PENGESAHAN PENYELIA

“ Saya akui bahawa saya telah membaca

karya ini dan pada pandangan saya karya ini

adalah memadai dari segi skop dan kualiti untuk tujuan penganugerahan

Ijazah Sarjana Muda Kejuruteraan Mekanikal (Rekabentuk & Inovasi)”

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FEASIBLE STUDY ON CHARACTERIZATION AND COMPARISON OF ACCELERATED LIFE TESTS AND THE COMPATIBLE SOFTWARE FOR AUTOMOTIVE COMPONENT

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Laporan ini dikemukakan sebagai

memenuhi syarat sebahagian daripada syarat penganugerahan

Ijazah Sarjana Muda Kejuruteraan Mekanikal (Rekabentuk & Inovasi)

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Universiti Teknikal Malaysia Melaka

MAY 2010

"I hereby to declare that this project report entitle FEASIBLE STUDY ON CHARACTERIZATION AND COMPARISON OF ACCELERATED LIFE TESTS AND THE COMPATIBLE SOFTWARE FOR AUTOMOTIVE COMPONENT is written by me and is my own effort except the ideas and summaries which I have clarified their sources."

Signature : ……………………………

Author : DILA AFNIDA BINTI AZMAN

Date : MAY 2010

To my lovely parents, Azman bin Yusof and Zuraina binti Serkawi, for everlasting supports, Ahmad Faruqy bin Mohamad Shabari, friends, Noor Asmah binti Arshad, Suhaila binti Mat Said and my housemates, lecturer, Mohd Asri bin Yusuff for guiding and endless help during the preparation of this report.

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ABSTRACT

ReliaSoft's Accelerated Life Test Analysis (ALTA) Software is used to determine the life span of component and the useful reliability information could be obtained in a matter of weeks instead of months. The comparisons were made between others Accelerated Life Test (ALT) analyses with Accelerated Life Test Analysis (ALTA) application. The advantages of ALTA are easy to use and navigate, very good tool to designing all reliability tests and treatment of data, ALTA removes most of calculation/number crunch errors, does multiple distributions, one data entry checks and ranks multiple distribution, to reduce the time taken to analyze the life span of a component, to increase the production rate and to reduce the time taken to complete a product. ALTA is chosen because it is compatible to test on automotive component. ALTA is the only commercial software for accelerated life test analysis. The advantages stated earlier shows that this software can be used to determine life expectancy on component effectively and faster.

ABSTRAK

Perisian komputer iaitu ReliaSoft's Accelerated Life Test Analysis (ALTA) digunakan untuk menentukan jangka hayat sesuatu komponen dan kebolehpercayaan maklumat yang bermanfaat boleh diperolehi dalam kiraan minggu berbanding bulan. Perbandingan telah dilakukan antara ALTA dan perisian yang setaraf dengannya. Kelebihan ALTA ialah ia mudah digunakan, ia juga merupakan alat yang sesuai untuk mengaplikasikan semua ujian dan membaiki data, selain itu, ALTA membuang sebahagian besar daripada perhitungan / nombor yang tidak diperlukan, ALTA boleh melakukan dan menyusun beberapa edaran dalam satu kemasukan data, ia juga dapat mengurangkan waktu yang diperlukan untuk menganalisis jangka hayat komponen, meningkatkan tahap pengeluaran dan mengurangkan masa yang diperlukan untuk menyelesaikan sesuatu produk. ALTA dipilih kerana ia adalah perisian yang sesuai untuk di aplikasi terhadap komponen automotif. ALTA adalah satu-satunya perisian komersil untuk mempercepatkan analisis jangka hayat. Kelebihan yang dinyatakan di atas menunjukkan bahawa perisian ini boleh digunakan untuk menentukan harapan hidup pada komponen dengan berkesan dan lebih cepat.

LIST OF CONTENT

CHAPTER	INDEX	PAGE

CHAPTER	INDEX	PAGE

LIST OF TABLE

LIST OF FIGURE

CHAPTER I

INTRODUCTION

This chapter contains the project background of the research study which entitled “Feasible study on characterization and comparison of accelerated life tests and the compatible software for automotive component”. This chapter is including the background of the project whereas a little bit of project summary will be include, objectives of the project’s research, scope, and problem statement of the project.

1.1 Background of Project

Traditional life data analysis involves analyzing times-to-failure data (of a product, system or component) obtained under normal operating conditions in order to quantify the life characteristics of the product, system or component. In many situations, and for many reasons, such life data (or times-to-failure data) is very difficult, if not impossible, to obtain. 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 this difficulty, and the need to observe failures of products to better understand their failure modes and their 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 term accelerated life testing has been used to describe all such practices.

