Available online at www.sciencedirect.com

SCIENCE DIRECT®

Int. J. Production Economics 101 (2006) 19–29

international journal of production economics

www.elsevier.com/locate/ijpe

A heuristic job-shop scheduling algorithm to minimize the total holding cost of completed and in-process products subject to no tardy jobs

Hiroshi Ohta*, Toshihiro Nakatani

Department of Industrial Engineering, Graduate School of Engineering, Osaka Prefecture University, Sakai, Osaka 599-8531, Japan

Available online 1 December 2005

Abstract

Meeting due dates is the most important goal of scheduling if the due date of each job has been promised to its customer. This paper considers the job-shop scheduling problem of minimizing the total holding cost of completed and in-process products subject to no tardy jobs. A heuristic algorithm based on the shifting bottleneck procedure is proposed for solving the minimum total holding cost problem subject to no tardy jobs. Several benchmark problems which are commonly used for job-shop scheduling problems of minimizing the makespan are solved by the proposed method and the results are reported.

Keywords: Job-shop scheduling; Heuristics; Due-date constraints; Holding cost; Shifting bottleneck procedure

1. Introduction

The job-shop scheduling problem has been extensively studied with the objective of minimizing some functions of the completion times of jobs. Enumerative methods have been proposed and heuristics have been designed for solving the minimum makespan problem, the minimum total tardiness problem and so on (e.g. Adams et al., 1988; Anderson and Nyirenda, 1990; Applegate and Cook, 1991; Carlier and Pinson, 1994, 1989; Liao and You, 1992; Raman and Talbot, 1993; Van Laarhoven et al., 1992; Vepsalainen and Morton, 1987). Meeting due dates is often the most important goal of scheduling, but the due-date constraints are rarely ever considered in job-shop scheduling problems. We treat due dates as deadlines and require the job-shop scheduling to meet job-specific due dates in order to avoid delay penalties including customer's bad impression, cost of lost future sales and rush shipping cost. A heuristic algorithm for solving

*Correspondence author. Tel.: +81 72 254 9346; fax: +81 72 254 9915.
E-mail address: ohta@ie.osakafu-u.ac.jp (H. Ohta).

0925-5273/$ - see front matter
doi:10.1016/j.ijpe.2005.05.004

the scheduling problem to meet due dates in a simple job-shop is developed to approximately minimize the total holding cost corresponding to the sum of product inventory cost and in-process inventory cost. The proposed method decomposes the job-shop problem into a number of single-machine problems with ready-time and due-date constraints. Each decomposed problem is strictly solved by a branch and bound (B&B) method using new due dates for each operation decided by considering to meet pre-specified due dates and minimizing objective functions, simultaneously. We used an elimination method adapted for a single-machine problem at each node to directly select some disjunctions or at least to determine whether or not a potentially global solution can be obtained. In this way, the B&B tree is trimmed efficiently. Several benchmark problems are solved by the proposed method and the results are reported.

2. Job-shop scheduling problem minimizing total holding cost subject to no tardy jobs

2.1. Problem formulation

A set of I jobs has to be processed on K machines. The processing of job J_i $(i = 1, 2, ..., I)$ on a machine is called an operation and each operation can be performed by only one machine. The processing order of a job is given. Let O_i^l $(l = 1, 2, ..., L_i)$ denote the lth operation of job J_i, where L_i corresponds to the number of operations for job J_i. The processing time p_i^l of operation O_i^l is pre-specified. Each machine k $(k = 1, 2, \ldots, K)$ can process only one operation at a time. Pre-emption is not allowed, and each job is available for processing at time 0. The due date d_i of job J_i is pre-specified by the associated customer. Every job must be completed before or just on its due date and no tardy jobs are allowed. The shop incurs the holding cost for in-process time once a job begins processing, and if a job is completed earlier than its due date, then the shop holds the job and incurs the holding cost for earliness. Assume $w_i^{l-1} \leqslant w_i^l$, where w_i^l $(l = 1, 2, ..., L_i - 1)$ denotes the holding cost per unit time for in-process product in idle time from end of operation O_i^l to start of operation O_i^{l+1}, and $w_i^{L_i}$ denotes the holding cost per unit time for completed product from end of operation $O_i^{L_i}$ to due date d_i. This assumption means that holding cost for in-process product is increasing based on the progress of the operation.

Let C_i^m (decision variable) denote the completion time of operation O_i^m and $\mathbf{E}_k$ the set of operations to be performed on machine k, then our problem is formulated as follows:

$$\text{(P)Minimize} \quad f = \sum_{i=1}^{I} \left\{ \sum_{l=1}^{L_i - 1} w_i^l (C_i^{l+1} - p_i^{l+1} - C_i^l) + w_i^{L_i}(d_i - C_i^{L_i}) \right\} \tag{1}$$

Subject to

$$C_i^m - C_i^{m-1} \geqslant p_i^m, \quad i = 1, ..., I, \quad m = 2, ..., L_i, \tag{2}$$

$$C_i^m - C_j^n \geqslant p_i^m \vee C_j^n - C_i^m \geqslant p_j^n, \quad \forall O_i^m, O_j^n \in \mathbf{E}_k, \quad k = 1, ..., K, \tag{3}$$

$$d_i - C_i^{L_i} \geqslant 0, \quad i = 1, ..., I, \tag{4}$$

$$C_i^1 - p_i^1 \geqslant 0, \quad i = 1, ..., I. \tag{5}$$

The objective function corresponds to the minimum total weighed flow time from the determined starting time to the pre-specified due date for every job. Eqs. (2) and (3) are the conjunctive and disjunctive