Hedging Point in the Production Control of Failure Prone Manufacturing Systems

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ABSTRACT

Most manufacturing systems are large and complex. It is natural to divide the control into a hierarchy consisting of a number of different levels. Each level is characterized by the length of the planning horizon and the kind of data required for the decision making process.

This paper describes an approach for the incorporation of Maintenance times into a hierarchical scheduling for a failure prone flexible manufacturing system. The Maintenance should not be performed too often because of the resulting reduction of capacity. The machine failure and preventive maintenance are considered simultaneously.

1. Introduction

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 machine failures and other events, including setups, preventive maintenance, absences of raw materials, engineering changes, training sessions for new personnel, expedited batches, and many others.

We study systems involving many part types that are disturbed by machine failures and others. The basic idea is to keep track of the capacity of the system, as it varies over time as machines fail and are repaired. It is important to develop models and algorithms which allow the FMS controller to generate production schedules which satisfy demand requirements and exercise control over the system so that the output conforms to the schedule.

Kimemia and Gershwin [5] derived a closed loop solution to the problem of dispatching parts to machines in a failure prone FMS. They found suboptimal strategies that are easy to calculate and that provide satisfactory performance.

The solution of dynamic program has two components. One is the calculation of the cost to go function $J(x, \alpha)$. Since the calculation of J is performed once, it is the longest term component of the scheduling rule. The other is the calculation of the control law, which requires J. The short term portion of the scheduling rule is the loading of parts in a way that agrees with the current production rates.

2. Problems of FMS

Design, planning, scheduling, and control problems of FMS involve some intricate operations research problems. FMS design problems include determining the appropriate number of machine tools of each type, the capacity of the material handling system, and the size of buffers. FMS planning problems contain part type selection, machine grouping, product mix, resource allocation, and loading problem. FMS scheduling problems are concerned with running the FMS during real time once it has been set up during the planning stage. FMS control problems are those associated with monitoring the system, keeping track of production to be sure that requirements and due dates are being met as scheduled.

Operational control of an FMS is very complicated. It involves accessing large static and dynamic data sets and complex control algorithms. The control algorithms are structured hierarchically, where an upper level issues commands to a lower level and gets feedback on the achievement of these command. In order to make good decisions under uncertainty, it is necessary to know something about the current state of the system and to use this information effectively.

3. Overview of hierarchical policy

Operating policies for manufacturing systems must repond to machine failures and other important events that occur during production such as setups, demand changes, expedited batches, preventive maintenance, etc. Each of these events takes up time at resource. Some events are controllable, others are not controllable but predictable. In this paper, we develop hierarchical scheduling and planning algorithms. The levels of the hierarchy correspond to classes of events that have distinct frequencies of occurrence.

Here, Three kinds of events are considered. They are production operations on parts, failures and repairs of machines, and preventive maintenances. Operations occur much more often than failures, maintenence, and we can use the continuous representation of material flow. The state of the system has two parts. One is a vector of real numbers (x(t)) that represents the surplus, the cumulative difference between production and requirements, the other is a vector of integers (α(t)) that represents the set of machines that are operational. The object is to choose the production rate vector (u(t)) as a function of the state (x(t)) and (α(t)) to keep the surplus (x(t)) near 0.

A three level control hierarchy designed to compensate for work station failures and maintenance is proposed. The hierarchy is illustrated in Fig. 1.

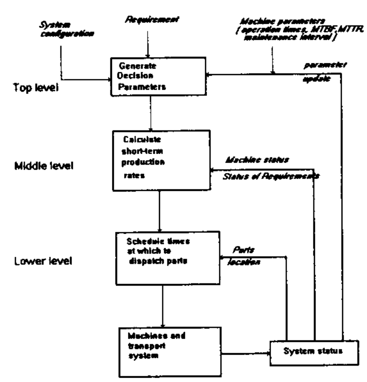

Figure 1. Three level control hierarchy

Assume that the production requirements are stated in the form of a demand rate vector d(t). Let the instantaneous production rate vector be denoted u(t). Define x(t) to be production surplus. It is the cumulative difference between production and demand and satisfies

$$\frac{dx}{dt} = u(t) - d(t) \qquad (1)$$

The production rate vector u is limited by the capabilities of the machines. Let part type j require time τ_{ij} for all of its operations on machine i. Then

$$\sum_{j=1}^{n} \tau_{ij}\, u_j(t) \leq \alpha_i(t) \qquad (2)$$

where $\alpha_i(t)$ is 1 if machine i is operational and 0 if it is down. If there is a set of identical type i machines, $\alpha_i(t)$ is the number of these that are operational at time t.

$$u_j \geq 0. \qquad (3)$$

Inequalities (2) and (3) can be written as

$$u(t) \in \Omega\,[\,\alpha(t)] \qquad (4)$$

These requirements and constraints on the production rates can be expressed as a dynamic optimization problem as follows.

$$J[x(0),\ \alpha(0)] = \min\ E\left\{ \int g[x(t)]dt \mid x(0),\ \alpha(0) \right\} \qquad (5)$$

subject to

$$\frac{dx}{dt} = u(t) - d(t)$$

$$\sum_{j=1}^{n} \tau_{ij}\, u_j(t) \leq \alpha_i(t)$$

$$u_j \geq 0.$$

given initial conditions x(0) and $\alpha(0)$

4. real time control with failure and maintenance

At the highest level of the control scheme is the off-line calculation of the parameters of the control policy to be used in the flow level. In order tocalculate the hedging point we consider Fig. 2 as follows.

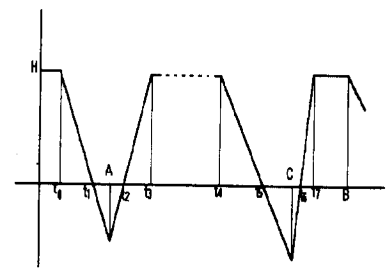

Figure 2. Production surplus

t_0 : the starting point of maintenance

A : the ending point of maintenamce

B : the next starting point of maintenance

t_4 : the starting point of machine failure

C : the ending point of machine repair

A maintenance begins at time t_0 that forces u_j to be zero. This causes x_j to decrease at rate $-d_j$. If maintenance continues for a length of time $A-t_0$ then the minimum value of x_j is $H_j-d_j(A-t_0)$, A failure occurs at time t_4 that forces again u_j to be zero. This causes x_j to decrease at rate $-d_j$. If failure lasts for a length of time $C-t_4$ then the minimum value of x_j is $H_j-d_j(C-t_4)$. We can find hedging point H to minimize the total inventory cost in Fig 2. We obtain

$$H = \frac{d(s+mT_r)(bU+ad)-(w+mT_f)ad(U-d)}{(m+1)U(a+b)} \qquad (6)$$

Where s is the mean maintenance time and w is the mean time interval between consecutive maintenances and T_r , T_f are MTTR and MTBF. Average inventory cost and shortage cost are a and b. Mean number of machine failure during w is m.

5. conclusion

This paper suggests an approach to incorporating maintenance times into the hierarchical control for unreliable FMS's. The goal of the control system is to meet production requirements while the machine fail and are repaired at random times.

The control is organized in a hierarchical structure according to the various decisions at the different time scales. Here the formulation of hierarchical scheduling and maintenance problem of FMS and the simple solution methodology are suggested. and the hedging point of this model is calculated.

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