Reliability Design of Mechanical Systems
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A Guide for Mechanical and Civil Engineers

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Springer
In the beginning of the twentieth century, new sophisticated mechanical systems such as bridges, rockets, automobiles, airplanes, and space shuttles were designed and built for people to live comfortable lives through the engineering design processes. Typical design process can be broadly summarized as (1) define the problems, (2) develop the product–prototype, design and testing, (3) production. Due to the frequent occurrence of disasters for new products, product reliability has become one of increasingly important factors (to consider) because of cost, competition, public demand, and adaptation of new technology. The most effective way to protect the reliability disaster is to develop the reliability-embedded design process including its methodology in parallel with the established design process.

As products with multiple modules require higher performance and material cost reduction, the reliability design of product has become more complex and increases the risk of product failure. The studies of reliability engineering have been deepened to prevent the reliability disasters of the past century. Even though there are a large number of concepts, theory, and texts on reliability, an up-to-date book for emphasizing the new methodology of reliability design is still required to prevent the reliability disasters of the mechanical/civil system.

From the standpoint of economics, company will decrease the operation profit for a failure in its expected product lifetime because of Product Liability Law in the global market. All products from tires to electric components are fabricated from the structure (or materials) that will tend to degrade or break down abruptly by random loads. The mechanical system can eventually fracture due to fatigue which can result from cyclical stresses (or loads). When products are subjected to random loads, they start the void in material (or design defects), propagate, and rupture it. If failure for a new product happens, the product may no longer meet the established specifications for proper product functionality. To avoid product failure in lifetime, product should be designed to robustly withstand a variety of loads.

The main objectives of writing this book are focused on explaining the development necessity of the reliability-embedded design process and its methodology.
As reliability methodology, we will suggest the new parametric accelerated life testing (ALT) that meets those market requirements—higher performance, material cost reduction, and higher reliability in field. The reliability-embedded design process consists of parametric ALT plan, failure mechanism and design, acceleration factor, sample size equation, and the parametric ALT. It produces the reliability quantitative test specifications (RQ) in accordance with the reliability target. A parametric ALT method therefore will assess the reliability of product subjected to repetitive stresses.

Based on the market data, parametric ALT plan will set up the reliability target of product and its modules. Mechanical system in field subjected to loads arise how to design product for the failure mechanisms—fatigue and fracture. The accumulated damage in system like palmer miner rule can be represented at the time-to-failure model. The acceleration factor with a new effort concept (or loads) was derived from a generalized life-stress failure model. So the new sample size equation with the acceleration factor enabled the parametric ALT to quickly evaluate the expected lifetime of product. This parametric ALT should help an engineer to uncover the missing design parameters affecting reliability during the design process of new product.

Consequently, if applied in the established design process, new parametric ALT helps companies to improve new product reliability and avoid the recalls of product failures in field. As the improper design parameters in the design phase are identified by this reliability design method, the product will improve the reliability that will be measured by the increase in lifetime, \( L_B \), and the reduction in failure rate, \( \lambda \). Product will meet the reliability target in industry. This book will help to prevent the reliability disaster through the parametric ALT. We also provide a lot of parametric ALT examples that are effective to be understood in the mechanical/civil field.

This book is composed of nine chapters. Chapter 1 presents the present aspect and need of reliability engineering in the advance of modern technology. Chapter 2 reviews the historical reliability disasters and their root cause within the past century. It will explain the significance of reliability assessment, and its methodology need to prevent reliability disasters in the design process. Chapter 3 will explain the most important fundamental definitions of statistics and probability theory, the mathematical essentials of reliability engineering, and the most significant aspects of reliability engineering developed within the past century. It will help one to understand the basic concepts of reliability methodologies that will be discussed in Chap. 8. Chapter 4 through Chap. 6 present load analysis, stress concept, and a brief overview of the typical reliability failure mechanism of product—fatigues and fractures. Chapter 7 will present the fundamental concepts of the parametric ALT in product that will be the core of this book. Chapter 8 will also present case studies that are useful in a variety of engineering areas. Chapter 9 will cover the future aspects of parametric ALT in mechanical product that will be developed as system engineering.
This book is intended to introduce the prerequisite concepts of the parametric ALT for senior level undergraduate and graduate students, professional engineers, college and university level lecturers, researchers, and design managers of the engineering system. We hope this noble methodology explained in this book will help to prevent the reliability disasters of new product in field. The authors would also like to thank Springer for the publishing of this work, especially Mayra Castro, Springer DE. With their help, this book has been published.

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