JOURNAL OF ENGINEERING
annals OF
FACULTY OF ENGINEERING HUNEDOARA
TOME VI (year 2008), FASCICULE 3, (ISSN 1584 – 2673)

PAPER CLIPS ACCELERATED LIFE TESTING ANALYSIS

Teodor VASIU, Adina BUDIUL-BERGHIAN

UNIVERSITY POLITEHNICA OF TIMISOARA,
FACULTY OF ENGINEERING HUNEDOARA

ABSTRACT:
This paper clip experiment illustrates the principles behind accelerated life testing. It will be test two samples of paper clips at bends of different angles. One angle represents the use stress level for the paper clip. The objective is to determine the mean number of cycles-to-failure of a given paper clip.

KEYWORDS:
Accelerated life testing, paper clips, mean life

1. INTRODUCTION

Accelerated life testing consists of tests designed to quantify the life characteristics of a product, component or system under normal use conditions by testing the units at higher stress levels in order to accelerate the occurrence of failures. Performed correctly, these tests can provide valuable information about a product's performance under use conditions that can empower a manufacturer to bring its products to market more quickly and economically than would be possible using standard life testing methods.

2. EXPERIMENT

This simple paper clip experiment illustrates the principles behind accelerated life testing. It will be test two samples of paper clips at bends of different angles. One angle represents the use stress level for the paper clip. This is the stress level at which the paper clip is expected to perform under normal use conditions. The other angle represent accelerated stress levels for the paper clip. These stress level is more severe than those expected to be encountered during normal use conditions.

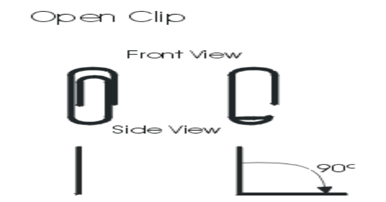
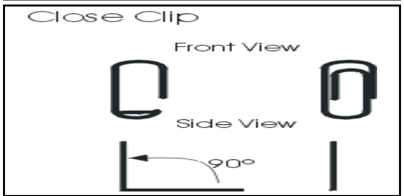
<table>
<tr><td>
</td><td>Hold the clip by the longer, outer loop.
With the thumb and forefinger of the other hand, grasp the smaller, inner loop.
Pull the smaller, inner loop out and down 90° so that a right angle is formed as shown.</td></tr>
<tr><td>
</td><td>Continue to hold the clip by the longer, outer loop.
With the thumb and forefinger of the other hand, grasp the smaller, inner loop.
Push the smaller, inner loop up and in 90° so that the smaller loop is returned to the original upright position in line with the larger, outer loop as shown.</td></tr>
<tr><td colspan="2">This completes one cycle. Repeat until the paper clip breaks. Count and record the cycles-to-failure for each clip.</td></tr>
</table>

FIGURE 1. TEST OF THE PAPER CLIPS USING THE PROCEDURE FOR THE 90°

The objective is to determine the mean number of cycles-to-failure of a given paper clip. The use cycles are assumed to be at a 45° bend. The acceleration stress is assumed to be the angle to which we bend the clips, thus one accelerated bend stresses of 90° is used.

Test a sample of ten paper clips using the procedure for the 90° bend shown below in figure 1. Use a similar procedure to test samples of six paper clips each 45° angles. Different paper clips yield different results. Use clips of similar size. RTC clips, capable of enduring repeated bending, are used in this example.

3. ANALYZING THE RESULTS

For the experiment, samples of ten paper clips each were tested to failure at both 90° bends. A base test sample of six paper clips was tested at a 45° bend (the assumed use stress level) to confirm the analysis. The cycles-to-failure are given next:

At 90°: 9, 11, 16, 17, 18, 19, 21, 22, 23, 27 cycles.
At 45°: 58, 63, 65, 72, 78, 86 cycles.

The accelerated test data were analyzed with ReliaSoft's ALTA accelerated life testing analysis software, assuming a Weibull life distribution (fatigue) and an inverse power law (IPL) relationship (non-thermal) for the stress-life model. By using the IPL relationship to analyze the data, we are actually using a constant stress model to analyze the cycling process. Caution must be taken when performing the test. The rate of change in the angle must be constant and equal for the 90° bends and constant and equal to the rate of change in the angle for the use life of 45° bend. Rate effects influence the life of the paper clip. By keeping the rate constant and equal at all stress levels, we can then eliminate these rate effects from our analysis. Otherwise, the analysis will not be valid.

