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Multi-criteria sequencing problem for a mixed-model assembly line in a JIT production system

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Abstract

Mixed-model assembly lines (MMAL) are a type of production lines where a variety of products models similar to product characteristics are assembled in a just-in-time (JIT) production system. There is a set of criteria on which to judge sequences of product models in terms of the effective utilization of these lines. In this paper, we consider three objectives simultaneously: (i) total utility work cost, (ii) total production rate variation cost, and (iii) total setup cost. In this study, these three objectives are first weighted by their relative importance weights and then a new mathematical model is presented. To solve this model, a memetic algorithm (MA) is proposed to determine suitable sequences. The performance of the MA is compared with the Lingo 6 software. A number of test problems are carried out to verify the good ability of the proposed MA in terms of the solution quality and computational time. The computational results reveal that the MA finds promising results, especially in the case of large-sized problems.

Keywords: Multi-criteria sequencing; Mixed-model assembly line; JIT system; Memetic algorithm

1. Introduction

Mixed-model assembly lines are a type of production lines that are capable of the diversified small lot production and are able to respond promptly to sudden demand changes for a variety of models without holding large inventories. The effective utilization of a mixed-model assembly line requires solving two problems in the sequential manner: (1) design and balance the line and (2) determine the production sequence for different models. In this paper, we assume that the line has already been balanced and a sequencing problem is only considered.

The sequence of introducing models to the mixed-model assembly line should be determined considering the main goals which are crucial to efficiently implement a just-in-time (JIT) production system. Numerous research efforts have been directed towards the development of computer approximation algorithms or heuristics as well as their subsequent implementation to solve mixed-model assembly lines. Monden [1] defines

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two goals for the sequencing problem: (1) leveling the load of the total assembly line for each station on the line and (2) keeping a constant rate of usage for every part used in the line. To handle these problems, goal chasing I and II (GC-I and GC-II) are developed by Toyota Corporation. The GC-I minimizes the one-stage assuming that the length of the unique workstation is equal to zero. The GC-II solves the GC-I under special assumptions regarding the product structure.

Miltenburg [2] developed a non-linear programming model for the second above-mentioned goal. The time complexity function of the proposed program was exponential. Thus, he developed and solved the problem by applying two heuristic procedures. Miltenburg et al. [3] solved the same problem with a dynamic programming algorithm. Inman and Bulfin [4] solved the problem introduced in [2] by converting it to a new mathematical model. Other objectives were also considered by a number of researchers. Yano and Rachamdugu [5] minimized the total utility work. Bard et al. [6] considered an objective to minimize the overall line length. Okamura and Yamashina [7] developed a heuristic algorithm to minimize the risk of conveyor stoppage.

Tavakkoli-Moghaddam et al. [8,9] presented the optimal schedule and sequence of a set of jobs for a single machine with idle insert, in which the objective function is to minimize the sum of maximum earliness and tardiness (n/1/I/ETmax). Sequencing mixed-model assembly lines have also been studied as a multi-criteria problem. Bard et al. [10] developed a model involving two objectives as follows: (1) minimizing the overall line length and (2) keeping a constant rate of part usage. They solved the problem by using the weighted sum and they proposed a tabu search (TS) method to solve such a problem. Hyun et al. [11] addressed three objectives as follows: (1) minimizing total utility work, (2) keeping a constant rate of part usage, and (3) minimizing total setup cost. This problem was solved by proposing a new genetic evaluation and selection mechanism. Korkmazel and Meral [12] developed a weighted sum approach for two goals introduced by Monden [1]. McMullen and Fraizer [13] developed a simulated annealing (SA) method for the model used by McMullen [14] and they compared this SA against the TS method. McMullen [15–17] also solved the same problem by using genetic algorithms, Kohonen self-organizing map (SOM), and ant colony optimization, respectively. He also compared the performance of these three methods with SA and TS methods. Mansouri [18] has also solved the same problem with genetic algorithms in which a new selection mechanism has been introduced. A number of other metaheuristic methods can be applied to any other combinatorial optimization problem. Tavakkoli-Moghaddam et al. [19] proposed an efficient memetic algorithm (MA) with a simulated annealing-based local search engine in order to solve a new model of a cell formation problem (CFP) for a multi-period planning horizon.

In this paper, we consider three objectives simultaneously: (i) total utility work cost, (ii) total production rate variation cost, and (iii) total setup cost. The structure of this paper is as follows: In Section 2, we present the detailed description of the mixed-model assembly line (MMAL). In Section 3, we discuss about the complexity of the proposed model and propose the memetic algorithm to solve such a hard model. Section 4 provides experimental results in which a number of test problems are solved to show the efficiency of the proposed MA. Finally, we present our conclusions in Section 5.

2. Multi-criteria sequencing problem for the MMAL

2.1. Mixed-model assembly line

In this paper, the MMAL is a conveyor system moving at a constant speed (v_c). Similar products are launched onto the conveyor at a fixed rate. The line is partitioned into J stations. It is assumed that the stations are all closed types. A closed station has boundaries in which workers cannot cross. Such a closed station is often found in reality where the use of facilities is restricted within a certain boundary. The tasks allocated to each station are properly balanced and their operating times are deterministic. The worker moves downstream on the conveyor while performing his/her tasks to assemble a product. To complete the job, the worker moves upstream to the next product. Suppose that the worker's moving time is ignored.

The design of the MMAL involves several issues such as determining operator schedules, product mix, and launch intervals. Two types of operator schedules (i.e., early start schedule and late start schedule) are found in [6]. An early start schedule is more common in practice and is used in this paper. Second, a minimum part set (MPS) production, which is a strategy widely accepted in the mixed-model assembly lines, is also used in this