A variety of methods that serve different purposes have been termed “accelerated life testing.” As the term is used in this reference, accelerated life testing involves acceleration of failures with the single purpose of quantification of the life characteristics of the product at normal use conditions.

More specifically, accelerated life testing can be divided into three areas: qualitative accelerated testing, Environmental Stress Screening and quantitative accelerated life testing. In qualitative accelerated testing, the engineer is mostly interested in identifying failures and failure modes without attempting to make any predictions as to the product's life under normal use conditions. In quantitative accelerated life testing, the engineer is interested in predicting the life of the product at normal use conditions, from data obtained in an accelerated life test. Each type of Accelerated Life Tests (ALT) analyses will be in detail explanation including its example.

1.2 Problem Statement

In the past, life test analysis is used to predict the life span of components. Normally, it takes longer to estimate the life span. This can cause problems to production line whereas it will reduce the production rate and takes longer to complete a product. With using accelerated life test analysis, the useful reliability information could be obtained in a matter of weeks instead of months.

Reliability is a very important measure of modern electronic products and its growth and improvement are vital to safeguarding progress in manufacturing industries. Reliability at first seems to be just a number without any meaning to many who do not have a deep understanding of its proper application. However, it is the only possible means by which the robustness of modern manufacturing and testing procedures may be measured.

An integrated reliability program includes all reliability testing programs such as Design Validation Testing, Accelerated Life Testing, Highly Accelerated Life testing, Reliability Demonstration Testing, and On-Going Reliability Tests. This should be implemented in such a way that all the reliability needs for the product are covered and there is no extra effort. The design of an optimal reliability testing program will also help reduce the overall life cycle costs of the product while improving the products reliability.

1.3 Objective

These analysis objectives are to analyze the characteristic of the accelerated life test analysis and to compare with Accelerated Life Test (ALT) softwares. Understand and quantify the effects of stress (or other factors) on product life.

Design accelerated tests that will be the most effective to achieve desired objectives. Significantly reduce the test time required to obtain reliability metrics for a product, which can result in faster time-to-market, lower product development costs and improved designs.

1.4 Scope

The scope of this analysis is to observe and study the methodology. Another major scope of this project is to make comparisons of the Accelerated Life Tests (ALT). An Accelerated Life Tests (ALT) software must been chosen to find the compatible ALT software that can be used on automotive component.

CHAPTER II

LITERATURE REVIEW

In this chapter, there is briefly explanation regarding to the purpose of this project which is to find the compatible Accelerated Life Tests (ALT) software for automotive component. Each of ALT will be briefly explained including its example. The functions and comparison of all ALT software will be stated.

2.1 Overview

In typical life data analysis, the practitioner analyzes life data of a product's sample operating under normal conditions in order to quantify the life characteristics of the product and make predictions about all of the products in the population. In life data analysis, the practitioner attempts to make predictions about the life of all products in the population by "fitting" a statistical distribution to life data from a representative sample of units. The parameterized distribution for the data set can then be used to estimate important life characteristics of the product such as reliability or probability of failure at a specific time, the mean life for the product and failure rate.

Life data analysis requires the practitioner to:

- Gather life data for the product.
- Select a lifetime distribution that will fit the data and model the life of the product.
- Estimate the parameters that will fit the distribution to the data.
- Generate plots and results that estimate the life characteristics, like reliability or mean life, of the product.

2.2 Accelerated Life Test (ALT)

Each type of test that has been called an accelerated test provides different information about the product and its failure mechanisms. Generally, accelerated tests can be divided into three types: Qualitative Tests (Torture Tests or Shake and Bake Tests), ESS and Burn-in and finally Quantitative Accelerated Life Tests.

2.2.1 Qualitative Tests

Qualitative Tests are tests that yield failure information (or failure modes) only. They have been referred to by many names including:

- Elephant Tests
- Torture Tests
- HALT (Highly Accelerated Life Testing)
- Shake & Bake Tests

Qualitative tests are performed on small samples with the specimens subjected to a single severe level of stress, to a number of stresses, or to a time-varying stress (i.e., stress cycling, cold to hot, etc.). If the specimen survives, it passes the test. Otherwise, appropriate actions will be taken to improve the product's design in order to eliminate the cause(s) of failure. Qualitative tests are used primarily to reveal probable failure modes. However, if not designed properly, they may cause the product to fail due to modes that would have never been encountered in real life.

