Hedging Point Policy for FMS with Preventive Maintenance

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Abstract

Typically, A flexible manufacturing system (FMS) consists of several automatic machines with automatic tool changes and automatic pallet changes connected by automatic material handling system including storage and retrieval system. Flexible manufacturing systems are characterized by several flexible manufacturing cells (FMCs) interconnected by a central material handling system such as conveyor systems and AGV, etc. While the technology of manufacturing is improving rapidly, a basic understanding of the systems issues remains incomplete. They are production planning, scheduling, and control of work in process.

They are complicated by randomness in the manufacturing environment particularly due to machines failures and other events, including setups, preventive maintenance, absences of raw materials, engineering changes, training sessions for new personnel, expedited batches, and many others.

Various production planning problems in flexible manufacturing systems have been modelled and studied in the literature. An interesting feature of many automated production systems is that they can be considered as deterministic system as long as no machine breakdowns or stoppages occur. These systems fall in the category of piecewise deterministic processes. Another class of systems are called systems with jump Markov disturbances.

The production planning problems can be gathered into two groups. The first group emphasizes the rate of production, focusing mainly on the determination of the optimal production rate with failure-prone machines. The second group of problems takes the machine age factor into consideration. These researches may improve the performance for the manufacturing system by adding controls of preventive maintenance in addition to controls of production rate. This paper consider a maintenance and production planning model.

The production planning of a manufacturing system is a very large and complex problem to

solve. The optimal control policy of FMS has been proved to be the solution of a set of Hamilton-Jacobi-Bellman equations. Those equation are so complex that we cannot solve analytically.

Another approach is the hedging point policy which is the optimal solution for the one machine one part type system. This policy is maintaining a significant stock level to compensate the possible backlog caused by machine failures.

The goal of the analysis reported here is to calculate the rates of production and maintenance to minimized total cost. The effect of the preventive maintenance is to reduce the machine failure rate and to improve the productivity of the system.

Consider a flexible manufacturing system that consists of one machine and produces one part type.

And let's define x(t) be the cumulative production surplus of parts at time t. u(t) be the production rate at time t. v(t) be the maintenance rate at time t. d be a given demand rate.

Then $\dot{x}(t) = u(t) - d,\ x(0) = x^o$ where x^o is given initial surplus value. The aging of the machine at time t, a(t), is an increasing function of the production rate u(t) and decreasing function of the maintenance rate v(t). That is $\dot{a}(t) = f(u(t), v(t)),\ a(T) = 0$

Let $\bar{u}$ and $\bar{v}$ denote the maximum production rate and the maximum maintenance rate.

We suppose that $f(u(t), v(t)) = k_1 u(t) - k_2 v(t) \geq 0$. The cost function is given by

$$J(\alpha, x, a) = E\left\{ \int_0^\infty e^{-\rho t}[c_1 x^+ + c_2 x^- + l(\eta(t))v]\,dt \mid x(0) = x,\ \eta(0) = \alpha,\ a(0) = a \right\}$$

For this optimization problem, we will establish the optimality condition by using the dynamic programming equation. we can find the optimal policy for maintenance rate and optimal production rate.

The problem is a stochastic optimal control problem, The Hamilton-Jacobi-Bellman equation should be solved. That is given by

$$\min[(u-d)\frac{\partial}{\partial x}J_1(x,a) + (k_1 u - K_2 v)\frac{\partial}{\partial a}J_1(x,a) + kv] - d\frac{\partial}{\partial x}J_2(x,a) \quad \text{for } u, v$$

For some case, the optimal policy for the production rate is given by

$$u^* = \left\{ \begin{array}{lll} \bar{u} & \text{if} & x(t) < Z^*(a) \\ d & \text{if} & x(t) = Z^*(a) \\ 0 & \text{if} & x(t) > Z^*(a) \end{array} \right\} \quad \text{Where } Z^*(a) \text{ is optimal inventory level}$$

The hedging point policy and the optimal policy for maintenance can be obtained to the individual case.