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LIHEM Failure Model Development

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Previously, a factor of safety criterion for the IHEs (LX-17 and PBX 9502) was defined using the ultimate strength of the material based on uniaxial compression and tension data at various temperatures and strain rates and an experimentally derived failure surface. The probability of failure was subsequently calculated using this factor of safety, uncertainty data, and assumptions. This year, the methodology was extended to incorporate the effect of cyclic loading into the Livermore Insensitive High Explosives Mechanical (LIHEM) model.

As mentioned in the previous section, we performed cyclic experiments on three-point-bend specimens in order to find cycles-to-failure as a function of failure load at various temperatures, frequencies, and amplitudes as shown in Figure 1.

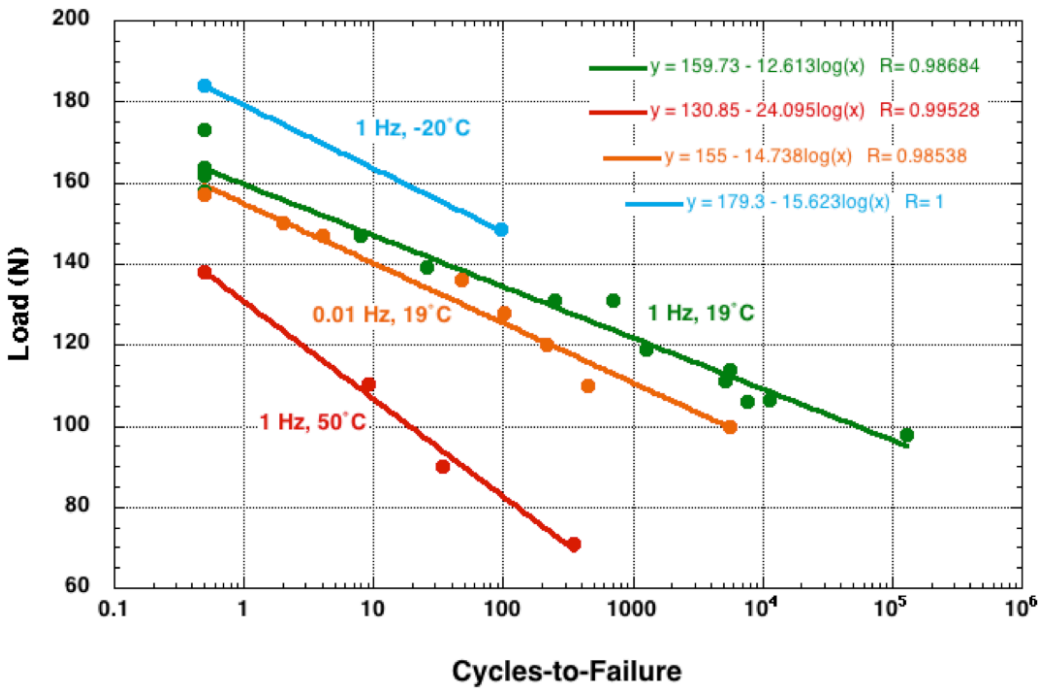

Figure 1 Cycles-to-Failure

It is observed from the experimental data that the failure load as a function of cycles-to-failure is log linear. No endurance limit has been found so far. The data is remarkably clean for fatigue data. It is noted that high cycle and low frequency data are still lacking. The data would need to be extrapolated in this regime. We are also planning on conducting some experiments to minimize extrapolations (i.e. 10 cycles at 1 cycle/day) and verify that this log-linearity holds in the extrapolated regimes.

In order to represent this damage accumulation due to cycles, the following simple damage model is proposed. This equation is a modified Miner's rule and accumulates damage linearly.

$$\frac{N_1}{N_{f1}} + \frac{N_2}{N_{f2}} + \ldots + \frac{N_k}{N_{fn}} = d$$

When $d = 1$, a failure is indicated. N_{fi} denotes the number of cycles to failure at a given temperature, frequency, and stress level while N_i represents the number of cycles under those condition.

This failure model makes predictions about the strength as a function of load history. In the experiment depicted in Figure 2, each specimen was cycled at 114N for a differing number of cycles and then loaded to failure. The number of 114N load cycles is plotted against the resulting failure strength. The prediction (blue line) is overlaid on the experimental data (red squares). The black line represents a traditional cyclic strength of the material.

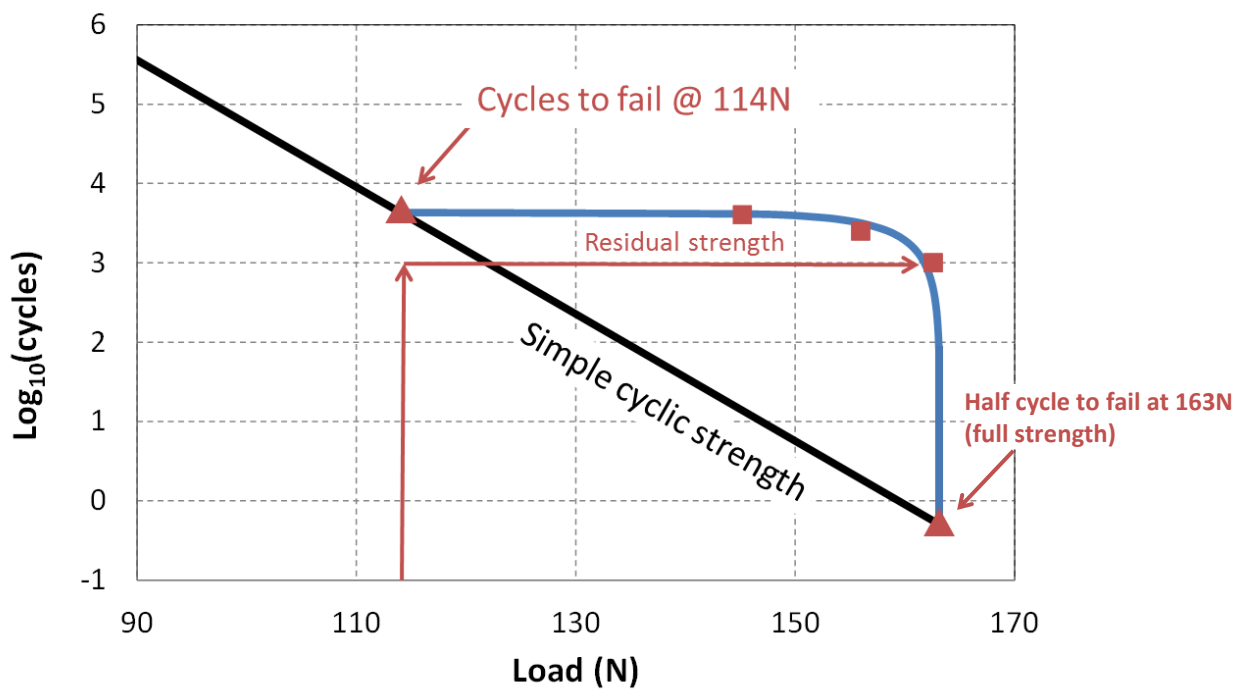

Figure 2. Residual strength as a function of prior load cycles at 114N

Future work includes accounting for an arbitrary stress temperature history. Counting stress cycles , amplitude, and frequency may not be as obvious. We are currently looking into ways of rainflow-counting algorithm to count the cycles. Final usage will modify the factor of safety used in the probabilistic failure model using ratio of cycled to un-cycled strength. Currently, we are assuming that the failure of this material is independent of geometry.