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IMPROVING PRODUCT RELIABILITY UNDER ACCELERATED LIFE TESTING USING MONTE CARLO SIMULATION

Sebastian Marian ZAHARIA[1], Ionel MARTINESCU[2]

[1,2]Transilvania University of Braşov
B-dul Eroilor, nr. 29, Romania
[1]zaharia_sebastian@unitbv.ro
[2]ionel_martinescu@unitbv.ro

Abstract

An accelerated life testing is an aging deterioration of a product to induce normal failures by operating at stress levels much higher than would be expected in normal use. Such a test and results derived there from help identify design weaknesses and also to quantify reliability indicators. Ten electronics systems were subjected to accelerated life testing involving thermal and vibration stresses to determine the operating and destruct limits, and to discover potential design, component and manufacturing related weaknesses.

Keywords: reliability tests, electronic systems, ALT, Monte Carlo simulation, failures

1. Introduction

The purpose of reliability testing is to discover potential problems with the design as early as possible and, ultimately, provide confidence that the system meets its reliability requirements [1].

Reliability testing may be performed at several levels, component, circuit board, unit, assembly, sub-system and system levels. For example, performing environmental stress screening tests at lower levels, such as component level or small assemblies, catches problems before they cause failures at higher levels. Testing proceeds during each level of integration through system testing, developmental testing, and operational testing, thereby reducing program risk.

Traditional life data analysis involves analyzing times-to-failure data obtained under normal operating conditions in order to quantify the life characteristics of a product, system or component. For many reasons, obtaining such life data (or times-to-failure data) may be very difficult or impossible. The reasons for this difficulty can include the long life times of today's products, the small time period between design and release, and the challenge of testing products that are used continuously under normal conditions. Given these difficulties and the need to observe failures of products to better understand their failure modes and life characteristics, reliability practitioners have attempted to devise methods to force these products to fail more quickly than they would under normal use conditions. In other words, they have attempted to accelerate their failures. Over the years, the phrase accelerated life testing has been used to describe all such practices [2, 3].

In general, the accelerated life testing can be divided into two categories: qualitative ALT and quantitative ALT. Qualitative ALT, such as Highly Accelerated Life Testing (HALT), Highly Accelerated Stress Screening (HASS), torture tests, shake and bake tests, are used primarily to reveal probable failure modes for the product so that product engineers can improve the product design. Quantitative ALT consists of tests designed to quantify the life characteristics of the product, component or system under normal use conditions and thereby provide reliability information [4, 5].

ALT of products can be used for the following purposes at both component and system levels (Fig. 1):

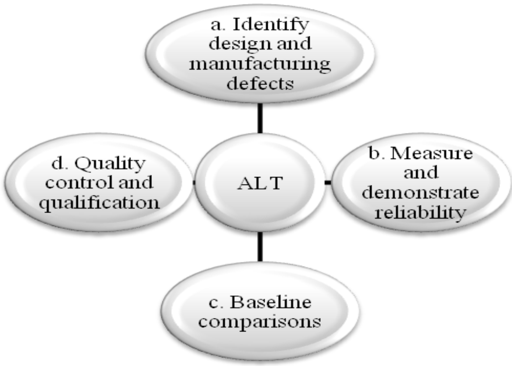

Fig. 1: The purpose of accelerated tests

Accelerated testing consists of a variety of test methods for shortening the life of products or hastening the degradation of their performance. The aim of such testing is to quickly obtain data which, properly modeled and analyzed, yield desired information on product life or performance under normal use. An ALT deals with theoretical considerations (including mathematical and statistical backgrounds of reliability) and technical concepts of products (including their failure modes, the economic and business considerations), so the identification of these elements by the manufacturer is necessary to obtain more realistic results from the ALT [6].

Pursuing the previously stated main purpose of the accelerated life tests, we need a model that relates life to accelerating stress, such as temperature, humidity, and voltage. Such models (Fig. 2), usually called acceleration models, can be classified into the following three types: physical models; quasi-physical models; empirical models [7].

