André Cabarbaye

ENRICHED VERSION

Implementation of accelerated life testing

Collection
Reliability in practice

Cab Innovation Editor

Collections

Reliability in practice

- Risk control & reliability of systems
- Estimation in Dependability and Safety
- Dependability Modelling, Evaluation and Optimisation
- From the quantification of the risk to the optimisation of the systems

  (gathers the contents of the two previous books)
- Dependability and Safety & optimization of systems

  (groups the contents of the first three books)
- Implementation of accelerated life testing

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To all those who contributed to the enrichment of this guide

Preface

The Nobel Prize-winning physicist Nils Bohr famously quipped, "Prediction is very difficult, especially if it is about the future".
Liability issues due to unreliable products were recently top of headlines: a consumer maker manufacturer recalls over 1 Million S7 phones because of 35 reports of overheating; so considering a 35 ppm issue can impact recall of entire product line!
The huge development of electronic or mechatronic based equipment in embedded systems, IoT, computers, laptops, tablets, autonomous cars, or smartphones as example, require system engineer developers to look at and analyse all kind of data. We often come across the end or maybe not the end of Moore's law but problems in reliability that were once difficult and time consuming for even experts can now be solved with a few well-chosen statistical methods and technics.
J. W. McPherson, Texas Instruments Senior Fellow Emeritus, recently recalled at the 2019 European Symposium on Reliability of Electron Devices, Failure Physics and Analysis: "All devices are expected to degrade with time --- so device reliability is of great practical importance. Reliability investigations generally start with measuring the degradation rate for a material/device and then modelling the time-to-failure versus the applied stress."
A series of tools and software's exist to address Quality, Robustness, Reliability, Health Monitoring, and Predictive Maintenance. Among number of publications and books related to applied reliability, the High Temperature Operating Life (HTOL) or steady state life test is a very conventional tool to determine the reliability of devices under operation at high temperature conditions over an extended period of time.

The book proposed by André Cabarbaye, Senior Expert in RAMS (Reliability, Availability, Maintainability, and Safety), that I have the honor and great pleasure to present here, is a compilation of statistical models and technics. It was a chance for me to benefit his expertise in various key projects developed at IRT Saint Exupery, Thales Alenia Space and in a CLEANSKY2 project called RYTHMS all covering applied reliability activities among Time-to-Failure to degradation modelling of Deep-Sub-Micron technology (CMOS bulk, FinFET), GaN Power Switch devices, Photonic products (transceivers, laser diodes).
Why should this book be considered a novelty?

This guide is a didactic upkeep for system engineers within industries, universities, manufacturers and research laboratories. It is a clear and precise support to cross the river between human quest in mathematic for prediction and scientists and engineers from the industrial sector still confronted with dynamic systems increasingly complex.
The book describes the major concepts, methods, and approaches of the applied theory of probability and provides numerous examples applicable to various areas of engineering.
In a first chapter, the basic reminders in probability and statistics are recalled: probabilistic methods used in engineering, confidence level, maximum likelihood, Bayes theorem, parametric and non-parametric reliability models (Kaplan-Meier), degradation models (Gamma or Weiner processes). The author presents the hypotheses underlying the standard accelerated life model as well as the acceleration laws usually encountered in electronics and mechanics. Different types of HALT, HASS, burn-in, endurance and reliability tests are described as well as their design logic illustrated by concrete examples and application spreadsheets. Lastly, the last chapter of this book addresses the crucial question of optimising trials in order to reduce the cost and improve the accuracy of the results.
The overall structure of the book is shaped to a rather broad audience of engineers and applied scientists. There is no doubt that this guide is a collection particularly useful to the reliability experts but also to all those who in their practice wish to implement reliability tests using state-of-the-art sizing and operating techniques.

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Foreword

While acceleration models are of interest to breweries whose beer production depends on climatic conditions (temperature, humidity, etc.) and the impact of major events (football matches, etc.), they cannot be ignored by product designers and users, given the extent to which environmental and use conditions influence their reliability.

For example, a car will not age in the same way in Norway as in the Sahara, or if it is driven by an elderly person compared with their grandchildren.

Allowing the transition from one stress condition to another, the acceleration factor may appear somewhat magical. However, it is not just the preserve of a few obscure experts and is based on hypotheses that need to be clearly explained and compared with operational data or test data for validation.

Its accuracy is essential in order to demonstrate, within reduced timeframes and at minimum cost, the operational capacity of products to perform their role through endurance or reliability tests.

Incorrect evaluation of the influence of stresses results in either optimistic testing results that will not materialise during the operational life of a product, or overly stringent testing conditions that lead to deadlock or costly overruns.

Similarly, it determines estimates of predicted reliability and those of remaining useful life (RUL) in the context of the health monitoring and predictive maintenance now required by most systems operators.

While diagnostics have hugely benefited from the capabilities of big data (most notably in the detection of weak signals), prognostics are still very much in their infancy.

