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A two-level method of production planning and scheduling for bi-objective reentrant hybrid flow shops

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ABSTRACT

This research deals with a two-level method of production planning and scheduling problems of the reentrant hybrid flow shops. The hybrid flow shop has serial stages where each stage consists of identical parallel machines. Products can be processed at any one of the parallel machines at a stage in the hybrid flow shop. Also a product may have reentrant operations which require revisits of some stages several times. We consider a two-level hierarchical process on production planning and scheduling of the reentrant hybrid flow shop with the bi-objective function to improve productivity and customer satisfaction. Computational experiments show that the combination of preemptive goal programming based production planning algorithms and Pareto genetic based scheduling algorithms outperforms other two-level algorithms. Also we provide results of the application of the proposed method to both randomly generated problems and a real world Thin Film Transistor and Liquid Crystal Display (TFT-LCD) industry.
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1. Introduction

This paper deals with a multi-stage production planning and scheduling problem in hybrid flow shops. In a hybrid flow shop, a product can be processed on any one of the parallel machines at a stage. A product may revisit any stage several times so called, a reentrant operation. In the real world, a reentrant hybrid flow shop may be found in electronics industry such as printed circuit board (PCB), semiconductor wafer fabrication, semiconductor assembly industry, and thin film transistor and liquid crystal display (TFT-LCD) manufacturing (Kumar & Omar, 2006; Lee & Lee, 2003; Linn & Zhang, 1999). Generally, a production planning and a scheduling determine the production quantities and the sequence to satisfy deterministic demand during multiple periods. A production planning and a scheduling problem can be solved by either a single-level or two-level hierarchical decision making procedures. In a single-level procedure, production quantity and scheduling decisions are determined simultaneously with the overall consideration of the entire problem. In a two-level procedure, production and scheduling decisions are divided into upper-level planning and lower-level planning. In the upper-level planning, we determine production quantity of different products to be processed in different layers assuming that the machines are aggregated. In the lower-level planning, we determine the scheduling on individual machine considering the production quantity determined by the upper-level planning.

The single-level procedure performs better than the two-level procedure in terms of solution quality. However the computational time to solve the problem will be increased exponentially as the problem size increases. The two-level procedure may produce infeasible solution when the production decision is implemented on individual machines due to the capacity aggregation of machines. However the two-level procedure is more realistic and widely accepted method in real TFT-LCD and semiconductor industries.

Most of the existing literatures on reentrant hybrid flow shop problems have not considered the practical need for multi-objective production planning and scheduling. In a real world situation, one of the main concerns of a plant manager is the productivity generally measured by throughput, makespan or machine utilization. Other important issues include the reduction of WIP and the minimization of changeover so that the inventory and production related costs are minimized. On the other hand, the production plan and schedule determined by master production schedule must meet due date for the customer satisfaction.

In this research, we consider a two-level method for reentrant hybrid flow shops considering the maximization of throughput and the minimization of the sum of delayed customer demand. The delayed customer demand is the difference between cumulative sum of the throughput and demand values from the first time

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period to the current time period. The throughput and the delayed customer demand are related to the productivity and the customer satisfaction respectively. The throughput is the amount of finished products in a period of time. Thus the maximized throughput implies that the machine utilization has been increased and the production lead time has been reduced by eliminating non-value added activities such as waiting time, transportation time and loading/unloading time on machines. The delayed customer demand is the difference between cumulative sum of the throughput and demand values from the first time period to the current time period. The delayed customer demand must be met after the due date has been passed which causes the dissatisfaction to customers. The upper-level planning and the lower-level planning must be designed so that they support the measure of the throughput and the delayed customer demands. We consider existing production planning and scheduling algorithms for reentrant hybrid flow shops. Considering the different combinations of planning and scheduling algorithms, we try to find out the best combinations of two-level method for the problems.

In the literature for a reentrant hybrid flow shop, the planning and the scheduling have been studied separately. The most recent and promising studies for planning were TB models (Lee, Lee, Yang, & Ignisio, 2008) and preemptive goal programming (Cho & Jeong, 2012). For the area of scheduling, NSGA-II (Deb, Pratap, Agarwal, & Meyarivan, 2002) and MLPGA (Cho, Bae, Kim, & Jeong, 2011) have attracted attention from many researchers. However the planning and the scheduling are not independent decisions but closely related to each other. To the best of our knowledge, this is the first attempt to combine different planning and scheduling models so that we can construct two-level hierarchical method to optimize bi-objective in a reentrant hybrid flow shop. Another contribution of this paper is to compare the performance of the single-level optimization method and the two-level hierarchical optimization. In terms of solution quality, the single-level procedure performs better than the two-level. However in terms of the computational time, the two-level method is better than the single-level method. It is conjectured that we can find the best combination of planning and scheduling algorithm to achieve a close to the optimal performance that can be achieved via single-level optimization.

