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Hybrid flow shop scheduling with sequence dependent family setup time and uncertain due dates

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ABSTRACT

This paper studies the scheduling problem in hybrid flow shop (HFS) environment. The sequence dependent family setup time (SDFST) is concerned with minimization of makespan and total tardiness. Production environments in real world include innumerable cases of uncertainty and stochasticity of events and a suitable scheduling model should consider them. Hence, in this paper, due date is assumed to be uncertain and its data follow a normal distribution. Since the proposed problem is *NP-hard*, two metaheuristic algorithms are presented based on genetic algorithm, namely: Non-dominated Sorting Genetic Algorithm (NSGAII) and Multi Objective Genetic Algorithm (MOGA). The quantitative and qualitative results of these two algorithms have been compared in different dimensions with multi phase genetic algorithm (MPGA) used in literature review. Experimental results indicate that the NSGAII performs very well when compared against MOGA and MPGA in a considerably shorter time.

1. Introduction

Scheduling is one of the important problems in production planning systems. In general form, scheduling problems are categorized as difficult problems and also flow shop scheduling problems include a wide range of production and assembly models. One of the scheduling environments that have a very good adaptability with most of the real world problems is hybrid flow shop (HFS). HFS is considered as one of the difficult problems due to its complexity [1]. According to Linn and Zhang [2] definition, scheduling problem of HFS includes a series of production stages that each individual one of these stages includes machine or parallel machines. And at least there is one stage which includes more than one machine. Parallel machines in each stage can be divided into three groups: identical parallel machines, uniform parallel machines, and unrelated parallel machines. In this paper, scheduling problem of HFS with identical parallel machines has been studied. All of machines located in one stage are quite identical and the processing time of each job in that stage does not depend on machine being used.

In most scheduling problems, setup time is considered very unimportant and insignificant or it is considered as a part of the processing time, this will result in simplification of analysis scheduling, but in most of real problems, this assumption is unreal and machine setup is unavoidable when changing job on the machinery. That is also introduced by Ulungn et al. [3]. They divided the setup time into two categories: sequence-independent: setup time is only dependent on the job that is being processed, therefore it is called sequence-independent. Sequence-dependent: setup time depends on the job to be processed and the one yet processed, therefore it is called sequence-dependent. One of the last studies that considered sequence-dependent scheduling, has been the study done by Behnamian and Fatemi Ghomi [4]. The most difficult

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condition of setup times occurs when setup times are dependent on sequence. In this condition, setup time is dependent on the current job that is being processed, and also the previous job that has been processed on that machine. In most cases these setup times are unsymmetrical. It means that the setup time from job i to j is different compared to the setup time from job j to i. Especially when the job processing is based on group technology (GT), there are sequence-dependent setup times between groups of jobs. In this paper the above mentioned condition is considered, which means sequence dependent setup times with respect to processing jobs is considered on a GT basis. GT is a management theory that its purpose is to group parts according to similarity of the production process or production characteristics (exterior shape of parts) or both of them. A lot of researchers have used GT in cell production system for scheduling jobs. In a cell production system, parts are grouped according to the similarity of production process and also the kind of machines that exist in a cell [5]. For all of parts included in one group, one setup time is considered. It means that setup time for the jobs inside one group is not considered, but it is calculated for each group. By doing this work, the total setup time decreases and system performance enhances [6].

In industrial world, nothing is certain and parameters that affect the production of a product are stochastic. In traditional methods, uncertain variables and constraints are not considered [7]. This paper studies due date as stochastic and hence stochastic modeling is applied in formulation of our problem.

Most of the real world problems include simultaneous optimization of different objectives that have conflict with each others. The final solutions show a compromise between different objectives according to the decision maker opinion. In this paper, two objectives have been considered as follows:

$$f_1 = \text{makespan}: \quad C_{max} = \max\{C_i\} \quad i = 1, 2, \ldots, n, \tag{1}$$

$$f_2 = \text{total weighted tardiness} = TWT = \sum_{i=1}^{n} W_i T_i = \sum_{i=1}^{n} W_i \max(0, C_i - d_i) \quad i = 1, 2, \ldots, n, \tag{2}$$

where n is the number of jobs.

Gupta and Darrow [8] expressed that even the (HFS) problem with sequence dependent setup time (SDST) and two machines is *NP-hard.* So, in this paper, two metaheuristic algorithms based on genetic algorithm (GA) have been used to solve the problem. These algorithms are called: Non-dominated Sorting Genetic Alghorithm (NSGAII) and Multi Objective Genetic Algorithm (MOGA). To evaluate performance of the algorithms, their results are compared with those of Multi Phase Genetic Algorithm (MPGA) used by Karimi et al. [9].

Our goal in this paper is to apply stochastic modeling to solve HFS problem with uncertain due date and sequence dependent family setup time (SDFST). The makespan and total weighted tardiness are to be optimized simultaneously. In order to obtain pareto optimal solutions, we apply two metaheuristic algorithms, NSGAII and MOGA. The paper is organized as follows: Section 2 gives the brief literature review of HFS problems. Section 3 is the problem description, mathematical model, and stochastic modeling. Section 4 gives a description of two metaheuristic algorithms based on genetic algorithm. Section 5 presents numerical results. Section 6 is devoted to conclusions and further research directions.

2. Literature review

2.1. Uncertain due date

Production environments in the real world include innumerable cases of uncertainty and stochasticity of events. Some cases are as follows: machinery breakdown, change in due date, uncertainty of process time of a job on a machine. A suitable scheduling model should consider all of the uncertainty conditions, in order to approach problems of the real world. Linn and Zhang [2] expressed that solving HFS problem that is an *NP-hard* problem, is usually difficult. The first study in the field of stochastic scheduling problems was done by Cheng [10] in single machine environment. He developed his article in 1991 and in this research, a common due date was defined for all jobs and each job has a stochastic process time with specific mean and variance. Elyasi and Salmasi [11] studied flow shop scheduling problem minimizing the expected number of tardy jobs. The authors assumed that the jobs with deterministic processing times and stochastic due dates arrive randomly to the flow shop cell. The due date of each job was assumed to be normally distributed with known mean and variance. A dynamic method was proposed for this problem by which the m machine stochastic flow shop problem was decomposed into m stochastic single machine sub-problems. Then, each sub-problem was solved as an independent stochastic single machine scheduling problem by a mathematical programming model. Kamburowski [12] examined the scheduling problem for flow shop with two machines. He considered the processing time as stochastic and assigned exponential distribution to the processing time. The objective function for this problem was minimization of the expected makespan. He extended problem with three machines [13]. The number of the researches studied the HFS together with stochastic assumptions is very limited. One of the researches in this field was studied by Rajendran and Holtheaus [14]. They studied dispatching rule in the flow shop and job shop environments while considering stochastic processing time and arrival time of jobs. Tang et al. [15] also proposed a similar problem. They considered flexible flow shop assuming stochastic arrival time of jobs. In the continuation of their work they used neural network method to select dispatching rule. Gourgand et al. [16] proposed stochastic scheduling problems in m machine flow shop with unlimited buffers. The processing time of each job on each machine is a random variable following exponentially distributed with a known rate. In order to solve the performance evaluation