Preface

The number of aged plants and infrastructures has been greatly increasing in advanced nations [1]. In order to conduct safe and economical maintenance strategies, modeling and analysis of wear or damage lurked within operating units in analytical ways play important roles in reliability theory and engineering. The damage models have been studied for decades, and some of which were summarized in the book *Shock and Damage Models in Reliability Theory* [2]. In this book, literatures of the past and our latest research results are surveyed systematically, and some examples in the book *Stochastic Process with Applications to Reliability Theory* [3] are cited to build the bridge between theory and practice.

We recently have proposed the models of *replacement first*, *replacement last*, *replacement middle*, and *replacement overtime* in maintenance theory [4–14], which were also surveyed in books *Random Maintenance Policies* [15] and *Maintenance Overtime Policies in Reliability Theory* [16]. These new models would be more effective in maintaining production systems with random working cycles and computer systems with continuous processing times. We have also noticed that these new models would be applicable to damage models [17–21]. We will compare the damage models with approaches of *replacement first*, *replacement last*, *replacement middle*, and *replacement overtime* with the standard model in the book [2] and show that our theoretical damage models can be applied to defragmentation and backup schemes for database management in computer systems.

Nine chapters with appendix, which are based on our original works, are included in this book: In Chap. 1, we take the reliability systems with repairs as examples to introduce stochastic processes, e.g., Poisson process, renewal process, and cumulative process. Formulations of damage models such as cumulative damage model, independent damage model, etc., are given without detailed explanations and full proofs.

In Chap. 2, we review the standard replacement model for cumulative damage process, in which shocks for an operating unit occur randomly and an amount of damage due to shocks is additive, causing the unit to fail when the total damage exceeds a failure threshold K. The unit is supposed to be replaced correctively after failure K and preventively before K at planned time T, at shock number N, or at damage level Z, whichever occurs first. We name this standard replacement model as *replacement first*, as it is formulated under the classical approach of *whichever triggering event occurs first*. Several combinational models of replacement policies with T, N and Z are optimized analytically, when shocks occur at a renewal process and at a Poisson process. In addition, extended replacement models, e.g., the level of failure threshold K is a random variable and the unit fails when the total number of shocks reaches N, are obtained.

In Chaps. 3 and 4, we center on discussions of the models with new approaches of *whichever triggering event occurs last*, *replacing over a planned measure*, and *whichever triggering event occurs middle*, which are named as *replacement last*, *replacement overtime*, and *replacement middle*, respectively:

1. Replacement Last: The unit is replaced preventively at time T, at shock N, or at damage Z, whichever occurs last.
2. Replacement Overtime: The unit is replaced preventively at the forthcoming shock over time T and at the next shock over damage Z.
3. Replacement Middle: Denoting t_N and t_Z be the respective replacement times at shock N and at damage Z, the unit is replaced preventively, e.g., at planned time T for $\{t_N < T \le t_Z\}$ and $\{t_Z < T \le t_N\}$.

In Chaps. 5 and 6, minimal repairs, to fix the failures with probability $p(x)$ when the total damage is x at some shock, and minimal maintenance, to preserve an operating unit when the total damage has exceeded a failure threshold K, are introduced into the modified models of replacement first, last, and middle. In Chap. 5, replacement overtime is modeled into the discussed policies, which are named as *replacement overtime first* and *replacement overtime last*. In Chap. 6, replacement models with shock numbers and failure numbers are surveyed, respectively.

In Chap. 7, it is assumed that an operating unit, degrading with *additive damage* produced by shocks, is also suffered for *independent damage* that occurs at a nonhomogeneous Poisson process. Corrective replacement is done when the total additive damage exceeds K, and minimal repair is made for the independent damage to let the unit return to operation. When the unit is replaced preventively at time T and number N of independent damages, the modified models of replacement first and replacement last are obtained. Furthermore, replacement overtime first and replacement overtime last for independent and additive damages are modeled and discussed, respectively. In addition, both number N of shocks and number M of independent damages are considered simultaneously for the modified replacement first, last, and middle, and their expected cost rates are obtained for further discussions.

In Chap. 8, the new approaches discussed in the above chapters are applied to database maintenance models. We suppose that a database system updates in large volumes at a stochastic process, and the fragmentation, which refers to the non-contiguous regions and should be freed back into contiguous areas, and the updated data files, which should be copied to a safer storage system, arise with respective amounts of random variables. We formulate several kinds of defragmentation and backup models, by replacing the random *shocks* with *database updates* in large volumes, and the amount of *damage* with the volumes of *fragmentation* and *updated data*.

Finally, in Chap. 9, we present compactly other damage models and their maintenance policies, such as follows:

1. Replacement policies for the periodic damage model where the damage produced by shocks is measured exactly at periodic times.
2. Periodic and sequential maintenance policies that are imperfectly conducted for periodic damage models.
3. Inspection policies for the continuous damage model where the total damage increases continuously with time.
4. Inspection and maintenance policies for the Markov chain model where the total damage transits among several states.

An interesting study throughout this book is that we compare models of new approaches with the standard model given in Chap. 2, and critical solutions of comparisons are found analytically and computed numerically. In Chap. 3, models of replacement last are compared with replacement first to find in what cases which model is better from the point of cost rates. In order to compare replacement overtime with replacement first, costs for preventive replacement policies are modified and a new policy of *replacement overtime first* is first modeled in Chap. 4. For the replacement middle policies, a new approach of *whichever triggering event occurs middle* is proposed for modeling and numerical examples of comparisons are conducted. In Chap. 5, replacement first and replacement last are compared for their optimum times T with given shock N and optimum shocks N with given T, replacement overtime first is compared with replacement overtime last for their optimum times T with given shock N, and the replacement policy done over time T is compared with the standard replacement and the policy done at shock N. Similar comparisons are also made in the following chapters.

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