The parameters of the IPL-Weibull model are: beta = 5.9136, K =1.4964E-5, n = 1.7865. The parameters of the Weibull distribution for the base test data set are: β = 2.4053, η = 26,983, γ = 48.24

The analysis and some of the results are shown in Figures 1, 2, 3 and 4. Figure 2 shows the analysis of the base data in Weibull++7 (with the "Expert" default settings) and the base MTTF estimate. In this case, our accelerated test correctly predicted the MTTF as verified by our base test.

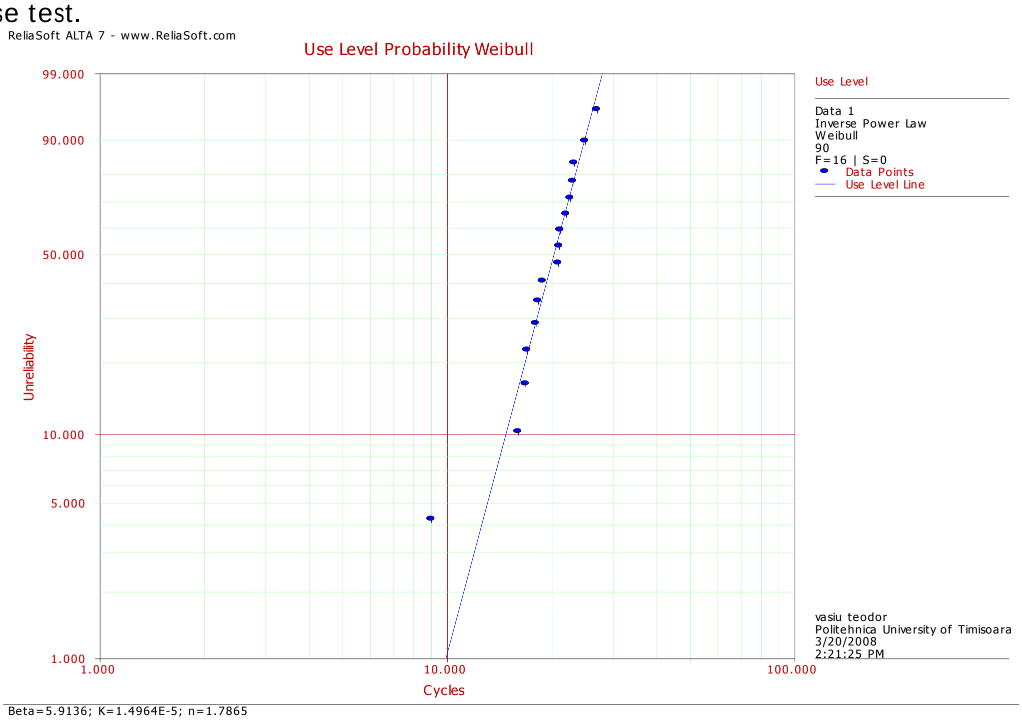


FIGURE 2. PROBABILITY PLOT TEST STRESSES (FROM ALTA)