A good qualitative test is one that quickly reveals those failure modes that will occur during the life of the product under normal use conditions. In general, qualitative tests are not designed to yield life data that can be used in subsequent analysis or for "Accelerated Life Test Analysis." In general, qualitative tests do not quantify the life (or reliability) characteristics of the product under normal use conditions. Highly Accelerated Life Testing (HALT) is chosen under this topic for further discussion.

2.2.1.1 Highly Accelerated Life Testing (HALT)

In recent years, the test techniques known as HALT (Highly Accelerated Life Testing) and HASS (Highly Accelerated Stress Screening) have been gaining advocates and practitioners. These test methods, quite different from standard life testing, design verification testing and end-of-production testing, are becoming recognized as powerful tools for improving product reliability, reducing warranty costs and increasing customer satisfaction.

A Highly Accelerated Life Test (HALT) is a stress testing methodology for accelerating product reliability during the engineering design process. It is commonly applied to electronic equipment and is performed to identify and thus help resolve design weaknesses in newly-developed equipment. Thus it greatly reduces the probability of in-service failures i.e. it increases the product's reliability.

Progressively more severe environmental stresses are applied building to a level significantly beyond what the equipment will see in-service.

By this method weaknesses can be identified using a small number of samples (sometimes one or two but preferably at least five) in the shortest possible time and at least expense. A second function of HALT testing is that it characterizes the equipment under test, and identifies the equipment's safe operating limits and design margins. Individual components, populated printed circuit boards, and whole electronic systems can be subjected to HALT testing.

The size of the test sample is governed by many factors including the number of samples available, cost, type of stresses applied, and physical size. For example, component manufacturers can typically test thousands of individual components at one time whereas often it is not economically feasible to write off more than a few items of very expensive equipment because production quantities or the application does not justify the cost.

A general principal is that whilst HALT test can and should be conducted at unit level, it is very desirable to conduct it at sub-assembly and piece-part level as well. Temperature cycling and random vibration, power margining and power cycling are the most common form of failure acceleration for electronic equipment. HALT does not measure or determine equipment reliability but it does serve to improve the reliability of a product. It is an empirical method used across industry to identify the limiting failure modes of a product and the stresses at which these failures occur.

On military design and development programs HALT is conducted before qualification testing. By so doing, significant cost savings can accrue, because the formal qualification of the equipment and subsequent customer acceptance will proceed more rapidly and at lower cost, and the need for multiple redesigns and repeat testing (regression tests) will be greatly reduced or eliminated.

There is no one recipe for a HALT test, but different stresses are applied with different failures occurring during each. The types of stress typically employed are:

1. Cold Step
2. Hot Step
3. Rapid Temperature Cycling
4. Stepped Vibration (random)
5. Combined Environment stress (temperature cycling and random vibration plus power switching and power margining)

In HALT these stresses are applied in a controlled, incremental fashion while the unit under test is continuously monitored for failures. Once the weaknesses of the product are uncovered and corrective actions taken, the limits of the product are clearly understood and the operating margins have been extended as far as possible. A much more mature product can be introduced much more quickly with a higher degree of reliability.

When HALT testing is applied during the design process, it can produce a very robust product without undue cost, because improvements are targeted only where they are needed. As failure modes are discovered and understood the product life can increase significantly. This makes the product more robust and risk of failure reduces drastically.

Individual components such as resistors, capacitors, and diodes, printed circuit boards, and whole electronic products such as cell phones, PDAs, and TVs, eventually fail at different rates under different end-user stress levels. For example, a typical consumer-owned television will not likely be operated at temperatures outside the range of normal living accommodations, or subjected to mechanical stress by being repeatedly dropped. A cell phone, on the other hand, may be dropped from 3 or 4 feet off the ground fairly often, and subjected to a varying range of vibrations.

A commercial telephone switch may be required to operate in remote installations ranging from Barrow, Alaska to Phoenix, Arizona, at an ambient temperature range of from minus 50 to plus 120 degrees Fahrenheit. Components used in military and aerospace applications may be subjected to even more severe operating temperature requirements as well as high G-forces and ionizing radiation, sometimes simultaneously, to meet specific MIL-SPEC standards.

Therefore, failure rate data used to select any device in a product must correlate with the stress levels in the product or application. To accomplish this, the required lifetime and operating conditions for the product into which the components are designed must first be determined. For instance, in the above examples, the television set may only be required to operate through its warranty period, whereas the telephone switch may be required to operate without being serviced for ten years or more.