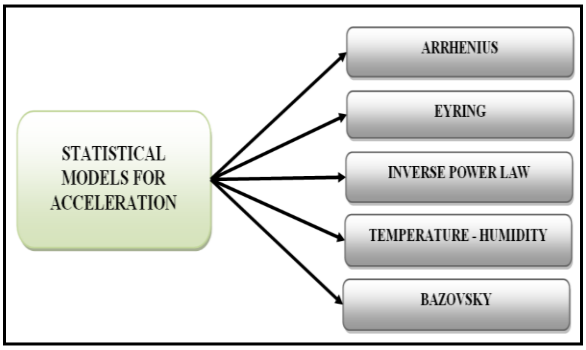

Fig. 2: Statistical model for accelerated data

2. Materials and methods

Monte Carlo simulation is a powerful tool for modeling: the reliability data of industrial products; the behavior of some activity, plan or process that involves uncertainty [8, 9]. If you face uncertain or variable market demand, fluctuating costs, variation in a manufacturing you can benefit from using Monte Carlo simulation to understand the impact of uncertainty, and develop plans to mitigate or otherwise cope with risk. A sample with 10 electronic systems (circuit board – Fig. 3) is subjected to a quantitative accelerated life test in which two stress types are applied to the units.

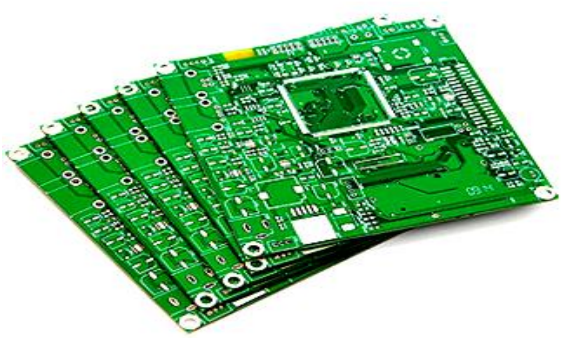

Fig. 3: Circuit board

The stress types include temperature and vibration. The chamber test is represents in Fig. 4.

Fig. 4: HASS chamber

The normal use stress levels are 50°C for temperature and 5 Hz for vibration. The general Temperature – Non Thermal life-stress model is used and the Weibull distribution is used as the underlying life distribution for the data set. In Fig. 5 is described the parameters used in the Monte Carlo simulation from the ALTA7 software.

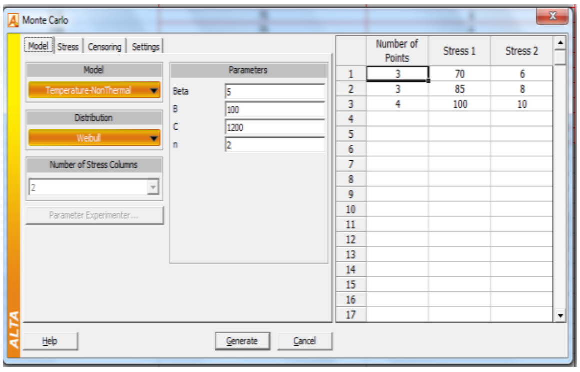

Fig. 5: Monte Carlo simulation

Fig. 6 shows the determination of failure times for the three accelerated regimes (70 °C, 85°C, 100 °C and 6 Hz, 8 Hz, 10 Hz).