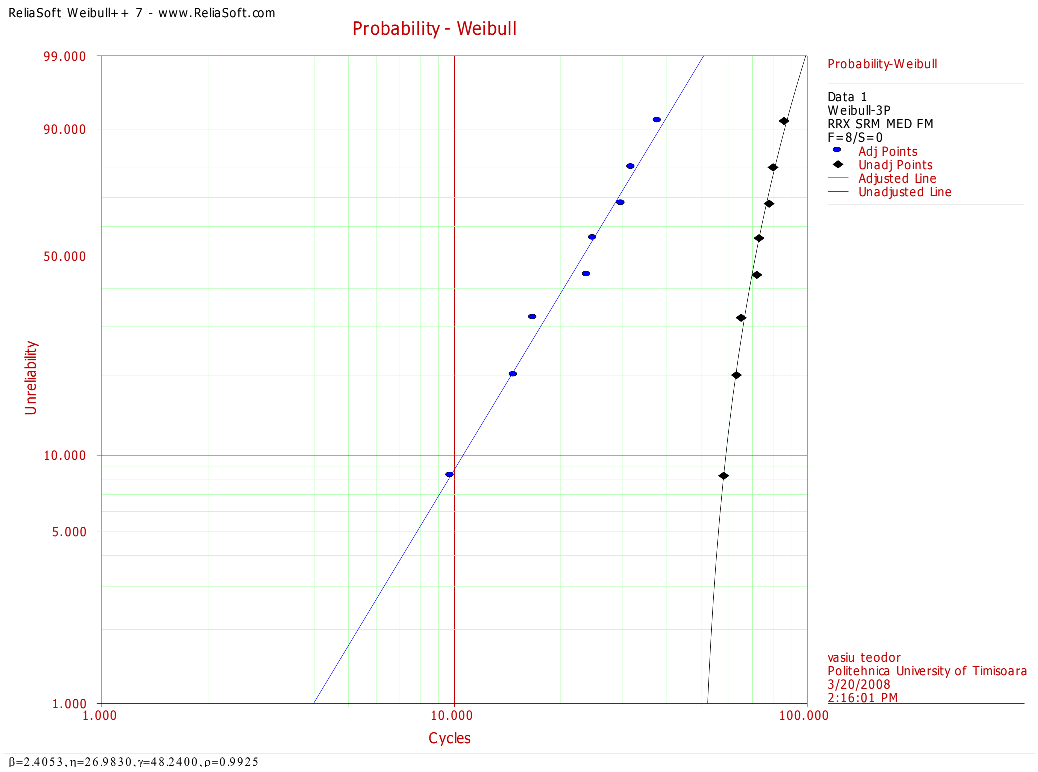


FIGURE 3. (PART 1) DATA ANALYZED USING WEIBULL++7

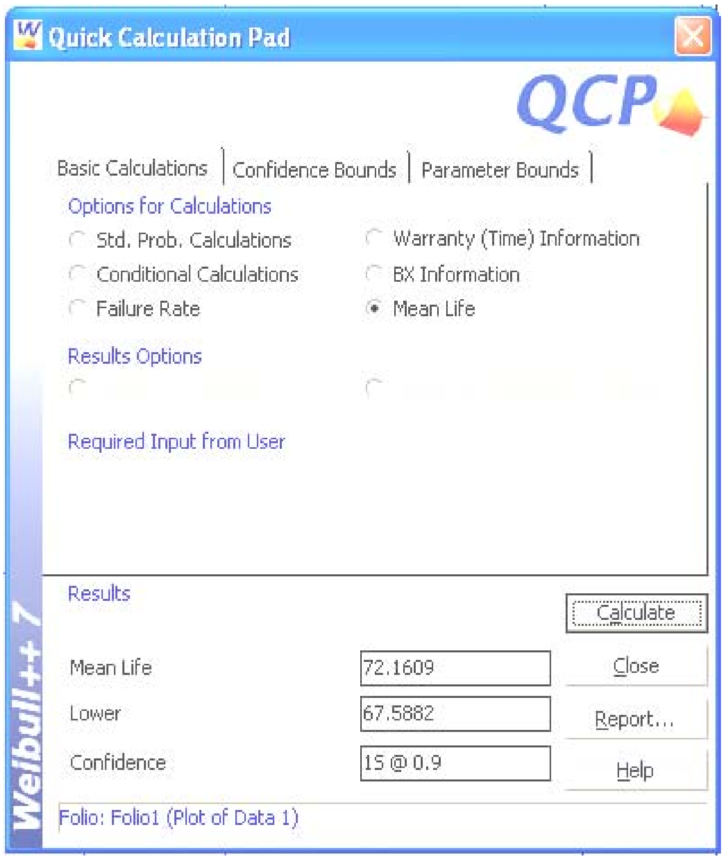


FIGURE 4. (PART 2) DATA ANALYZED USING WEIBULL++7

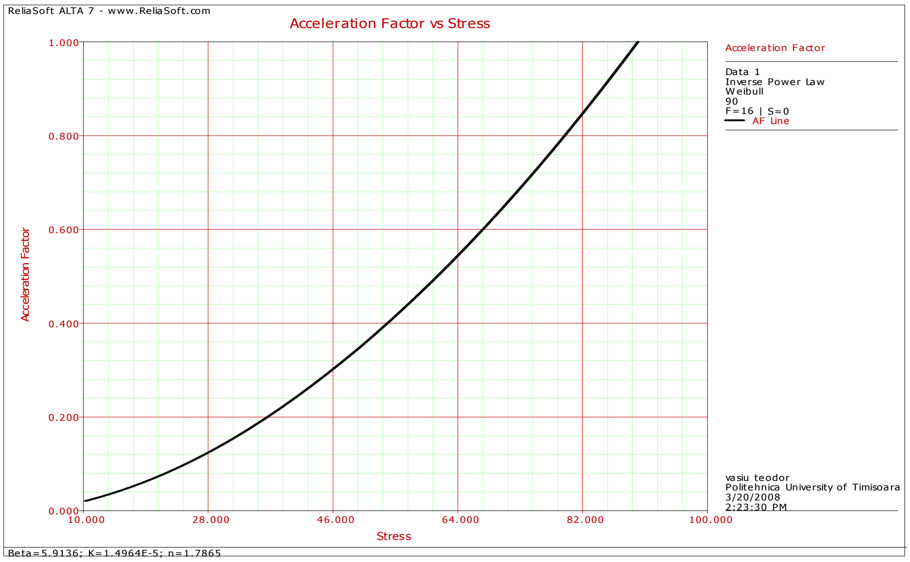


