Computers & Industrial Engineering 126 (2018) 217–231

Contents lists available at ScienceDirect

Computers & Industrial Engineering

journal homepage: www.elsevier.com/locate/caie

Bi-level genetic algorithms for a two-stage assembly flow-shop scheduling problem with batch delivery system

Saeedeh Ahmadi Basir*, Mohammad Mahdavi Mazdeh, Mohammad Namakshenas

Department of Industrial Engineering, Iran University of Science and Technology, Tehran, Iran

ARTICLE INFO

Keywords:
Two-stage assembly flow-shop
Tardy jobs
Batch delivery system
Bi-level genetic algorithms
Hierarchical decision making

ABSTRACT

In this paper, an integrated production and distribution scheduling on a two-stage assembly flow-shop setting with a batch delivery system is addressed. The objective is to schedule the jobs in the two-stage assembly flow-shop and groups the completed products into a suitable number of batches for delivery with the minimum number of weighted tardy jobs and sum of delivery costs. After extending a mixed-integer linear programming (MILP) model, we proposed a bi-level genetic algorithm to solve the addressed problem that the first level of its chromosome is supposed to determine the sequence of the processing jobs, and the second level of it is responsible for allocating jobs to batches independently. To offer the more efficient algorithm, we change the structure of the proposed GA. Therefore, by applying the hierarchical decision-making approach, we present a bi-level improved genetic algorithm (IGA) in which according to the determined sequence in the first level, batches are determined. The proposed algorithms are evaluated based on computational experiments. The experiments reveal that IGA, which has the decreased decision-making space for the second level, outperforms GA. Moreover, to validate the proposed model and the efficiency of the proposed algorithms, a real-life example is presented and solved.

1. Introduction and literature

In many manufacturing companies, each product consists of the different parts which are produced and assembled through two stages. In other words, each product requires m components to be manufactured at the first stage by *M* different machines, and all these components need to be assembled at the second stage (assembly stage). Therefore, the problem of two-stage assembly flow-shop scheduling is applicable in many real-life environments.

In this study, we investigate a furniture manufacturing industry. There are several operations processing in two stages. In the first stage, components of a furniture such as legs, arms, seat, and backrest are produced by a number of furniture manufacturing machines. When all of these components are completed, the final product is assembled in the second stage. Among all manufacturing processes of furniture industry, the assembling has longer process. A number of workers are allocated to each assembly line. Each of these lines and their workers can be considered as a single machine.

On the modeling of assembly flowshop with cross-industry applications, Lee, Cheng, and Lin (1993) described an application in a fire engine assembly plant and modeled it as a two-stage assembly flowshop scheduling problem to minimize makespan of *N* products, where there are 2 machines at the first stage. The second example, which arises in the manufacture of personal computers, is given by Potts, Sevast'Janov, Strusevich, Van Wassenhove, and Zwaneveld (1995) for this problem. Both Lee et al. (1993) and Potts et al. (1995) gave proofs for being the strong NP-complete of the problem. Lee et al. (1993) proposed a branch and bound scheme. Also, they employed three heuristics to find approximate solutions to the problem. While Potts et al. (1995) proposed a heuristic for the problem. Another application was presented by Allahverdi and Al-Anzi (2006b) in the area of queries scheduling on distributed database systems in order to minimize the makespan with setup times. They developed the evolutionary heuristics including a particle swarm optimization (PSO) and a taboo search (TS) to solve the problem Hariri and Potts (1997) also studied the same problem as Potts et al. (1995) and developed a branch and bound algorithm. Sun, Morizawa, and Nagasawa (2003) have suggested some powerful heuristic algorithms based on the basic idea of Johnson's algorithm and Gupta's idea for this problem. Lin, Cheng, and Chou (2007) have studied the same problem with batch assembly machine and established the problem is NP-hard where all the jobs have the same processing time on the second stage machine. Sung and Juhn (2009) investigated a two-stage assembly problem where each job is assembled with two types of components with the objective function of makespan

* Corresponding author.
E-mail addresses: s.basir149@gmail.com (S.A. Basir), mazdeh@iust.ac.ir (M.M. Mazdeh), m.n.shenas@chmail.ir (M. Namakshenas).

https://doi.org/10.1016/j.cie.2018.09.035
Received 17 October 2017; Received in revised form 16 July 2018; Accepted 19 September 2018
Available online 20 September 2018
0360-8352/

minimization. One of the two components of each job is outsourced subject to job-dependent lead time and the other is manufactured by a single machine. Three heuristic algorithms are derived to solve it and also a branch and bound algorithm was applied. Komaki and Kayvanfar (2015) studied two-stage assembly flow-shop scheduling problem with the release time of jobs. For solving the problem, they proposed a novel meta-heuristic algorithm called GWO, which is inspired by wolves' living and hunting behavior.

The literature can be reviewed based on the performance measures and objective policies of the industry. Allahverdi and Al-Anzi (2006a) and Al-Anzi and Allahverdi (2007) address the two-stage assembly flow shop problem with respect to a due date based performance measure, i.e. maximum lateness. Allahverdi and Al-Anzi (2006a) proposed three heuristics for the problem. Al-Anzi and Allahverdi (2007) used a self-adaptive differential evolution heuristic to a scheduling problem for the first time.

The performance measure of total tardiness in two-stage assembly flowshop (TSAFS) is considered by some researchers. Allahverdi and Aydilek (2015) considered this problem for the first time and proposed a genetic algorithm, an insertion algorithm, two versions of simulated annealing algorithm (SA), and two versions of cloud theory based SA to solve it.