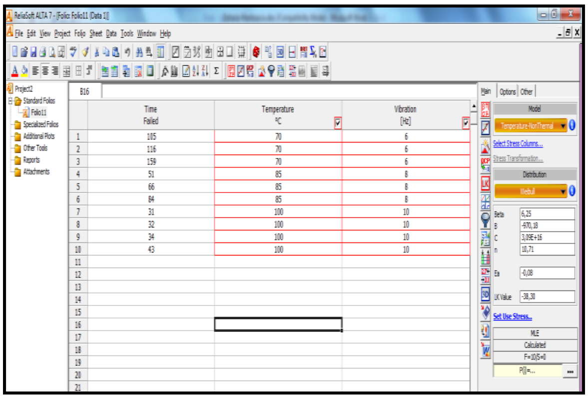

Fig. 6: Accelerated data

3. Simulation, statistics and data analysis

As awareness of product reliability increases, so does the responsibility of engineering organizations to insure that reliability requirements are met. As a result, engineers and managers who have had little experience with life data analysis or applied statistics may find themselves responsible for calculating and reporting on a product's reliability [10, 11, 12]. The purpose of reliability analysis is to indicate the probability of success for a specified time. This probability is called the reliability and is always associated with a given time [13]. That is, the given percentage representing the probability of success is a function of time and is essentially paired with an associated time. In Fig. 7 was described the plot of reliability vs. time vs. temperature.

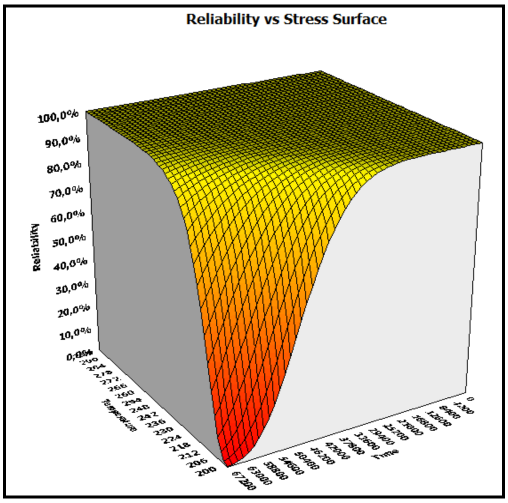

Fig. 7: Reliability function vs. temperature

Plot 3D allows you to view a variety of three-dimensional plots for the currently calculated data set. The available 3D plots include the likelihood function plot, pdf plot, failure rate plot, reliability plot and unreliability plot [14]. In Fig. 8 was described the plot of reliability vs. time vs. vibration.

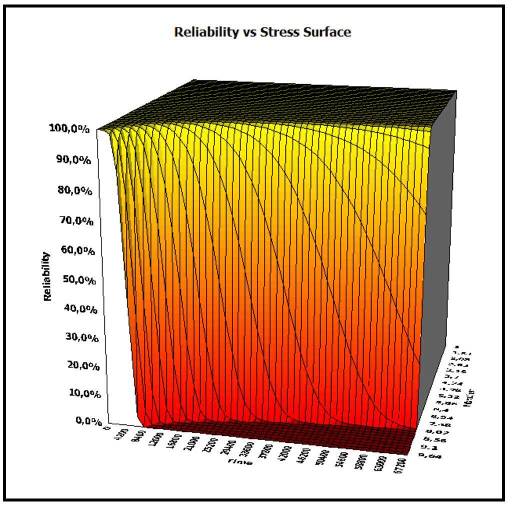

Fig. 8: Reliability function vs. vibration

In accelerated life data analysis, however, we face the challenge of determining the use level probability density function (Fig. 9) from accelerated life test data, rather than from times-to-failure data obtained under use conditions. To accomplish this, we must develop a method that allows us to extrapolate from data collected at accelerated conditions to arrive at an estimation of use level characteristics.

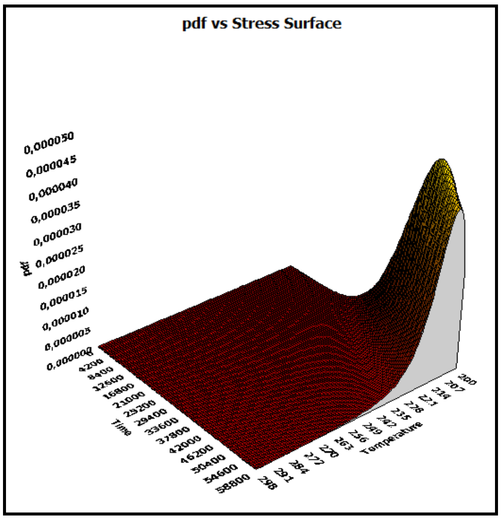

Fig. 9: Probability density function

The instantaneous failure rate is a function of time and stress [15]. For this reason, a 3-dimensional plot of Failure Rate vs. Time and Stress (Fig. 10) can be obtained in ALTA.