FIGURE 5. ACCELERATION FACTOR PLOT (FROM ALTA)

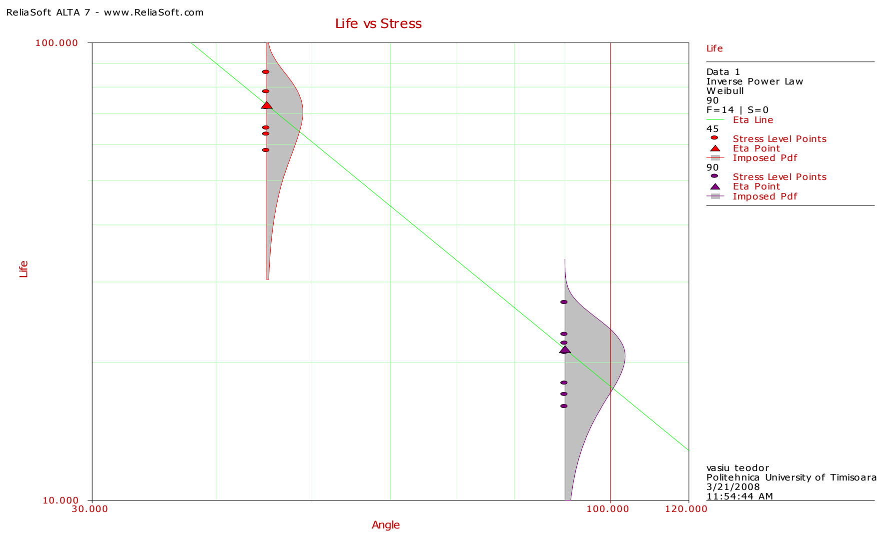


FIGURE 6. MEAN LIFE VS. STRESS PLOT (FROM ALTA)

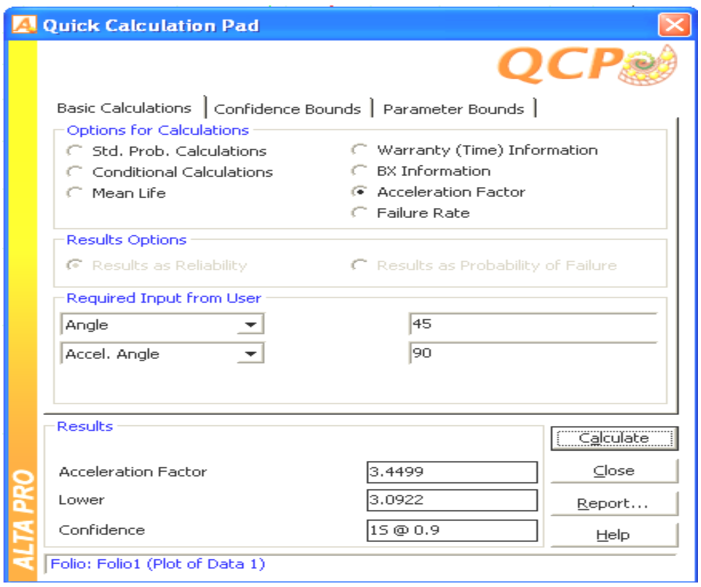


FIGURE 7. ACCELERATION FACTOR CALCULATION (FROM ALTA)