They require models of reliability or degradation in a variety of use and environmental conditions, which can only be established on the basis of significant but usually belated feedback.

However, these same models can also be produced from accelerated testing performed at the end-of-design phase. Fulfilling a dual objective, the benefits of these models are significantly enhanced and their costs therefore easier to justify.

However, in addition to reliability modelling problems, testability and in particular observability of degradation in the presence of wear phenomena is too often forgotten by designers, when in fact it guarantees the feasibility of tests (as well as online diagnostics) and can significantly reduce their costs.

The enriched version of this book has benefitted from the feedback and comments of manufacturers to whom we extend our warmest thanks.

1. Introduction

Stress increases the risk of failure, and as a result is factored in to reliability models.

However, it is also used in endurance and reliability tests to reduce the duration of testing and/or the number of test objects by increasing stress levels beyond those experienced in the operational life of a product (temperature, vibration, humidity, etc.).

This ingenious utilisation of use and environmental conditions does, however, impose two requirements:
- any increase in stresses must be limited so as not to create additional failure or degradation phenomena during the tests other than those that would be observed under nominal conditions,
- the acceleration laws used to transition from test results to operational performance must be perfectly defined in order to accurately demonstrate the actual capacity of the products in question.

In order to fully explain the modelling of physical phenomena, the first part of this book will review the theoretical foundations of accelerated testing, and include a short detour on the basic principles of probability and statistics.

The different types of tests are then presented together with their field of application and respective conditions of implementation.

A guide to using accelerated testing is then offered to clarify and explain practices based on the test situations encountered:
- for a component or an assembly grouped into a product,
- in the presence or absence of wear phenomena,
- with or without precise knowledge of acceleration laws, etc.

The final section of the book covers methods for optimising the design and planning of accelerated testing. These attempts to reduce the cost and duration of a strategic activity used to demonstrate the operational capability of products and provide models of operating behaviour, in an increasingly service-oriented economy.

6. Conclusion

The ability to accelerate endurance or reliability testing by increasing stress levels relative to operational life is a boon to designers who can therefore demonstrate the operational capacity of their product to perform a role, at a lower cost and over a shorter timeframe.

To be credible, however, this demonstration must be based on explicit hypotheses, justified by experience or validated by tests.

By combining reliability or degradation distributions with acceleration distributions, accelerated life models are based on relatively solid theoretical foundations; however, these should be adapted to each situation in agreement with experts and technology specialists in the fields involved (electronics, mechanical engineering, etc.).

The predominant failure modes should be identified beforehand, together with the stresses that accelerate their onset.

The effect of combined stresses on specific failure modes can be difficult to identify accurately.

The test methods available do not always allow good representation of behaviours with respect to operational lifetime.

Testability, and in particular direct or indirect observability of degradation or wear levels, is not an issue to be considered just before testing but an intrinsic characteristic of products that should be taken into account in the design phase.

Accelerated life models are highly sensitive to the value of their different parameters and can give totally erroneous results if this value is inaccurate.

These parameters can be estimated through the tests themselves provided that they produce sufficient data and that it can be processed correctly using powerful optimisation tools to adjust models.

These same tools can be used to optimise the preliminary design and planning of tests in order to improve result accuracy or reduce all related costs (number of parts to be tested, test methods and duration, etc.).

In addition, accelerated testing can be used to establish design-phase reliability or degradation models in a variety of use and environmental conditions; these are an essential input for prognostics in the context of the health monitoring and predictive maintenance now required in the operation of products and systems.

They therefore deserve the greatest attention from decision-makers.

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Implementation of accelerated life testing

Stress increases the risk of failure and should be taken into account in reliability models.

However, any resulting complexity is an asset in the field of endurance or reliability tests conducted to demonstrate the ability of a product to perform its role. It can be used to reduce the duration of testing and/or the number of test objects by increasing stress levels (temperature, vibration, humidity, etc.).

Tests should, however, reveal the same failure or degradation phenomena under accelerated and nominal conditions, and the acceleration distributions allowing the transition from test results to operational performance should be known or characterised by the tests themselves.

The design of tests and then their implementation in accordance with various strategies can be optimised to reduce their cost.

However, existing standards (EN 62506, etc.) provide few precise recommendations on their application (number of objects to be tested, the types and conditions of stress to be applied, the theoretical models to be used, the value of acceleration distribution parameters, etc.).

This educational book on the implementation of accelerated life testing therefore explains its theoretical foundations and offers a practical application guide which covers state-of-the-art thinking on design techniques and optimal planning of tests, the results of which also constitute an input for health monitoring and predictive maintenance.

A senior expert in operational safety, this book has been written by the CEO of Cab Innovation, a company which develops and markets optimisation and reliability software. The author of numerous scientific papers during his time at the French National Centre for Space Studies (CNES), he has set up operational safety groups in the Occitanie region of France and on LinkedIn.

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