Nearly Identical Twins or Distant Cousins, Revisited.
Weibull or Log-Normal Distributions to Characterize Fatigue Life Scatter – Which is Recommended?

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I was greatly honored to present the Plantema Memorial Lecture in Nagoya (2017). My lecture consisted of three topics; the middle one was entitled *"Nearly Identical Twins or Distant Cousins?"* which dealt with the differences between the Weibull and Log-Normal distributions, both of which are meant to deal with fatigue test scatter.

The current paper, which I propose to present at the 2019 ICAF Symposium, describes further developments on this topic, including a tentative conclusion on which distribution is more correct.

One of the downsides of using fatigue life methodology to determine the safe-life, is that considerable scatter exists, which needs to be accounted for in determining the life to crack initiation.

SuperSMITH Software[1] has been developed by *Fulton Findings* to analyze several statistical distributions, including obtaining their statistical parameters and plotting their results. This software is based on the theoretical methods described in the *"New Weibull Handbook"*[2].

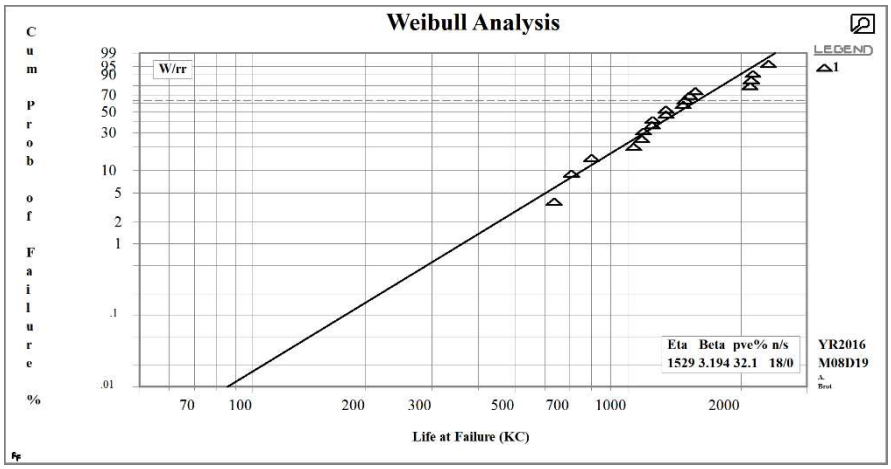

Figure 1. Weibull analysis performed by SuperSMITH Software[1] indicates a Safe-Life of 86 KC (86,000 cycles) for a typical application.

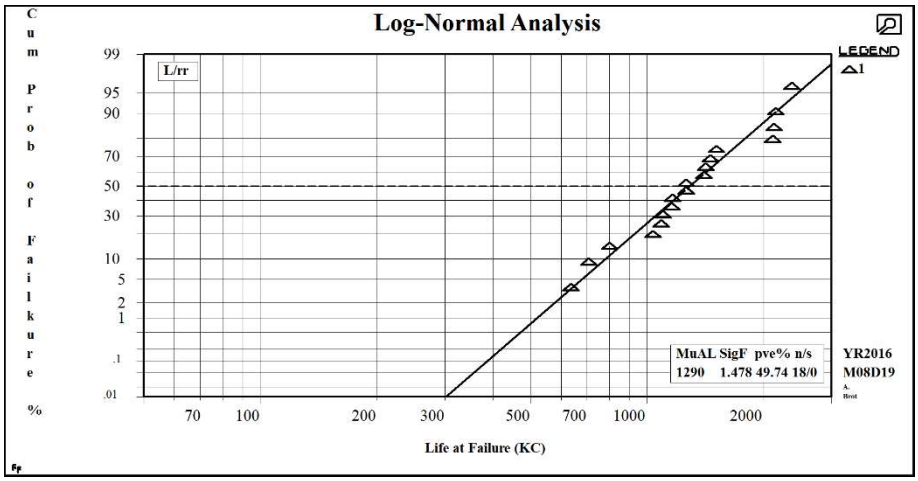

Figure 2. Log-Normal analysis performed by SuperSMITH Software[1] indicates a Safe-Life of 300 KC (300,000 cycles) for the identical application.

By comparing the results shown in Figure 1 to those shown in Figure 2, vast differences in the calculated safe-life exist between the two distributions. Both cannot be correct!

