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Optimal just-in-time buffer inventory for regular preventive maintenance

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Abstract

Most manufacturing organizations, if not all, are trying to implement some of the ideas adopted by the just-in-time (JIT) philosophy, a philosophy that promises a continuous improvement in total productivity. Preventive maintenance, an essential element of the just-in-time structure, induced the idea of this paper. Performing regular preventive maintenance results in a shutdown of the production unit for a period of time to enhance the condition of the production unit to an acceptable level. During such interruption, a just-in-time buffer is needed so that normal operations will not be interrupted. The optimum just-in-time buffer level is determined by trading off the holding cost per unit per unit of time and the shortage cost per unit of time such that their sum is minimum.

Keywords: Preventive; Maintenance; Buffer; Inventory; Just-in-time

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1. Background

The British Standards Institute [1] defined maintenance as a combination of actions carried out to retain an item in, or restore it to, an acceptable condition. Olorunniwo and Izuchukwu's [2] survey of the literature noted that preventive maintenance has been based on one of the two extreme assumptions: The production unit is restored to either a bad-as-old or good-as-new condition after maintenance. In real world situations, preventive maintenance may enhance the condition of the equipment at a level between these two extremes. In developing the mathematical model of this paper, it is assumed that the regular preventive maintenance will enhance the condition of the production unit to an acceptable level that prevents any sudden failure and, as well as, maintains the same quality of output as before. During preventive maintenance, a just-in-time buffer inventory is needed so that normal operations will not be interrupted. Hanssmann [3] considers two machines working together to produce a common result. The product comes from one machine in semi-finished form, and is then processed by the second machine for completion. The author determines the optimum value of the safety stock of semi-finished product needed to withstand the breakdowns of the first machine. Billington [4] focused on quality improvement through lot size reduction. Bonney [5] discussed new trends occurring in inventory management and how these trends

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are influencing inventory planning and control. A preventive maintenance program may include in addition to the routine checkup, of the production unit, provisions for immediate repair or overhauls. The authors' survey of literature did not site a study that deals, in particular, with the just-in-time buffer inventory to be used during regular preventive maintenance. Groenevelt et al. [6] focused on the effects of machine break downs and corrective maintenance on the economic lot-size decisions. Groenevelt et al. [7] addressed the problem of determining the economic lot-size for an unreliable manufacturing facility. They showed a tradeoff to exist between the overall investment to increase the maintenance level and the resulting saving in the safety stocks and repair cost. Van Der Duyn Schouten and Vanneste [8] considered preventive maintenance policy, which is based on the information about the age of the installation and the inventory buffer. Wijngaard [9] considered two machines with exponential upand-down times and an intermediate buffer. Balasubramanian [10] provided an approach for preventive maintenance scheduling in light of a production plan.

2. Introduction

The success of the just-in-time production system lies in the considerable reduction in material inventories. This reduction captured the greatest public attention and to an extreme, some people led to adopt the mistaken notion that inventories are of no value and should be totally eliminated. However, a well designed just-in-time production system requires some inventory to operate efficiently as illustrated herewith.

In this paper, we assume that the production unit runs for a maximum scheduled period T units of time before preventive maintenance interruption occurs. Before the end of period T, the just-in-time buffer S is built at a finite rate of α units per unit time. This finite replenishment starts (S/α) units of time before the end of period T, so that before the end of period T, a buffer of level S is accumulated. At the end of period T, the regular preventive maintenance starts; and lasts for a period of t units of time. This time t is a random variable that depends on how long it takes to enhance the condition of the production unit to an acceptable level that prevents any random failures, during T, as well as, maintains the same quality of output as before. During t, the demand is met from the just-in-time buffer, at the rate of β units per unit of time. If the buffer supply time is greater than t, then the number of units short will be zero; otherwise the number of units short will be $\beta(t - S/\beta) = \beta t - S$. After the production unit is preventively maintained during t, the production process resumes for another period T.

3. Mathematical model

The fundamental problem in this paper is to determine the optimum just-in-time buffer level to withstand the regular preventive maintenance interruption. The following assumptions will apply through out this research:

1. The just-in-time buffer is not subject to deterioration or obsolescence.
2. The regular preventive maintenance guarantees that the probability of a breakdown of the production unit during T is approximately zero.
3. Before the beginning of any normal preventive maintenance, the just-in-time buffer is S.
4. T is large enough compared with t, so that during any time period T, buffer replenishment starts from a zero level.
5. Unused buffer inventory during t is depleted to zero during the next cycle T.

The behavior of the system is depicted in Fig. 1. Define

S	buffer stock level.
T	running time of the production unit per cycle.
t	preventive maintenance time per cycle.
$F(t)$	probability density function of t.
α	buffer replenishment rate (units/unit time).
β	consumption rate from the buffer during t (units/unit time).
h	buffer holding cost (\$/unit/unit time).