Components used in a missile may only be required to operate for a few hours of testing and a few minutes of actual use, but their failure rate will be expected to be zero during that period. Devices used in satellites or space vehicles where replacement is not possible are expected to have a zero failure rate for the lifetime of the vehicle. Knowing the required failure rate as determined by the application, components can be selected based on the failure rate data supplied by the manufacturer as described above.

A test chamber designed for HALT testing is really required for satisfactory and successful HALT testing. A temperature ramp rate of at least 45 degrees C/minute is required, and some HALT chambers can achieve closer to 60 degrees C /minute. To achieve these high ramp-rates, cooling by means of the evaporation of liquid nitrogen is required. Chambers equipped with one or two compressors for cooling, such as those typically employed during qualification testing, are really not adequate. Such chambers are typically only capable of 15-18 degrees C/minute, and are subject to frequent breakdowns if always pushed to their limit.

A suitable chamber also has to be capable of applying random vibration with a suitable spectral density profile in relation to frequency. It has to be capable of doing this at the same time as it applies temperature cycling so a combined chamber is essential rather than separate chambers for vibration and temperature cycling. Whereas chambers used for qualification testing often use electro-dynamic vibrators (like a giant moving-coil loudspeaker). Chambers designed for HALT testing use pneumatic hammers arranged to strike the base plate upon which the equipment is mounted. The hammers produce six degree of freedom random vibration: they produce simultaneous vibration in each principle axis and rotations about each axis. This compares with the single axis of vibration provided by electro-dynamic vibrators.

2.2.2 Environmental Stress Screening (ESS) and Burn-In

The second type of accelerated test consists of ESS and Burn-In testing. ESS is a process involving the application of environmental stimuli to products (usually electronic or electromechanical products) on an accelerated basis. The surviving population, upon completion of screening, can be assumed to have a higher reliability than a similar unscreened population. The goal of ESS is to expose, identify and eliminate latent defects which cannot be detected by visual inspection or electrical testing but which will cause failures in the field. ESS is performed on the entire population and does not involve sampling.

Developed to help electronics manufacturers detect product defects and production flaws, ESS is widely used in military and aerospace applications, less so for commercial products. The tests need not be elaborate, for example, switching an electronic or electrical system on and off a few times may be enough to catch some simple defects that would otherwise be encountered by the end user very soon after the product was first used.

Tests typically include the following:

- Temperature variations
- Vibration tests
- Pressure
- Flexibility tests

ESS can be performed as part of the manufacturing process or it can be used in new product qualification testing. An ESS system usually consists of a test chamber, controller, fixturing, interconnect and wiring, and a functional tester. These systems can be purchased from a variety of companies in the environmental test industry.

The stress screening from this process will help find infant mortality in the product. Finding these failures before the product reaches the customer yields better quality and lower warranty expenses. Associated military terminology includes an operational requirements document (ORD) and on-going reliability testing (ORT).

To conduct an effective screen, the product must be capable of surviving the high stimulation levels needed to accelerate the failure mechanism of assembly related defects. The participation of design and reliability engineering is to determine the limits of environmental stimulation which the product can endure before its performance is permanently degraded. A mechanically "weak" design may be changed to improve its margins with respect to a specific form of environmental stimulus.

The form of ESS chosen by the factory is dependent on the failure mechanisms for the relevant field failures. An ESS program is faulty when it does not expose the locus of faults seen by the customer. The ESS process is a dynamic process which must change as product failure behavior changes. For this reason, it is not appropriate to "spec" an ESS regimen and leave the regimen unchanged throughout product life.

Again, the purpose of any environmental stress screening (ESS) regimen is to expose the hidden defects that were introduced during the manufacturing process. More succinctly, manufacturing defects are precipitated from latent to patent.

ESS, however, is not designed to find deficiencies in product design although in many cases it does expose design deficiencies. Rather than design an ESS program to find design weaknesses, an important ingredient of product qualification must be the undertaking of environmental testing to ensure that the design is robust enough to meet its design goals. As the electronics industry has matured, component technology and assembly techniques have changed profoundly.

The first product to be subjected to environmental stress screening in the form of “burn-in” was products designed with vacuum tube technology. Burn-in can be regarded as a special case of ESS. For these products, high temperature burn-in was the best stimuli for precipitating latent defects. Early transistor and integrated circuit technology defects were also efficiently stimulated to failure using high temperature burn-in. During this time, most product defects were component related defects. Today we see a much different failure behavior for electronic products. Components have become so reliable that most product defects are related to the assembly process. As the product fault spectrum has changed, the screening stimuli for rapid defect precipitation must also change to ensure that latent defects are efficiently stimulated to an observable failure.

