

Optimal production, maintenance and lockout/tagout control policies in manufacturing systems

E. Charlot, J.P. Kenné*, S. Nadeau

Mechanical Engineering Department, Laboratory of Integrated Production Technologies, University of Québec, École de technologie supérieure, 1100, Notre-Dame Street West, Montreal (Quebec), Canada H3C 1K3

Received 26 January 2006; accepted 6 September 2006

Available online 22 December 2006

Abstract

We consider a production control problem for a manufacturing system subject to random failures and repairs. This paper differs from similar research projects in that it considers preventive maintenance activities and differentiates two types of repairs: repairs with lockout/tagout, associated with accident prevention, and repairs without lockout/tagout. Its goal is to find the optimal production rate, preventive maintenance rates and repair rates in order to minimize operating costs, backlog costs, inventory costs and unforeseen costs (accidents). The optimization criterion is that of minimizing the total expected infinite horizon discount cost. In order to solve this problem, a more realistic analysis model is proposed in this paper to consider the effects of machine age-dependent preventive and corrective maintenance policies on optimal safety stock levels. Hence, a unified framework is developed, allowing production, preventive and corrective maintenance to be jointly considered. Optimality conditions are provided for the manufacturing systems considered, and numerical methods are used to obtain machine age-dependent optimal control policies (production, preventive and corrective maintenance rates). Numerical examples and sensitivity analyses are included to illustrate the importance and effectiveness of the proposed methodology.

© 2006 Elsevier B.V. All rights reserved.

Keywords: Manufacturing systems; Preventive maintenance; Corrective maintenance; Numerical methods; Lockout/tagout

1. Introduction

Production planning has attracted growing attention due to its ever increasing importance in today's highly competitive environments (see Karen et al. (2003) and the references included). Planning requires making decisions for a manufacturing system, in which many different types of events, such as operation activities, failure activities, maintenance activities, injuries, and raw material supply, as well as fluctuations in customer demand, may

occur concurrently. In such a competitive environment, all employees must be protected from injuries arising from delivery of power that start up machines inadvertently, or injuries resulting from the release or discharge of energy stored during service, repair, maintenance, operation and associated activities. Considering lockout/tagout activities and relevant production policies leads to a more realistic context and increases the complexity of the optimal control problem for a manufacturing system comprising such events. Such a complexity makes the planning task very challenging.

This paper considers such a challenging problem for a stochastic manufacturing system consisting of

*Corresponding author. Tel.: +1 514 396 8549; fax: +1 514 396 8530.

E-mail address: jean-pierre.kenne@etsmtl.ca (J.P. Kenné).

one machine producing one part type. The stochastic nature of the system is due to the fact that the machine is subject to random breakdowns and repairs. The capacity of the system is improved by controlling both the operational mode of the machine (preventive maintenance) and its repair rates (corrective maintenance). The machine dynamics are assumed herein to be described by a finite state Markov chain. The decision variables are the input rate to the machine, the preventive maintenance rates of the machine and its repair rates (with lockout/tagout), which influence the surplus. The surplus is the difference between the cumulative production and the cumulative demand of finished goods or commodities. Many authors have contributed to the flexible manufacturing systems (FMS) problem of production planning, as is the case in this paper, without considering preventive maintenance, lockout/tagout, production and corrective maintenance in the same model.

Machine breakdowns, risks of accidents during maintenance, downtime needed for corrective and preventive maintenance activities, occur randomly and are common to all classes of manufacturing systems. Consequently, the real productive capacity of considered manufacturing systems is not constant. Production planning as presented in the literature focuses mainly on optimizing output without considering employee and equipment safety. Based on the pioneering work of [Rishel \(1975\)](#), [Older and Suri \(1980\)](#) presented a model for FMS with unreliable machines whose failure and repair rates are described by homogeneous Markov processes (i.e., constant transition rates). The production planning of such systems is a complex stochastic control problem. The related optimal control policy has been proved in [Gershwin \(1994\)](#) to be the solution of a set of coupled Hamilton–Jacobi–Bellman (HJB) equations which are too complex to solve analytically.

The non-homogeneous Markov processes, such as in [Boukas and Haurie \(1990\)](#) and in [Gharbi and Kenne \(2000\)](#) are considered in order to increase the capacity of the FMS. Those papers assume that failure rates and control policies are machine-age dependent. Hence, the machine becomes more available with preventive maintenance. Instead of proceeding with preventive maintenance, using corrective maintenance as in [Boukas \(1998\)](#) and in [Kenne et al. \(2003\)](#) increases the availability of the production system with a model which is not age

dependent. In such a situation, the capacity of the FMS is improved by controlling the machine's repair rates. In order to improve the results presented in the aforementioned papers, the overall availability of the production system is increased through the use of corrective and preventive maintenance. The aim of this paper is firstly, to propose a stochastic control model for simultaneous production planning, lockout/tagout, preventive and corrective maintenance actions in manufacturing systems and secondly, to develop an efficient technique for the computation of the optimal control policy.

Ideally, optimum rates of output are achieved while undertaking all steps needed to render the workplace free of accident risk during preventive and corrective maintenance activities. Details on risk measurement can be found in [Beckers \(1996\)](#). Measures aimed at improving safety, lowering accident rates, and curbing costs associated with accident prevention may be offset by increased production costs owing to reduced machine availability, added time needed to deliver finished products (goods), and inventory, repair and preventive maintenance costs. A number of factors need to be considered in setting clearly defined goals to optimize production: economic factors (reducing machine failure and maintenance costs), human factors (working conditions, safety, without harmful effects) and technical factors (availability and durability of machines).

This paper seeks to unite two approaches by extending stochastic models in manufacturing systems to real facilities where employee safety is important. Control of the lockout/tagout procedure is integrated into production planning. The optimal control problem under study consists of finding optimal policies, which need to be followed to rationalize maintenance and output, given the changing status of a machine over an infinite horizon. In general, the analytic form of the optimal solution is difficult to obtain, since the corresponding optimality conditions are represented by a set of coupled non-linear partial differential equations which are not easy to solve. The Numerical methods are used in this paper to get a solution of the problem.

This paper is organized as follows: in Section 2, we define the assumptions used in the model and provide the problem statement in Section 3. In Section 4, we present the HJB equations and prove that the control policy obtained is insensitive to a

متن کامل مقاله

دریافت فوری ←

ISIArticles

مرجع مقالات تخصصی ایران

- ✓ امکان دانلود نسخه تمام متن مقالات انگلیسی
- ✓ امکان دانلود نسخه ترجمه شده مقالات
- ✓ پذیرش سفارش ترجمه تخصصی
- ✓ امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
- ✓ امکان دانلود رایگان ۲ صفحه اول هر مقاله
- ✓ امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
- ✓ دانلود فوری مقاله پس از پرداخت آنلاین
- ✓ پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات