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STATISTICAL ANALYSIS OF DATA RESULTING FROM ACCELERATED LIFE TESTS SIMULATION

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Abstract: *Increasing global competition has placed great pressure on manufacturers to deliver products with more features and higher reliability at a lower cost and in less time. The unprecedented challenges have motivated manufacturers to develop and deploy effective reliability programs, which include accelerated life tests (ALT). This paper presents theoretical research and a simulation of a case study (mechanical component) using the accelerated life testing. The case study was simulated with Monte Carlo method and the statistical analysis was realized using the ALTA 7 software.*
Key words: *ALT, design, reliability, simulation, stress*

1. INTRODUCTION

Product reliability contributes much to quality and competitiveness. Many manufactures yearly spend millions of dollars on product reliability. Much management and engineering effort goes into evaluating reliability, assessing new designs and design and manufacturing changes, identifying causes of failure, and comparing designs, vendors, materials, manufacturing methods, and the like (Nelson, 2004).

Major decisions are based on life test data, often from a few units. Moreover, many products can be life tested at high stress conditions to yield failures quickly (Pham, 2008). Analyses of data from such an accelerated test yield needed information on product life tested at design condition (low stress).

Many of the devices produced (Zio, 2007) today for complex technical systems have very high reliability under normal use conditions. The questions then arise of how to make the optimal choice between several types or designs of a device and how to collect information about the corresponding life distributions under normal use conditions. A common way of tackling these problems is to expose the device to sufficient overstress to bring the mean time to failure down to an acceptable level. Thereafter, one tries to "extrapolate" from the information obtained under over stress to normal use conditions. This approach is called Accelerated Life Testing (ALT) or overstress testing.

Stress that accelerates the failure process may be applied in many forms, high or low temperatures, cycling between excessively high and low conditions, humidity, excess usage, electrical stress, vibration, and so forth. In order to conduct and analyses an accelerated life test, the challenge is to relate the results obtained under conditions of higher stress to those that would result under normal conditions (Zaharia & Martinescu 2009). This requires an adequate understanding of failure mechanisms and appropriate models that express the relationship. Planning an ALT in advance is a critical step toward success in obtaining valid and accurate information. A feasible and reasonable test plan should include managerial, logistical, and technical considerations. Managerial considerations deal with formation of a team, definition of the roles and responsibilities of each team member, coordination of the team, and other personnel management tasks. Logistical tasks are to secure the availability of test facilities such as chambers, functionality inspection systems, and measuring devices. Technical considerations include determining the test's purpose, sample units and size, failure definition, time scale, acceleration methodology, and data collection and analysis methods (Bertsche, 2008).

ALTs are often conducted to estimate life distribution at use conditions. The statistical error of the estimate depends on the test plan. Certainly, it is desirable to devise the optimal test plans that minimize error. For a constant-stress test, a test plan consists of stress levels, the number of test units allocated to each stress level, and values of other variables. A step-stress test plan usually consists of the times at which a stress level is increased or the number of failures to trigger the increase in stress level (Yang, 2007).

2. CASE STUDY

For reliability purposes, a Monte Carlo simulation can basically be used to estimate a value or simulate the stochastic process describing the behavior of a complex system. In this sense, a Monte Carlo simulation is useful to achieve results, numerically verify an analytical solution, get an idea of the possible time behavior of a complex system or determine interaction among variables. In this paper, information on case study will be simulated using software ALTA 7. The SimuMatic utility (from ALTA 7) expands on this capability by allowing you to automatically perform specified reliability analyses on a large number of simulated data sets. Monte Carlo data simulation allows you to generate data based on the life-stress model, distribution, parameters, and stress levels that you specify.

For a tensile component of a landing gear was simulate an accelerated life testing with Monte Carlo methods. With Alta 7 software, failure times were simulated for the 14 units tested in accelerated conditions. The component of landing gear were tested at two different levels of shock loads (80 and 110 kips). The component was designed for a peak shock load of 50 kips with an estimated return of 10% of the population by 10.000 landings. Using the inverse power law - lognormal model, determine whether the design life was met. The Monte Carlo simulation window is described in figure 1.

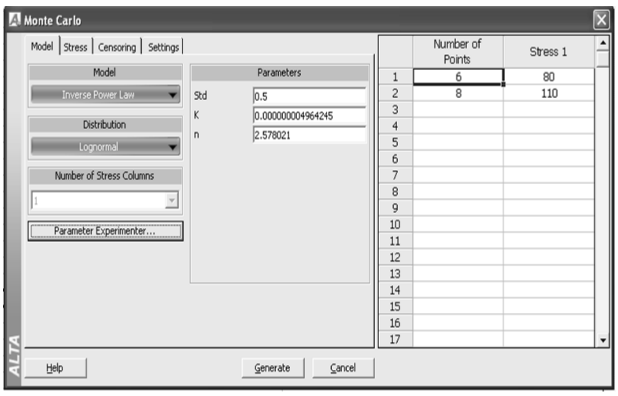

Fig. 1. Monte Carlo simulation window

Failure times resulting from Monte Carlo simulation method are described in Table 1.