Due to these great differences, the author developed a method to help determine which distribution is more accurate. A large fatigue-life database was constructed using *test results* of many fatigue tests, all composed of various aluminum alloys. In total, the database consisted of 86 specimens.

The above 86 fatigue test results were combined to result in a single test result. The 86-fatigue test lives were normalized to result in a "Characteristic Life" of 50,000 cycles. The lowest failure among the 86 *virtual specimens* was at 18,975 cycles, while the highest failure was at 99,784 cycles. Weibull and Log-Normal plots (Figures 3 and 4) were built for the 86-specimen database, again using SuperSMITH Software[1].

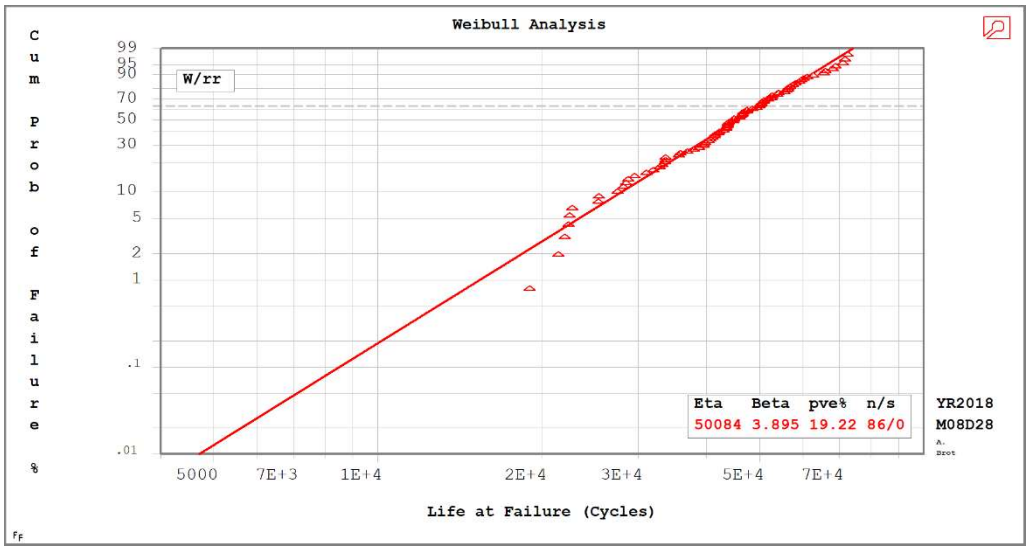

Figure 3. Weibull plot for the 86-specimen test, indicating a safe-life of about 4,700 cycles.

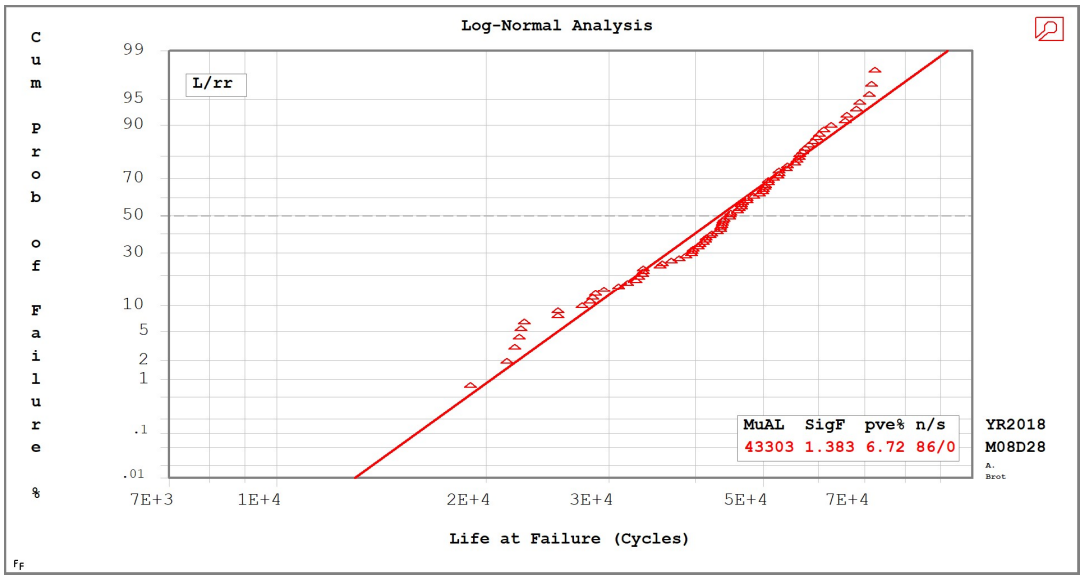

Figure 4. Log-Normal plot for the 86-specimen test, indicating a safe-life of about 13,000 cycles.

