ARTICLE IN PRESS

Applied Mathematical Modelling xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Applied Mathematical Modelling

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

Joint optimization of maintenance, buffer, and spare parts for a production system

Shuyuan Gan [a,b,c], Zhisheng Zhang [b,*], Yifan Zhou [b], Jinfei Shi [d]

[a] Department of Mechanical Engineering, Jiangsu University, Zhenjiang 212013, PR China
[b] Department of Mechanical Engineering, Southeast University, Nanjing 211189, PR China
[c] Jiangsu Key Laboratory of Large Engineering Equipment Detection and Control, Xuzhou Institute of Technology, Xuzhou 221018, PR China
[d] Nanjing Institute of Technology, Nanjing 211189, PR China

ARTICLE INFO

Article history:
Received 15 June 2013
Received in revised form 14 December 2014
Accepted 12 January 2015
Available online xxxx

Keywords:
Maintenance
Spare part
Buffer
Mathematical analysis
Optimization
Genetic algorithm

ABSTRACT

Maintenance research catches growing attention for its increasing importance in reality. Spare parts and intermediate buffer are two important factors related to maintenance activity, and both of them may greatly influence the system cost. Although some researchers have considered maintenance and buffer inventory, or maintenance and spare parts inventory together, the joint optimization of the three has not been considered before. This paper is focused on the interaction between maintenance, buffer inventory, and spare parts inventory, to achieve the minimization of the long-term expected cost rate for a production system. The investigated production system of the paper consists of two serial machines, an intermediate buffer, and a spare part inventory. The practical example for this type of system can be an automated work center or an automobile general assembly. The cost model that represents the long-term expected cost rate is developed by mathematical analysis. Four control variables corresponding to decisions made on maintenance, buffer, and spare parts are included. Then by using the genetic algorithm method, the cost model is optimized. The proposed method is applied to different simulation cases to show its efficiency and necessity. Additionally, the related optimization results indicate that the joint optimization can effectively alleviate the influence caused by the change of buffer accumulation speed.

1. Introduction

Maintenance optimizations may lead to system cost increasing if some important factors are not considered. This is because there is a complex interaction between maintenance and these factors, for example, spare parts or buffer [1,2]. Therefore, in recent years, many studies tend to deliver maintenance optimization considering spare parts or buffer inventory, which are both closely related to maintenance.

Spare parts are essential for maintenance implementation. Their shortage will cause a delay of maintenance, and affect a system's reliability or availability. On the contrary, having too many spare parts will cause additional inventory holding costs. To deal with the balance between system reliability and spare parts inventory holding costs, the simultaneous optimization of maintenance planning and spare parts provisioning (or spare parts inventory controlling) is developed. Some

* Corresponding author. Tel.: +86 25 52090509; fax: +86 25 52090529.
E-mail address: oldbc@seu.edu.cn (Z. Zhang).

http://dx.doi.org/10.1016/j.apm.2015.01.035

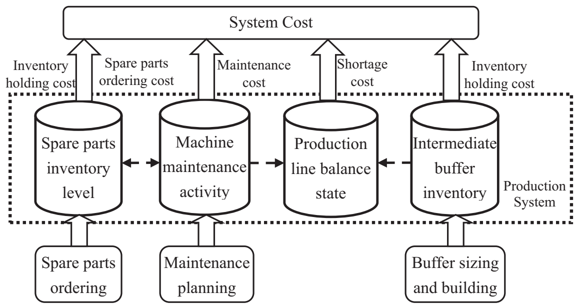

Fig. 1. The relationships between maintenance, spare parts, and intermediate buffer, and their influences on system cost.

articles studied a continuous review (s, S) policy for spare parts associated with certain maintenance strategies [3–5]. De Smidt-Destombes et al. took into account repair capacity, spare numbers, and maintenance frequency together, to investigate the availability function of k-out-of-N systems, and achieved joint optimization [1,6–8]. Other examples for joint optimization of maintenance and spare parts can be seen in Brezavšček and Hudoklin [9], Ilgin and Tunali [10], Huang et al. [11], and Chien [12], etc. Additionally, a few papers optimized maintenance and spare parts in sequence, rather than optimizing them simultaneously [13–15].

Buffer inventory is another important factor that is usually considered in maintenance optimization. In a production system with buffer built between deteriorating machines, the influence caused by maintenance duration can be alleviated, and the maintenance frequency will conversely make an effect on the buffer level and buffer inventory holding cost. To investigate the interaction between maintenance and buffer inventory level, some research dealt with one type of system that consists of two units and an intermediate buffer with the buffer size predetermined, and the optimal policies are all proved to be control-limit type [16–22]. Some other research was devoted to the joint optimization of maintenance and buffer size, which can be seen in Chelbi and Ait-Kadi [2], Kenné et al. [23], Ribeiro et al. [24], Zequeira et al. [25] and Teresa Murino [26], etc.

The articles on optimizations that are surveyed above considered two issues (i.e., maintenance and buffer inventory, or maintenance and spare parts inventory). The brief review indicates that there is no study that considers the joint optimization of maintenance, spare parts inventory, and buffer inventory. Nevertheless, there is an interaction between intermediate buffer and spare parts inventory due to maintenance activities, and the system cost is related to decisions made on maintenance and buffer size, and spare parts inventory leve (see Fig. 1). Hence, a study along this line is necessary to analyze the interaction between them. In an earlier study of ours, the intermediate buffer was analyzed for a two-machine inventory system with maintenance and spare parts order involved, and three expected costs related to the buffer inventory were derived by mathematical analysis [27]. In this paper, another production system is studied, which is similar to the system of Gan et al. [27], but differs from it in taking into account the spare parts inventory additionally. This paper proposes the need to deal with the trade-off between the maintenance cost, inventory holding and shortage costs, and the cost of disposing surplus buffer inventory, to achieve the minimal long-term expected cost.

The system investigated in this paper consists of two serial machines, an intermediate buffer inventory, and a spare parts inventory. The upstream machine subject to deterioration and the maintenance is considered. Based on the renewal reward theorem, the cost model is constructed, which takes into account the maintenance cost, buffer inventory holding cost and shortage cost, spare parts ordering cost and inventory holding cost, and the cost of disposing surplus buffer inventory. Then it is developed through mathematical analysis. Three expected costs related to the intermediate buffer inventory (including the expected buffer inventory holding cost, expected shortage cost, and the expected cost of disposing surplus buffer inventory) which were obtained in Gan et al. [27] are used. Four control variables, including the preventive maintenance age, the spare parts arrival time, the buffer size, and the initiating time of buffer accumulation, are determined for the minimal long-term expected cost rate by using genetic algorithm. Additionally, the necessity of the joint optimization of maintenance, buffer inventory, and spare parts is investigated by the comparisons with the two-variable optimization (optimizing maintenance and spare parts only, the corresponding control variables are the preventive maintenance age and the spare parts arrival time) and the three-variable optimization (optimizing maintenance and buffer inventory only, the correspond-

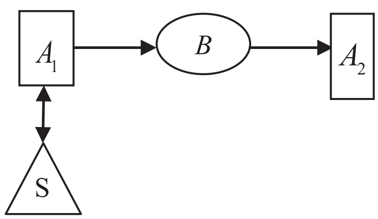

Fig. 2. The production system investigated.