No.	Time to failure [cycles]	Shock Loads [kips]
1	1827	80
2	2528	80
3	2570	80
4	3416	80
5	4740	80
6	5055	80
7	578	110
8	589	110
9	720	110
10	1121	110
11	1195	110
12	1287	110
13	1332	110
14	1832	110

Tab. 1. Time to failure vs. Stress (Shock Load)

The data were entered into ALTA 7, and the following estimates were obtained for the parameters of the IPL - lognormal model: Std. = 0.380; k = 4.705E-11; n=3.588.

In the following plot (figure 2), the 10% unreliability line is plotted (the first line from the left). For the stress of 50 kips (X axis) and for the 10% unreliability line, the cycles-to-failure can be obtained by reading the value on the Y-axis. Again T(0.1) 10420 landings.

However, a more accurate way to obtain such information is by using the Quick Calculation Pad (QCP) in ALTA. The QCP extracts the parameters and other information from the active Folio and returns results based on the analysis and, when applicable, your inputs. Warranty (Time) Information returns time based on a given stress level and reliability. The required inputs are the stress level and the required reliability. Using the QCP, the life for a 10% probability of failure at 50 kips is estimated to be 10433 cycles (or landing) as shown in figure 3. The design criterion of 10000 landings is met.

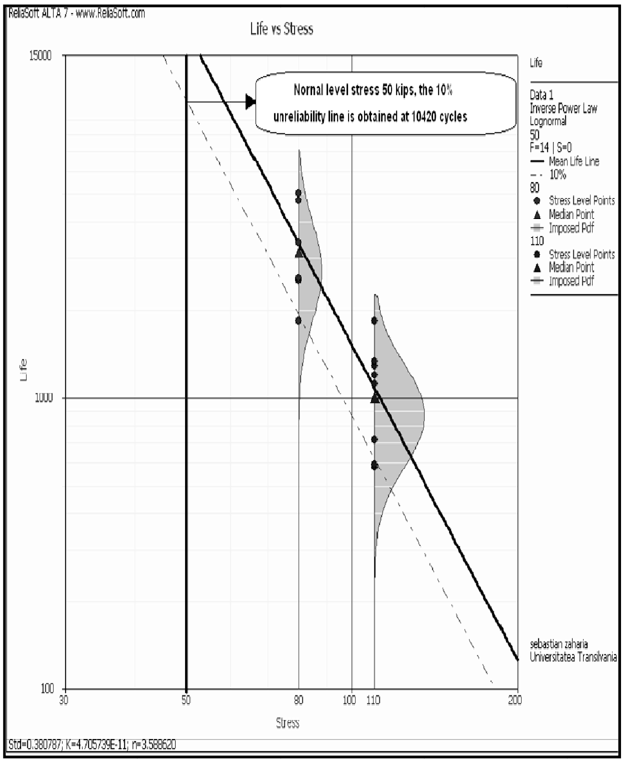

Fig. 2. Mean Life Line (left) and 10% unreliability line (right) vs. Stress (Shock Load)

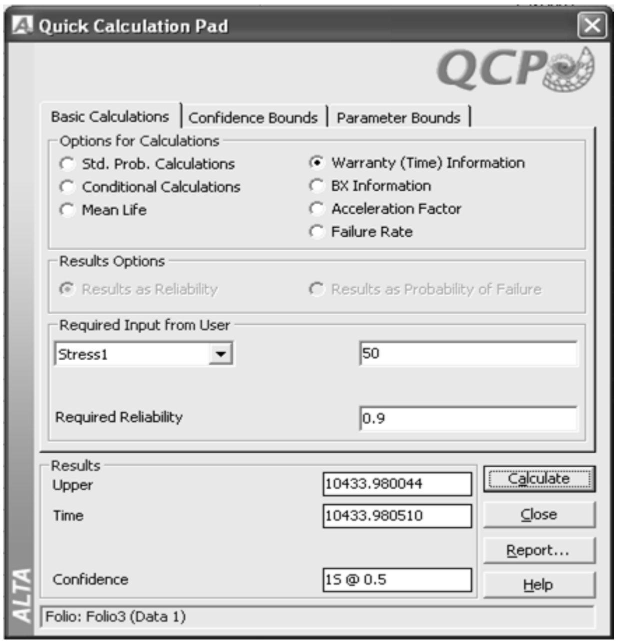

Fig. 3. Quick Calculation Pad (warranty time information)

3. CONCLUSION

The life of most products depends on the operating stresses they experience in service. Therefore, the need to relate life and stress becomes a necessity in order to perform reliability predictions. In addition, the stresses experienced by a product in service are usually time - dependent. Accelerated life testing provides the data from which life-stress relationship of a product can be obtained. Such tests are becoming increasingly popular in today's industry due to the need to quickly obtain the life data. Such testing saves much time and money.

As further research I will expand the accelerated life testing on other components from aviation and engineering products.

4. ACKNOWLEDGEMENTS

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