According to MIL-STD-883C, Burn-in is a test performed for the purpose of screening or eliminating marginal devices. Marginal devices are those with inherent defects or defects resulting from manufacturing aberrations which cause time and stress-dependent failures. As with ESS, Burn-in is performed on the entire population. The intention is to detect those particular components that would fail as a result of the initial, high-failure rate portion of the bathtub curve of component reliability. If the burn-in period is made sufficiently long (and, perhaps, artificially stressful), the system can then be trusted to be mostly free of further early failures once the burn-in process is complete.

A precondition for a successful burn-in is a bathtub-like failure rate, that is, there are noticeable early failures with a decreasing failure rate following that period. By stressing all devices for a certain burn-in time the devices with the highest failure rate fail first and can be taken out of the cohort. The devices that survive the stress have a later position in the bathtub curve (with an appropriately lower ongoing failure rate).

Thus by applying a burn-in, early in-use system failures can be avoided at the expense (tradeoff) of a reduced yield caused by the burn-in process. When the equivalent lifetime of the stress is extended into the increasing part of the bathtub-like failure-rate curve, the effect of the burn-in is a reduction of product lifetime. In a mature production it is not easy to determine whether there is a decreasing failure rate. To determine the failure time distribution for a very low percentage of the production, one would have to destroy a very large number of devices.

When possible, it is better to eliminate the root cause of early failures than doing a burn-in.

Because of this, a process that initially uses burn-in may eventually phase it out as the various root causes for failures are identified and eliminated. For electronic components, burn-in is frequently conducted at elevated temperature and perhaps elevated voltage. This process may also be called heat soaking. The components may be under continuous test or simply tested at the end of the burn-in period.

There is another use of the term by some audiophiles, who leave new audio equipment turned on for multiple days or weeks, to get the components to achieve optimal performance. However, many debates arise about the beneficial effects of this practice.

2.2.3 Quantitative Accelerated Life Tests

Quantitative Accelerated Life Testing, unlike the qualitative testing methods (i.e., Torture Tests, Burn-in, etc.) described previously, consists of quantitative tests designed to quantify the life characteristics of the product, component or system under normal use conditions, and thereby provide “Reliability Information.” Reliability information can include the determination of the probability of failure of the product under use conditions, mean life under use conditions, and projected returns and warranty costs. It can also be used to assist in the performance of risk assessments, design comparisons, etc. Accelerated Life Test Analysis (ALTA) software has been chosen for QALT.

2.2.3.1 Accelerated Life test Analysis (ALTA)

Accelerated Life Testing can take the form of “Usage Rate Acceleration” or “Overstress Acceleration.” Both Accelerated Life Test methods are described next. Because “Usage Rate Acceleration” test data can be analyzed with typical life data analysis methods, the Overstress Acceleration method is the testing method. For all life tests, some time-to-failure information for the product is required since the failure of the product is the event we want to understand.

In other words, if we wish to understand, measure, and predict any event. Most products, components or systems are expected to perform their functions successfully for long periods of time, competitive, the time required to obtain times-to-failure data must be considerably less than the expected life of the product.

Two methods of acceleration, “Usage Rate Acceleration” and “Overstress Acceleration,” have been devised to obtain times to-failure data at an accelerated pace.

For products that do not operate continuously, one can accelerate the time it takes to induce failures by continuously testing these products. This is called “Usage Rate Acceleration.” For products for which “Usage Rate Acceleration” is impractical, one can apply stress at levels that exceed the levels that a product will encounter under normal use conditions and use the times-to failure data obtained in this manner to extrapolate to use conditions. This is called “Overstress Acceleration.”

i) Usage Rate Acceleration

For products that do not operate continuously under normal conditions, if the test units are operated continuously, failures are encountered earlier than if the units were tested at normal usage. For example, a microwave oven operates for small periods of time every day. One can accelerate a test on microwave ovens by operating them more frequently until failure. The same could be said of washers. If we assume an average washer use of 6 hours a week, one could conceivably reduce the testing time 28-fold by testing these washers continuously. Data obtained through usage acceleration can be analyzed with the same methods used to analyze regular times-to-failure data. The limitation of “Usage Rate Acceleration” arises when products, such as computer servers and peripherals, maintain a very high or even continuous usage. In such cases, usage acceleration, even though desirable, is not a feasible alternative. In these cases the practitioner must stimulate the product to fail, usually through the application of stress. This method of accelerated life testing is called “Overstress Acceleration”.

ii) Overstress Acceleration

For products with very high or continuous usage, the accelerated life-testing practitioner must stimulate the product to fail in a life test.

This is accomplished by applying stress that exceeds the stress that a product will encounter under