Preface

This book is dedicated exclusively to the subject of minimal repair. The book presents the state of the art and the recent advancements in studying the effects of minimal repair on a system's state, and introduces a large number of mathematical models that can be used in order to plan minimal repair and maintenance actions efficiently

The book contains six parts. Part I is dedicated to mathematical modeling of minimal repair. It consists of three chapters (1, 2, and 3) that analyze in depth the effects of minimal repair on replacement strategies, the generalization of these strategies when information concerning the system's condition is available, and when competing dependent and independent failure modes are considered, respectively.

Chapter 1 is an exhaustive literature review that divides replacement models with minimal repair into two categories: age replacement and block replacement. In each category, papers are grouped in three groups. In the first group, the replacement models in which a system is minimally repaired up to time T, and replaced at the first failure after T, are presented. These models are called the T-policy. The second group of models is similar to the T-policy with the difference being the replacement is signaled when a prespecified number of minimal repairs is achieved. Finally, in the third group, replacement is performed when either a time T or a prespecified number, n, of minimal repairs is reach. In each of these three groups, the presented models aim at optimizing an objective function. This function usually represents cost and may take into consideration production costs; inventory costs, warranty costs, inspection costs, costs of imperfect repairs, leasing costs, and out-sourcing costs. All the models of this chapter are presented in a way that allows practitioners to use the results without having to go through the details of mathematical derivation.

In Chap. 2, a repair is defined according to its relation with the number of failures or with the system's condition. Traditionally minimal repair has no effect either on the age or on the condition of the system. This can be expressed by a failure rate or a number of failures that are not affected by the minimal repair. In this chapter, the author gives mathematical expressions of failure rates which are functions of age and of condition respectively. The condition is defined by the number of shocks that the system receives. He also gives a mathematical expression of the failure rate of a system composed of many components which are minimally repaired upon failure. A mathematical definition of minimal repair process is introduced. A repair is minimal if the repair process is not a stopping time. Mathematical condition for minimal repair is also given. Finally, the author presents two optimal replacement policies under minimal repairs. The first is a period replacement policy. The second is an optimal policy of replacing a system composed of many components.

In Chap. 3, minimal repair models with competing failures modes are considered. The failure modes are categorized as maintainable and non maintainable. The rate of maintainable failure modes is improved by preventive maintenance actions while the rate of non maintainable failure modes is unaltered. A cost function is introduced for the cases of dependent and independent failure modes.

Part II is dedicated to preventive maintenance models and optimal scheduling of imperfect preventive maintenance activities. It consists of two chapters (4 and 5) that analyze the effect of PM actions on parameters of the hazard rate, and discuss optimal schedules of two periodic imperfect PM policies.

In Chap. 4, the author uses a novel approach in order to review preventive maintenance models that appear in the literature. The first differentiate, on one hand, between maintenance strategies namely the Reliability Centered Maintenance (RCM), the Total Productive Maintenance (TPM), the Risk Based Maintenance (RBM), and, on the other hand, between maintenance policies, namely the Preventive Maintenance (PM) and the Corrective Maintenance (CM). The author then introduces a mathematical formulation of the hazard rate with four parameters, and he showed that the existing literature on PM can be categorized according to the effect of PM actions on these four parameters since these actions will affect either one of these parameters or a combination of them. This leads to a change in the scale parameter or the location parameter or both, thus affecting the hazard rate or the virtual age of a system or both. The author concluded by noting that the effect of PM actions on the shape parameter has not been found.

In Chap. 5, the authors compare two imperfect preventive maintenance policies. They call them local and global. The local policy has a local effect of wear-out, while the global policy restores the global wear-out. For both policies the optimal number of preventive actions, as well as, the optimal period between these actions are calculated.

Each one of parts III, IV, and V consists of one chapter. Chapter 6 presents a new warranty servicing strategy with imperfect repair. The authors study the case of a product sold with a two-dimensional warranty: the age and the usage. The strategy is based on finding a specified region of the warranty defined by these two parameters. This involves finding three disjoint intervals before the expiration of warrant. If the first failure occurs in the specified middle interval, it will be rectified by an imperfect repair, all other failures being minimally repaired. For a given usage rate, the values of intervals are selected such that the expected warranty servicing cost is minimized.

Chapter 7 is dedicated to mathematical models combining burn-in procedure and general maintenance policies. Burn-in is intended to eliminate early failures. If burn-in period is too long it may induce unnecessary failure, while if it is too short it will miss some early failures. Thus, the objective of mathematical modeling is to find the optimal burn-in period combined to optimal maintenance actions of replacement and minimal repair such that average cost is minimized. Stochastic models for burn-in procedures in accelerated environment and optimal accelerated burn-in and maintenance actions with age or block replacements, failures type I and type II, are also proposed.

Part V (Chap. 8) presents methods for parameters' estimation of some minimal repair models. In this chapter it is assumed that minimal repair affects virtually the age of the system. The virtual age depends on the actual real age of the system and the degree of repair which can be at one of four levels: perfect, imperfect, minimal and sloppy. Two parameters' estimation models are introduced. The first model estimates the conditional probability distribution of the degree of the nth repair by using a Hidden Markov Model and the Expectation–Maximization algorithm. In the second model, the transitional probabilities of a Markov chain are estimated. The M-ary detection procedure is used in Electrical Engineering to describe sequential hypothesis testing for M hypotheses, and it is applied in this chapter in order to find the hypothesis that best represents the sequential states of a system subjected to minimal repair random variable.

Chapter 9 is dedicated to the subject of product support. This means the design of all elements of the service after sale including installation, training of operators, maintenance, repair, warranty, and in particular the availability of spares. The objective is to increase the service after sale's performance while keeping the costs at an acceptable level. The author gives special consideration to the surrounding environment which affects the product's performance. He emphasizes that product support is usually thought of in the design phase, this is called design for supportability. He also explains that product reliability characteristics are called product dependability because its availability depends on those characteristics, on maintainability and on maintenance support. It is discussed that product geographical location is a critical factor of product support since it determines service delivery strategies, spare parts logistics and inventory management, which aim at minimizing the product support cost of ordering, holding, and transportation, while spare parts management program ensures the availability of spare parts at optimal cost, by categorizing the spare parts into classes based on their importance to the production operation, their costs, and their number in the system. Since the optimal number of spare parts depends on the demand rates, which in turn depends on product's reliability, reliability prediction methods and spare parts provisioning methods occupy a lengthy part of this chapter. These methods include the Poisson process, the renewal process, the normal distribution, the constant interval replacement model, the age-based prevention model, the Bayesian approach and the Proportional hazards model. Again the estimation and calculation of the required number of spare parts while considering their techno-economical characteristics and the operating environment is discussed.

In conclusion this book is a useful reference to faculty members, researchers, and practitioners who are interested in all aspects of minimal repair and its effect on maintenance policies and strategies. It is presented in a way that seeks a middle ground between a very detailed mathematical models and a simple practical use of some interesting results and models which are found in the literature. The references are chosen such that the subject of minimal repair is covered in a complete versatile way that was thought to be the most interesting to the reader.

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