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Karmarkar's and interaction/prediction algorithms for hierarchical production planning for the highest business benefit

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Abstract

This paper explores the hierarchical production planning (HPP) problem of flexible automated workshops (FAWs), each of which has a number of flexible manufacturing systems (FMSs). The objective is to decompose medium-term plans (assigned to an FAW by ERP/MRP II) into short-term plans (to be executed by FMSs in the FAW) for the highest business benefit. Here, ERP is short for enterprise resource planning and MRP II short for manufacturing resource planning. For practical purposes, the HPP problem is modeled after a linear programming (LP) model. Because the scale of the model for a general workshop is too large to be solved by the simplex method on a personal computer, Karmarkar's algorithm and an interaction/prediction algorithm are used to solve the model, the former for the large-scale problems and the latter for the very large scale. With the help of the programs written by using the above-mentioned algorithms and sufficient HPP examples, Karmarkar's algorithm, the interaction/prediction algorithm and the LP method in Matlab 5.0 are compared, the results showing that the proposed approaches are very effective.

Keywords: Flexible automated workshops; Flexible manufacturing systems; Hierarchical production planning; Karmarkar's algorithm; Interaction/prediction approach

1. Introduction

The problem of production planning (PP) for a flexible automated workshop (FAW) consisting of flexible manufacturing systems (FMSs) (or cells) is an important problem worth examining. In a manufacturing setting, PP is essential to achieving efficient resource allocation over time while meeting demands for finished products. Since the scope of PP problems generally prohibits a monolithic modeling approach, a hierarchical production planning (HPP) approach has been widely advocated in the PP literature [1]. To model PP problems, the existing hierarchical approaches usually employ the following concepts: (1) product disaggregation [2]; (2) temporal decomposition [3–7]; (3) process decomposition [8,9]; and (4) event-frequency decomposition [10]. However, those approaches are not very suitable for the decomposition of medium-term plans (assigned to an FAW by ERP/MRP II) into short-term plans (to be executed by FMSs in the FAW). To be specific, the product disaggregation only considers the structures of products, but not the organizational structure of a manufacturing department. Although the process decomposition in [8] considers the organizational structure of the manufacturing department, it only

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considers a manufacturing system (in which each part passes through each workshop in turn) consisting of a chain of workshops linked in a forward direction. Because the relationships among FMSs in an FAW are not always serial and even quite complicated, it is not applicable to the decomposition of medium-term plans for FAWs. Reference [9] explores the performance of linear regression and workload-based models for order acceptance in a decentralized production control structure for batch chemical manufacturing. The order acceptance problem is taken as a planning one for centralized allocation of an order to a specific period. The approaches are methods of combining the principles of both a temporal decomposition and a process one. Although multipurpose (i.e. products follow different routings) [9] is considered, it is not suitable for routings among FMSs in the FAW. Both temporal decomposition and event-frequency decomposition fail to take the organizational structure of the manufacturing department into consideration.

For this end, [11,12], propose the two different kinds of new approaches to the optimal decomposition of production plans for FAWs with respect to delay interaction or not. By building up linear quadratic models of PP problems and using interaction/prediction, the proposed approaches optimally decompose medium-term plans (assigned to an FAW by CIMS (computer integrated manufacturing system)/MRP II) into short-term plans (to be executed by FMSs in the FAW) at a high speed. These approaches are the new methods to combine the principles of both a temporal decomposition and a process one with the FAW's organizational structure (i.e. FAW's components, and part moving relationships between them). However, the overproduction penalty and the underproduction penalty in the objective function are the same, and so are the overload penalty and the underload penalty. In practice, the penalty for underproduction is usually heavy and the overproduction only leads to the increase in finished-product inventory, so the underproduction penalty should be much greater than the overproduction penalty. As with the overproduction and underproduction, the wages for overtime are several times those for the usual hours and the underload only leads to the decrease in the utilization of resources (such as persons and equipment), so the overload penalty should be much greater than the underload penalty. Thus, a linear programming (LP) model for HPP should be built up. As the model for a general workshop has thousands of constraints and variables, it tends to take too much time to solve the model through the simplex method on a personal computer. For this end, we propose that Karmarkar's algorithm and an interaction/prediction approach based on Karmarkar's algorithm respectively should be applied to solving the model, the former for the large-scale problems and the latter for the very large scale.

2. Production planning model for FAW

An FAW considered in this paper is inspired by the FAW of the CIMS in the Chengdu Aircraft Industry Company which consists of the two FMSs and two flexible direct numerical control systems. To solve the general problem of HPP, we suppose that an FAW consists of a shop computer, a material handling system (MHS), a tool handling system (THS), a shop testing and monitoring system (STMS), and FMS_{1-m}. They are connected by a local area network (LAN). The shop computer manages the production of the FAW. Its main functions are: (1) receiving medium-term plans from ERP/MRP II and decomposing them into short-term plans (to be sent to the FMSs in the FAW); (2) based upon short-term plans, developing tool requirement plans (to be sent to the THS) and material requirement plans (to be sent to the MHS); and (3) reporting, in time, to ERP/MRP II on production situations (including the fulfillment of the medium-term plans), error information and so on. Each of the FMSs in the FAW can produce finished products or semi-finished products (which need sending to the successive FMSs for further processing). The main functions of the FMSs are: (1) executing short-term plans coming from the shop computer; and (2) reporting to the shop computer on the production situations (including the fulfillment of the short-term plans) and error information in time [13,14].

The objective of HPP in the FAW is to obtain the highest business benefit simultaneously by maximizing the gross benefit of finished products and by minimizing the blank cost, production-time-related cost, in-process inventory, overload and underload on work centers, and cumulative overproduction and cumulative underproduction of finished products