Research Article

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Some results for repairable systems with minimal repairs

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In this paper, we consider a repairable system with minimal repairs whose number of repairs is a positive random variable with a given probability vector. Some preservation theorems and aging properties of repairable systems are established. Under the condition that at time t the system is working, a new random variable for the residual lifetime of the system is proposed. Some stochastic ordering results among the lifetimes and residual lifetimes of two systems are obtained. Similar results for coherent systems with independent components and exchangeable components were obtained in the previous literature. Copyright © 2013 John Wiley & Sons, Ltd.

Keywords: aging properties; minimal repair; residual lifetime; stochastic ordering

1. Introduction

There are some situations in industrial engineering and reliability life testing in which it is much more economical to repair a failed system rather than replace it with a new one. In this direction, the *minimal repair* policy is the most popular. It is an appropriate model to describe in a simple way the fact that many repairs in real life bring the system to a condition that is basically the same as it was just before the failure occurred [1]. Such a repair may be used to model a system where a component of the system is replaced or repaired. The purpose of repairing is to bring the system back to operation as soon as possible. In this model, it is assumed that the system failure rate remains unchanged by any repair between the periodic replacements. Indeed, minimal repair means that the system is brought to the condition it had immediately before the failure occurred, that is, the age of the system is not changed as a result of the repair. The very first mention of a notation of minimal repair is found in Morse [2], who called it optimum repair effort. In the context of reliability theory, the term minimal repair was introduced by Barlow and Hunter [3]. This model has been extended in many ways. Nakagawa and Kowada [4] defined minimal repair in terms of failure rate, which plays the most important role in the reliability theory. Block *et al.* [5] introduced an age-dependent minimal repair model and studied the conditions for preserving some aging properties. Inferential procedures for minimal repair models are presented by Ascher and Feingold [6]. Kijima [7] introduced models that feature 'degree of repair' random variables, which allow perfect or minimal repairs. Boland and El-Neweihi [8] discussed and developed the concept of a rate function for minimal repairs of the statistical and physical types. Finkelstein [9] discussed the concept of the statistical and physical minimal repairs. Recently, Beutner and Cramer [10] constructed nonparametric prediction intervals for repair times of a future minimal repair system. Chang *et al.* [11] considered a replacement model with minimal repair based on a cumulative repair-cost limit policy, where the information of all repair costs is used to decide whether the system should be repaired or replaced. Cha and Finkelstein [12] revisited the discussion on minimal repair in heterogeneous populations in Finkelstein [13]. For some other useful references, we refer the reader to Finkelstein [14, 15], Aven [16], Aven and Jensen [17] and Tadj *et al*. [18].

There are various ways of comparing lifetime distributions of two systems. The simplest way is to compare their means, although it does not have enough information. To provide more information for comparing two lifetime distributions, stochastic comparison methods are used. We refer the reader to Müller and Stoyan [19] and Shaked and Shanthikumar [20] for more details on stochastic orderings. In the literature, several authors studied stochastic comparisons

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