This paper is organized as follows: in Section 2, we provide literature review of the problem. Section 3 introduces existing models and algorithms for planning and scheduling problem for reentrant hybrid flow shops. The comparison with all possible two-level methods is provided in Section 4. The application of the proposed two-level method to a real world TFT-LCD industry is shown in Section 5. Section 6 concludes the paper with possible extension in the future.

2. Literature review

The reentrant hybrid flow shop production planning and scheduling has been studied mostly in environments of semiconductor wafer fabrication and TFT-LCD manufacturing. In the production planning, Kim, Yea, and Kim (2000, 2002) and Yea (1997) studied how to determine target WIP levels using the fab. balance on semiconductor wafer fabrication. Also they suggested a mixed integer programming model and heuristic methods for shift scheduling to achieve production target. Lee, Park, and Kim (2002) suggested dispatching rules to derive target production level and target WIP level in order to reduce the production and the cycle time on semiconductor fabrication line. Lee and Kim (2002) studied a balance control policy for bottleneck scheduling and operation management on fab. line. Also they proposed an optimization model to reduce the production and the cycle time by applying the balance measurement. Lee and Lee (2003) considered bottleneck process step as managing points and suggested the mathematical models for the production planning of the reentrant manufacturing process. The models were a throughput driven push model, a balance driven push-pull model using WIP controlling policy, and a target driven pull model using incapacitated production target projection. Hsieh and Hou (2006) have developed a production-flow-value-based job dispatching by the theory of constraints (TOC). Kang and Lee (2007) suggested due date based optimization models of a target control model, a movement control model and a WIP control model for make-to-order semiconductor industry. Lee et al. (2008) suggested target balance (TB) optimization models using production target, due-date, and WIP for single bottleneck stage on semiconductor fabrication. Also authors applied the model on TFT-LCD fabrication of multiple bottleneck stages. Cho and Jeong (2012) suggested preemptive goal programming (PGP) based models for the production planning of the bi-objective reentrant hybrid flow shops.

In the scheduling with multiple objectives, Alfieri (2009) studied a tabu search based heuristic on simulation-based environment for permutation scheduling with minimizing maximum tardiness and minimizing total weight delay in a reentrant hybrid flow shop. Kim and Lee (2009) studied heuristic algorithms to minimize makespan under maximum allowable due dates for the reentrant hybrid flow shop with unrelated parallel machines. Choi et al. (2009) suggested an optimal solution algorithm with semi-permutation schedules and heuristic algorithms with non-permutation schedules to minimize the same objective for the two-stage reentrant hybrid flow shop. Dugardin, Yalaoui, and Amodeo (2010) suggested heuristic algorithms for the maximization of the bottleneck utility and the minimization of maximum completion time in the reentrant hybrid flow shop. Cho et al. (2011) suggested a Pareto genetic algorithm with four different versions of local search strategies for bi-objective function of minimizing makespan and total tardiness. Moghaddam, Yalaoui, and Amodeo (2012) suggested a heuristic algorithm for permutation scheduling problems with bi-objective reentrant flow shops with rejection.

Recently, Kim and Lee (2016) proposed an algorithm for the integration of production plan and scheduling where production plan is generated with a single objective optimization model and the schedule is produced by the suggested dispatching rules in a simulation model. In this research, we propose a two-level hierarchical algorithm to solve planning and scheduling problem of a reentrant hybrid flow shop considering the bi-objective. The objective of the research is to find the best combination of models and algorithms for upper-level planning and lower-level scheduling among existing models and algorithms. Also we want to compare the performance of the existing single-level optimization method and the proposed two-level hierarchical optimization.

3. Problem description

3.1. Upper-level planning

This sub-section presents the mathematical models for the upper-level planning which is the production planning for multi-stage reentrant hybrid flow shops. First, we introduce the target balance (TB) models (Lee et al., 2008) which are Linear Programming and preemptive goal programming (Cho & Jeong, 2012) which is bi-objective Linear Programming.

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