Chapter 28
Single Batch-Processing Machine Scheduling Problem with Fuzzy Due-Dates: Mathematical Model and Metaheuristic Approaches

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ABSTRACT

This paper focuses on a problem of minimizing total weighted tardiness of jobs in a real-world single batch-processing machine (SBPM) scheduling in existence of fuzzy due date. In this paper, first a fuzzy mixed integer linear programming model is developed. Then, due to the complexity of the problem, which is NP-hard, we design two hybrid metaheuristics called GA-VNS and VNS-SA applying the advantages of genetic algorithm (GA), variable neighborhood search (VNS) and simulated annealing (SA) frameworks. Besides, we propose three fuzzy earliest due date heuristics to solve the given problem. Through computational experiments with several random test problems, a robust calibration is applied on the parameters. Finally, computational results on different-scale test problems are presented to compare the proposed algorithms.

1. INTRODUCTION

A batch processing machine (BPM) is a special variant of a scheduling problem, in which several jobs can be simultaneously processed in such a way that all the jobs in a batch start and complete their processing at the same time. The main advantage is to reduce setups and/or facilitation of material handling. The problem of BPM scheduling is often encountered in real industries. The industrial application of these

DOI: 10.4018/978-1-4666-9644-0.ch028

machines can be found in semiconductor burn-in operations, environmental stress-screening (ESS) chambers, chemical, food and mineral processing, pharmaceutical and construction materials industries, etc.

The BPM scheduling problem is important because the scheduling of batching operations has a significant economic impact. It is mainly motivated by an industrial application, namely, the burn-in operation found in the final testing phase in semiconductor manufacturing (Uzsoy *et al.*, 1992; Uzsoy *et al*., 1994). In the semiconductor manufacturing, the jobs have different processing times and sizes that are both required by the customers. The jobs are grouped in batches where a batch means a subset of jobs. The BPM can process a batch of jobs as long as the sum of all the job sizes in the batch does not violate the capacity of the machine. The processing time of a batch is equal to the longest processing time of all the jobs in that batch.

Ikura and Gimple (1986) were the first researcher who studied the BPM problem and Lee *et al.* (1992) first presented a detailed description for burn-in operation. As reported in the studies, the exact algorithms have a slow convergence rate and they can solve only small instances to optimality.

As this study addresses SBPM with fuzzy due dates using metaheuristics, the review on SBPM scheduling under a fuzzy environment and the application of metaheuristics to these problems is carried out. For an extensive review on BPM scheduling problems, we refer to Potts and Kovalyov (2000) and Mathirajan and Sivakumar (2006).

In BPM scheduling problems, Wang and Uzsoy (2002) firstly proposed a metaheuristic algorithm. Considering dynamic job arrivals, they combined a dynamic programming algorithm with a random key genetic algorithm (GA) to minimize the maximum lateness. Melouk *et al.* (2004) used a simulated annealing (SA) to minimize the makespan. Koh *et al.* (2005) proposed a random key representation-based GA for the problems of minimizing the makespan and total weighted completion time. Sevaux and Peres (2003), Husseinzadeh Kashan *et al.* (2006) and Damodaran *et al.* (2006) used a GA and redesigned the coding and decoding methods.

Mönch et al. (2006) presented a GA combined with dominance properties to minimize the earliness–tardiness of the jobs. Chou *et al.* (2006) and Wang *et al.* (2007) presented a hybrid GA and a hybrid forward/backward approach to minimize the makespan. Husseinzadeh Kashan and Karimi (2008) developed two versions of an ant colony optimization (ACO) framework under the situation considered in Koh *et al.* (2005). Chou and Wang (2008), Mathirajan *et al.* (2010) and Wang (2011) proposed a hybrid GA, SA and iterated heuristic for the objective of the total weighted tardiness, respectively. Husseinzadeh Kashan *et al.* (2010) considered bi-criteria scheduling for the simultaneous minimization of the makespan and maximum tardiness.

In the classic scheduling problems, it is usually assumed that the aspects of the problem in hand are certain. Most existing models neglect the presence of uncertainty within a scheduling environment. In many real-world scheduling problems; however, uncertainty and vagueness in due date often do exist that make the models more complex. This uncertainty may come about because of production problems (e.g., defect in raw material, machine malfunctioning) or problems with delivery itself (e.g., transportation delay, traffic jam). Although classic BPM scheduling models are extensively studied in the literature, there are only three studies on fuzzy-based BPM models.

Ishii *et al.* (1992) introduced the concept of fuzzy due dates to scheduling problems, fuzzy due dates scheduling problems have been investigated by many researchers. Harikrishnan and Ishii (2005) presented a polynomial time algorithm for bi-criteria scheduling of serial-batching problem with fuzzy due dates to minimize the total weighted resource consumption and maximize the minimal satisfaction degree. Yimer & Demirli (2009) considered a fuzzy goal programming problem for batch scheduling