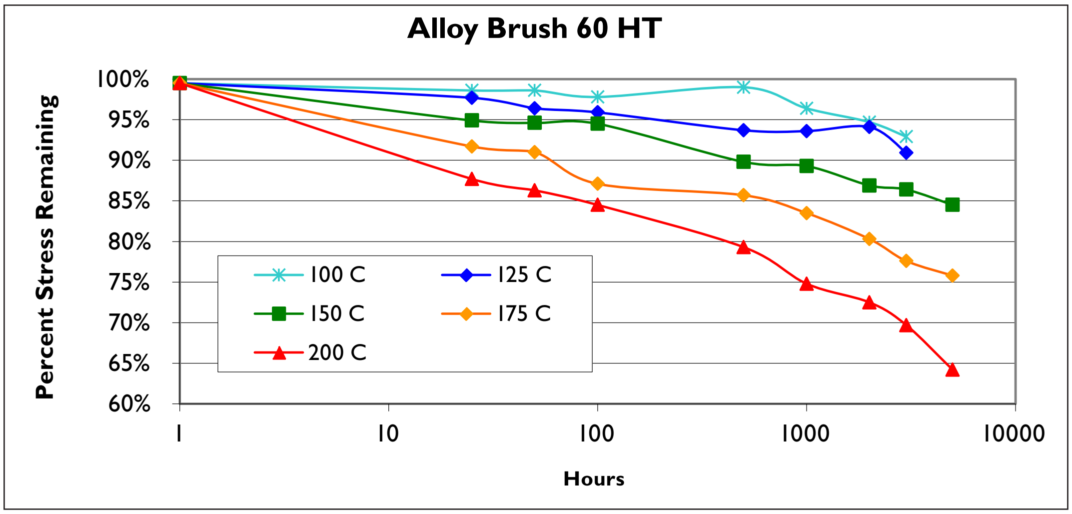

Figure 2. More Traditional Means of Displaying the Data shown in Figure 1.

A more accurate means of predicting stress relaxation behavior would be to use modern software programs to curve-fit or even surface-fit the data, as discussed in Technical Tidbits issue #89. You can then calculate the amount of stress relaxation under the conditions of interest by hand or by software. You may also use finite element modelling, once you have determined the appropriate creep constitutive model. By presenting data in a format like that of Figure 2, you can see how easy it would be to interpolate between times at a given temperature, and vice versa.

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References:

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Mechanical Metallurgy
McGraw- Hill 1961

F.R. Larson and J. Miller, "A Time-Temperature Relationship for Rupture and Creep Stresses", Trans. ASME, Vol. 74, July 1952, pp. 765-771.

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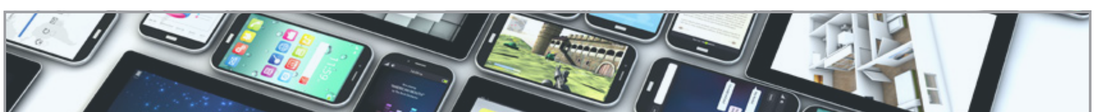

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