Computers & Industrial Engineering 98 (2016) 102–112

Contents lists available at ScienceDirect

Computers & Industrial Engineering

journal homepage: www.elsevier.com/locate/caie

Optimal maintenance policy for a system with preventive repair and two types of failures

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ARTICLE INFO

Article history:
Received 30 July 2015
Received in revised form 31 March 2016
Accepted 2 May 2016
Available online 4 May 2016

Keywords:
Maintenance policy
Geometric process
Preventive repair
Failure repair
Average cost rate

ABSTRACT

Maintenance policy is one of the most critical issues in operations management. In reality, the proper functioning of productive systems is affected by so many complicated factors that even preventive repair cannot eliminate the possibility of system failures of different types. A cost-effective maintenance strategy is usually desired. In this paper, a geometric process maintenance model with preventive repair and two types of failures (repairable failure and unrepairable failure) is studied. A maintenance policy (T, N) is proposed, where preventive repair will be conducted when the successive operating time reaches T, and the system will be replaced by a new one when an unrepairable failure or the Nth repairable failure occurs. The optimal policy (T^*, N^*) is obtained such that the average cost rate (i.e., the long-run average cost per unit time) is minimized. The model is generalized to reflect three different types of maintenance systems. An algorithm is proposed to obtain the optimal policy (T^*, N^*). Numerical experiments are conducted to examine the impacts of system parameters on the optimal maintenance policy.

1. Introduction

The proper maintenance of productive systems is vital to ensure the normal operation of productive systems in various industries, including manufacturing, healthcare and power industries. It extends equipment life, improves equipment availability, retains equipment in proper condition and thus contributes to the overall performance of the company (Swanson, 2001; Waeyenbergh & Pintelon, 2002). The growing importance of maintenance management has generated increasing interests in academic research. In the past decade, maintenance and replacement problems have been studied extensively in the literature.

In the earliest studies of the maintenance problem, repair-replacement models were commonly considered as perfect repair models, which assumed that a failed system would be "as good as new" after repair. In practice, most systems cannot be considered "as good as new" after repair. Barlow and Hunter (1960) introduced a minimal repair model, in which minimal repair does not alter the aging of the system. Brown and Proschan (1983) considered the imperfect repair model, which involves two types of repair, i.e., perfect repair with probability p, and minimal repair with probability $(1 - p)$. Following the introduction of this model, relevant studies have been conducted by Park (1979), Phelps (1981), Block, Borges, and Savits (1985), and Kijima (1989). In reality, many systems are considered to be degenerative because of aging effects and accumulated wearing. This means that the successive operating time between failures monotonously decrease with the times of repair. Given this fact, Yeh (1988) and Lin (1988) presented the geometric process (GP) model to describe a degenerative system. This model proposed a new replacement policy N^*, in which the system would be replaced when failure occurs for N^* times. Thereafter, the GP model has been extensively applied to the maintenance problem for its capability in describing real maintenance data sets. Yeh (1992) and Yeh and Chan (1998) applied a GP model to fit three real data sets by using nonparametric and parametric methods. Lam, Zhu, Chan, and Liu (2004) used the GP model to analyze more real data sets. Through the analysis of the data of aircraft, computer, car and so on, they found that on average the GP model was the best model among four homogeneous and nonhomogeneous Poisson models for fitting these real data from a series of events. Subsequently, Tang and Lam (2006), Zhang and Wang (2007), Wang and Zhang (2009), and Finkelstein (2010) conducted further studies to extend the geometric process model.

All aforementioned models assume that a system has unique modes of failure. However, a system can have two or more failure modes in many circumstances. Some system failures can be classified based on causes. For instance, an electronic system may fail because of a short circuit or an open circuit. In a manual control

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http://dx.doi.org/10.1016/j.cie.2016.05.007
0360-8352/