The two safe-life calculations differed by a factor of 2.7, which is unacceptable!

In order to analyze which is the more accurate distribution, the data of Figures 3 and 4 were replotted on log-log axes, as is shown in Figure 5.

Figure 5 indicates that six of the eight *earliest failures*, which are below the 10% probability of failure line, clearly indicated that the Weibull distribution is more accurate than the Log-Normal distribution, when

dealing with fatigue failures. In addition, two other considerations point to additional benefits of utilizing the Weibull distribution when dealing with fatigue-life failures to determine the safe-life.

(All these considerations will be explained fully in the final paper.)

In view of these results, the author concluded *(tentatively)* that the Weibull distribution should be preferred to determine the safe-life of a fatigue-critical structural member that has undergone fatigue testing.

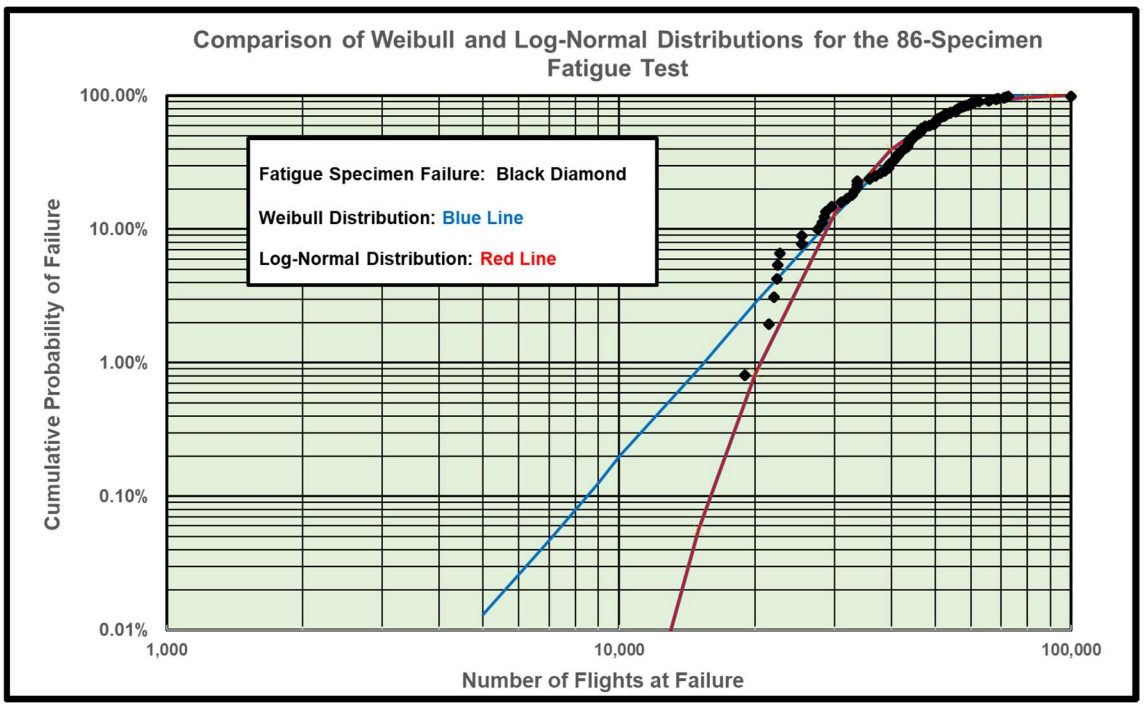

Figure 5. Weibull and Log-Normal plots for the 86-specimen test.

References

1. SuperSMITH Software, release 5.0-CY, developed by Fulton Findings.

2. R. B. Abernethy, *"The New Weibull Handbook", 5th edition, 2009.*