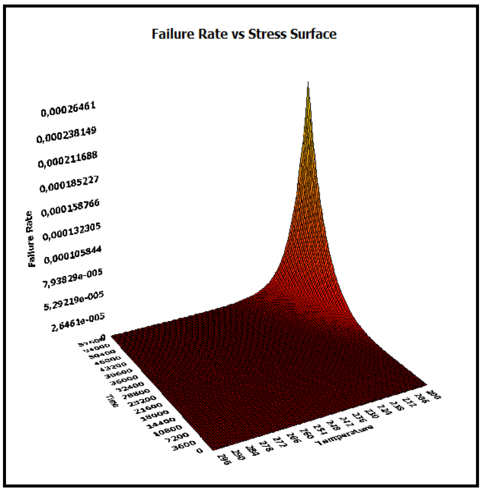

Fig. 10: Failure rate

Life vs. Stress plots and Probability plots are the most important plot types in accelerated life testing analysis. Life vs. Stress plots are widely used for estimating the parameters of life-stress relationships. Any life measure can be plotted versus stress in the Life vs. Stress plots available in ALTA. Confidence bounds information on each life measure can also be plotted. Graphical determination of the mean life in the normal operating condition (50°C and 5 Hz) of the electronic systems is described in Fig. 11.

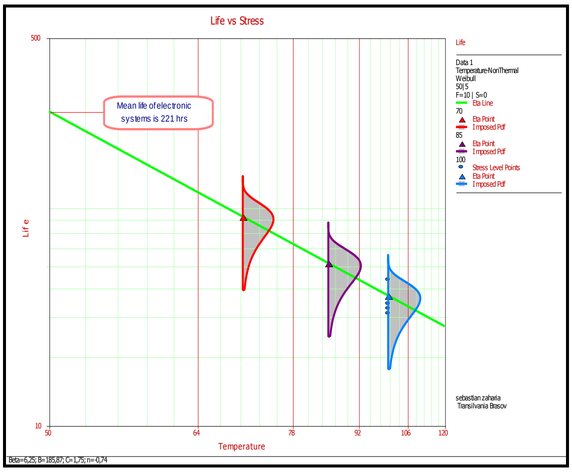

Fig. 11: Life vs. Stress Plot

Engineering specifications may call for a certain BX life, which also represents a time period during which a certain proportion of the population will fail. For example, the B10 life is the time in which 10% of the population will fail. In Fig. 12 was determined B10 indicator for the case study analyzed in this paper.

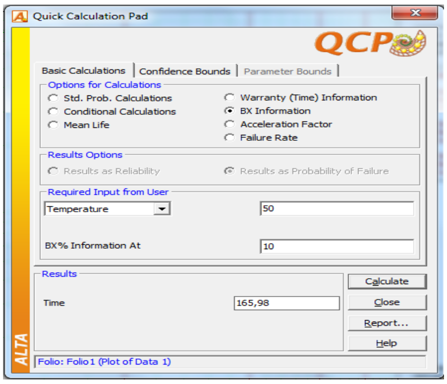

Fig. 12: B10 indicator

4. Conclusion

ALT is an effective technology of demonstrating and improving industrial product reliability and quality. ALT accelerates a given failure mode by testing at amplified stress level in excess of operational limits. This paper explains the technical and mathematical methodology for acceleration life test models using engineering rationale, and a mathematical approach in the test design and data analysis. At some industrial products, for which a high reliability is estimated, the determination of the life time and of the reliability parameters, under normal stress conditions, implies a long testing period. For this reason we opted for the accelerated life testing methods. These are tests being performed at more intense stress conditions, compared to the normal stress conditions, with the purpose of intensifying the degradation processes and, as an economic result, the shortening of the period and costs related to the testing, while preserving the same failure modes and mechanisms.

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