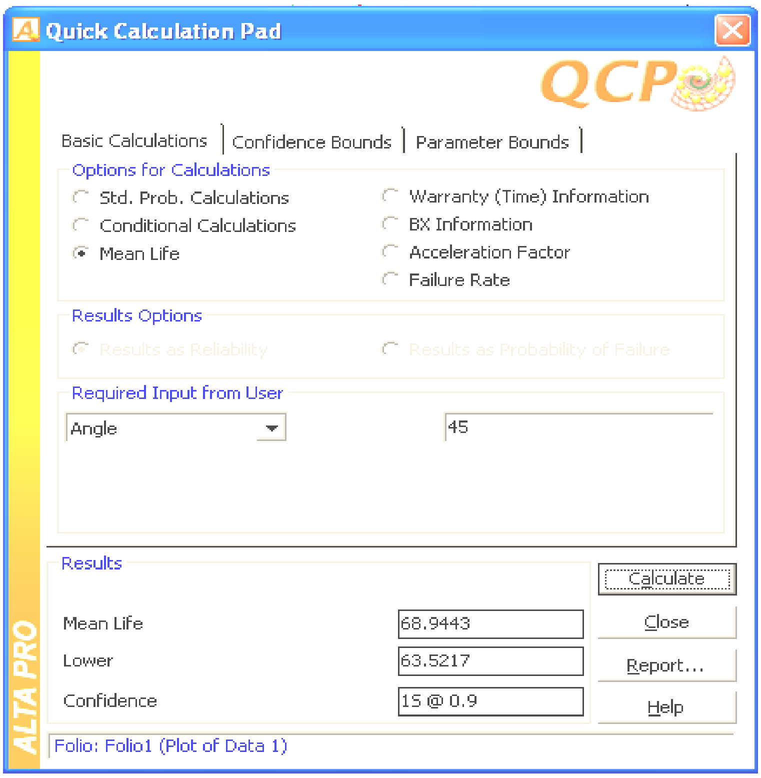


FIGURE 8. MEAN LIFE CALCULATION USING ALTA

4. CONCLUSIONS

In this example, a test at 45° was performed in order to compare the results with the accelerated test analysis results. An MTTF value of 72.1609 (Figure 2, part 2) was obtained from our base test and an MTTF of 68.9443 from the accelerated test (Figure 6). Other metrics of interest can be compared as well. For example, the B10 life estimated from the base test data is 50.8354 cycles, where the B10 life at 45° estimated from the IPL-Weibull model is equal to 58.8269 cycles.

The objective of the accelerated test was to quickly estimate the mean life of the paper clip at the 45° bend. Has this objective been achieved? From the data, it can be seen that the accelerated test yielded significantly reduced cycles-to-failure than the base test. Even though it is obvious from the data, a look at the acceleration factor will quantify this observation. The acceleration factor for the 45° bend is plotted in Figure 3. Using the QCP, a more exact value for the acceleration factor can be obtained, as shown in Figure 5.

Therefore, by testing at 90° we accelerated the occurrence of failure by a factor of 3.4499 (or reduced the cycles-to-failure by 3.4499 times). Note that the accuracy of the measured cycle-to-failure becomes extremely important as the accelerating stress increases, since the failures occur very closely in time to each other.

REFERENCES

[1.] Baron, T., ş.a., *Calitate şi fiabilitate* - manual practic, vol. 1 şi 2, Editura Tehnică, Bucureşti, 1988.
[2.] Mihoc Gh., Muja A., Diatcu E., *Bazele matematice ale teoriei fiabilităţii*, Editura Dacia, Cluj-Napoca, 1976.
[3.] Vasiu T., *Fiabilitatea sistemelor electromecanice*, Editura Bibliofor, Deva, 2000.
[4.] ***, ReliaSoft Weibull++7 software.
[5.] ***, ReliaSoft ALTA 7 software.
[6.] ***, *A Simple Demonstration of Accelerated Life Testing Analysis*, Reliability Edge Home, Quarter 1, 2001, Volume 2, Issue 1.