Allahverdi and Al-Anzi (2008) and Torabzadeh and Zandieh (2010) addressed the problem with the objective of minimizing makespan and mean completion time. Allahverdi and Al-Anzi (2008) proposed three heuristics; simulated annealing (SA), ant colony optimization (ACO), and self-adaptive differential evolution (SDE); to solve the problem. They showed that both SA and SDE perform better than ACO. While Torabzadeh and Zandieh (2010) proposed the cloud theory based simulated annealing algorithm (CSA) to solve it. With comparison with the proposed algorithms in Allahverdi and Al-Anzi (2008), Torabzadeh and Zandieh (2010) revealed that CSA performs better.

Another important performance measure, related to due date of jobs, is the number of tardy jobs. Allahverdi, Aydilek, and Aydilek (2016) considered the two-stage assembly flow shop scheduling problem with the objective of minimizing the number of tardy jobs for the first time in 2016. They proposed a genetic algorithm (GA), improved genetic algorithm (IGA), simulated annealing algorithm with three different neighborhood structures (SA-1, SA-2, SA-3), Dhouib et al.'s simulated annealing algorithm (DSA), and an improved cloud theory-based simulated annealing algorithm (CSA) to solve the problem. Among them, the proposed heuristic of SA-3 outperformed.

Rendition of a job always occurs after its completion. However, in literature, in some studies, a batch delivery system is assumed to reduce the delivery costs. In such a batch delivery system, each job can be dispatched to the customer immediately after completion or it can wait for the next job/s in order to be delivered as a batch. Therefore, always, rendition time is greater than or equal to the completion time.

The batching problem was first addressed by Santos and Magazine (1985) for single machine problem. After that, scheduling problems with a batch delivery system have been considered by many researchers, especially in single machine environments.

Ji, He, and Cheng (2007) and Mazdeh, Shashaani, Ashouri, and Hindi (2011) considered the performance measure of weighted flow time and delivery costs on a single machine problem. Ji et al. (2007) showed that the problem is strongly NP-hard and presented a dynamic programming algorithm to solve it. Mazdeh et al. (2011) investigated structural properties of the problem and used them to present a branch and bound algorithm.

Lu, Yuan, and Zhang (2008) considered a single machine scheduling problem with the objective of minimizing makespan with job release times and job delivery by capacitated vehicles are assumed. They investigated the problem in two states; when preemption is allowed to all jobs and not. They used a polynomial time and a 5/3 approximation algorithms for these problems respectively.

Minimizing the total weighted number of tardy jobs and delivery costs on a single machine scheduling problem is addressed by Mahdavi Mazdeh, Hamidinia, and Karamouzian (2011) and Rasti-Barzoki, Hejazi, and Mazdeh (2013). To solve the problem Mahdavi Mazdeh et al. (2011) proposed a meta-heuristic method based on simulated annealing and Rasti-Barzoki et al. (2013) used a branch and bound algorithm.

Rostami, Kheirandish, and Ansari (2015) considered the maximum tardiness and delivery costs as an objective function for a problem with job release times. They developed a branch and bound algorithm to solve this problem. Pundoor and Chen (2005) and Mazdeh and Rostami (2014) considered this performance measure for a make to order production–distribution system and two-machine flow-shop setting respectively. Pundoor and Chen (2005) assumed the capacity limit for each shipment and used a fast heuristic for the problem. Mazdeh and Rostami (2014) proposed a branch and bound algorithm for their problem.

Wang, Ma, Luo, and Qin (2016) studied a scheduling problem in which product components are first produced and assembled in a two-stage assembly flow-shop, and then are delivered to a customer in batches with one of the vehicles. They considered the delivery cost and transportation time between fire and the customer are fixed. To minimize the weighted sum of average arrival time at the customer and total delivery cost, they applied two fast heuristics (SPT-based heuristic and LPT-based heuristic) and a new hybrid meta-heuristic (HGA-OVNS).

This study addresses a scheduling problem in a two-stage assembly flow-shop system where products can be dispatched to the customer in batches. In order to make the model more applicable to the real world situations, the size of the products is considered different. Therefore, the size of batches are various. The capacitated vehicles are responsible for dispatching the batches. There is no limitation of the number of vehicles; they can immediately serve as soon as some deliveries are requested. The objective function minimize the number of weighted tardy jobs plus the sum of delivery costs, which to the best of our knowledge, has not been considered so far for this problem. A mixed integer linear programming (MILP) model and two meta-heuristic algorithms are developed to solve it. The rest of this paper is organized as follows. Section 2 presents the problem definition and model. In Section 3 the solution algorithms are introduced and developed. In Section 4 a number of experiments are applied to evaluate the efficiency of the proposed model and the performance of the suggested algorithms. The last section discusses a brief conclusion.

2. Definition and mathematical model

In this section, first of all, the structure of the problem is described in details. Then, after a brief introduction of the notations, a mixed-integer linear programming (MILP) model is developed for the problem. After that, we also develop a tractable linear mathematical model. Finally, the performance of the model is shown through an example.

2.1. Problem definition

Consider the workshop has two stages. Each job is supposed to go through both stages in $M + 1$ operations. In the M first operations at stage one the M components of each job are produced by M different machines. When all of the M components are completed at the first stage, the final operation can be conducted by one of the Q identical assembly machines in the second stage. All machines are always available and each of them can process only one job at a time.

Let N be the number of jobs which are ordered by H customers. The weight of each job is shown by W and its value indicates the delay cost of each job. Jobs are ready for scheduling at time zero and no preemption is allowed. Jobs are submitted to the customer in a batch delivery system after being finished. Each job can be dispatched to the customer immediately after completion or it can wait for the next job/s in order to be delivered as a batch. Therefore, the maximum number of