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Production and Maintenance Optimization for Multi-Machines under Degradation Constraint

Tarek A., Hajej Z., Rezg N.

LGIPM, University of Lorraine, Metz, 57945
FRANCE (Tel: 0033605322540; e-mail: tarek.askri@univ-lorraine.fr).
(zied.haje@univ-lorraine.fr)
(nidhal.rezg@univ-lorraine.fr)}

Abstract: In this paper, we have developed an integrated maintenance policy for a manufacturing system, composed by numerous parallel machines, which has to satisfy a random demand during a finite horizon given a required service level. The aim of this study is to determine the production plan of each machine in the manufacturing system minimizing the total production cost and the optimal maintenance strategy for different machines taking into account the degradation of each one according to its production rate and minimizing the total preventive and corrective maintenance cost

Keywords: Production Plan, Maintenance Strategy, Minimal Repair, Service Level, Multi Parallel Machines

1. INTRODUCTION

Literally, several works have been presented devoted to prove an optimal maintenance strategy motivated on different points of view, mainly oriented to the optimization of single degradation equipment and without taking into account the configuration of the manufacturing system which contains the equipment to be maintained. The optimization approaches of single equipment may be particularly interesting when productive bottlenecks or continuous processes are studied. However, these initiatives might be less valuable in manufacturing machines which work in multi-equipment systems, as they usually do not take into account the influence that the whole system has in each of the studied machines.

In the next, we will present several works concerning the production and maintenance optimization of multiple manufacturing components. In the context of optimization model for maintenance of multi-component systems, we can cite the work of (Shalaby et al., 2004). They proposed a new optimization problem of multi-component and multi-state systems by developing an optimization model for preventive maintenance scheduling. The principal objective is to minimize the total cost of preventive maintenance, minimal repair, and downtime by considering the sequence of preventive maintenance activities as the decision variables. For a subsequent assembly line operating, (Chelbi et al., 2008) presented a mathematical model by minimizing the sum of the maintenance cost, the inventory holding cost, and the shortage cost and considering the buffer stock size, and the PM period length as decision variables. (Nakagawa et al., 2007) studied an Entoropy model with the application of a maintenance policy in which machine's failure time satisfied Weibull distribution.

Concerning the integrated maintenance optimization, (Kenne et al., 2008) proposed a mathematical model for a several workstations model taking into account the failure prone manufacturing system. The objective is to minimize the total production and maintenance cost. In order to control the production level and the reparation date, (Kenne et al., 2004) proposed and minimized a mathematical model of manufacturing system composed by numerous identical machines and subjected to reparation periods. Using the hedging point policy which the machine failure rate be determined by the production level, (Hu et al., 1994) treated the optimality of a production system. (Rezg et al., 2004) proposed a jointly stock and maintenance optimization in a production system of numerous machines.

Based in the works of (Medhioub et al., 2014) and (Hajej et al., 2015), our work proposes a new integrated maintenance strategy for multi-machine under degradation constraint. Indeed, (Medhioub et al., 2014) and (Hajej et al., 2015) considered a production system containing several parallel machines which has to satisfy a random demand under given service level and to minimize the total production, inventory cost in order to obtain the optimal production plan characterized by the optimal number of machines, facility time and inventory levels. Indeed, this works treated the impact of the withdrawal right on the production and maintenance strategies of different equipment's.

In our work, we propose maintenance strategy integrated to production policy by considering the influence of the production rates variation on the degradation degree of each machine and consequently the influence on the average number of failure and the optimal maintenance strategy. The objective of this work is to determine the optimal combination of machine number, production quantity of each

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machine and inventory levels in order to minimize the total production cost and consequently to help to obtain the optimal maintenance strategy characterized by the optimal number of preventive maintenance action for each machines and minimized the total maintenance cost.

This paper is planned as follow: Section 2 proposes the production and maintenance mathematical model by presenting the different costs. Section 3 presents an analytical study of policies and establishes a deterministic equivalent problem. A numerical example is presented in section 4. A conclusion is proposed in section 5.

2. PRODUCTION AND MAINTENANCE MODEL

2.1 Problem Description

In this section, a jointly production and maintenance strategy optimization problem for a multi-machines system is studied. We consider a manufacturing system which produces one type of product during a finite production time horizon denoted by $H.\Delta t$ with Δt is the length of production period and composed by M_k machines mounted in parallel at each production period k and bordered between lower bounds of machines number m and the upper bounds of machines number M. the production rate at each period k denoted by U_k and each machine characterized by an amount of products u_{ik} determined according to the amount of production u for each machine per time unit (hour); (the same for all machines). Indeed, the production system composed by one store S (where the manufactured products are stored and where the customer demand receives his demand (products). The customer demand which is denoted by d is random and given by a Normal distribution with first and second statistical moments given respectively, by $\hat{d}$ and σ_d^2. The satisfaction of the demand is made at the end of each period under a given service level θ. For each production period, the work time of each machine is characterized by a normally time of work t_{ik}^N that not exceeds to the upper bound of work time units $t_{\max}^N$ and the overtime of each machine t_{ik}^O that not exceeds the upper bound of time units $t_{\max}^S$. The production system is characterized by the variation number of machines from production period to another depending to production quantity, random demand and given service level.
In other words, each machine M_i is subject to a random failure. The probability degradation law of each machine M_i is described by the probability density function of time to failure $f_i(t)$ and for which the failure rate $\lambda_i(t)$ of each machine M_i increases with time and according to the production rate.

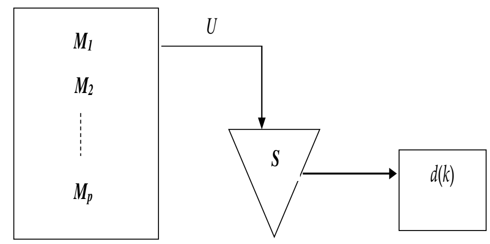

Fig. 1. Problem description.

Our objective is to determine an economical production plan and an optimal maintenance strategy for the each machine. The production policy characterized by the variation of machines number and the variation of production rate from period to another and consequently their impact on the degradation degree as well as on the maintenance strategy for each machine.

2.2 Production and Maintenance Policies

In this section, a constrained stochastic problem is formulated. The mathematical model provides a decision rule that optimize the inventory, production policy characterized by the decision variables presented by the variation number of machines and the production rate (M_k^*, U_k^*) according to normal and overtime times of machine work (t_{ik}^N, t_{ik}^o) and optimize the maintenance strategy presented by the optimal number of maintenance strategy N_i *(i:1….M)*

- Production policy

The production policy use a quadratic cost function allows penalizing both excess and shortage in the inventory level and considering the following costs: the cost of installation and removal for each machine, the cost of overtime work based on a binary variable θ_k that equal to 1 when the quantity of demand at production period k surpasses the production quantity and all used machines M_k work with upper bound normal time and equal to 0; the cost of inventory and unexploited capacities cost, is defined as follows:

$$\underset{(M_k, t_{ik}^N, t_{ik}^O, N)}{Min} \begin{pmatrix} \text{Cost of using machines} \\ + \\ \text{Costs of overtime work} \\ \text{and unexploited capacities} \\ + \\ \text{Inventory Cost} \\ + \\ \text{Maintenance Cost} \end{pmatrix}$$

Subject to
The production quantity for each production period k and for each machine i, according to the work times, are given by the following equation