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A vibration damping optimization algorithm for a parallel machines scheduling problem with sequence-independent family setup times

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ABSTRACT

Parallel machines scheduling problem is a branch of production scheduling, which is among the most difficult combinatorial optimization problems. This paper develops a meta-heuristic algorithm based on the concept of the vibration damping in mechanical vibration, called vibration damping optimization (VDO) algorithm for optimizing the identical parallel machine scheduling problem with sequence-independent family setup times. The objective function of this problem is to minimize the total weighted completion time. Furthermore, the Taguchi experimental design method is applied to set and estimate the appropriate values of the parameters required in our proposed VDO. We computationally compare the results obtained by the proposed VDO with the results of the genetic algorithm (GA) and branch-and-bound method. Consequently, the computational results validate the quality of the proposed algorithm.

1. Introduction

The main elements of machine scheduling problems are machine configuration, job characteristics, and the objective function. The machine configuration can be classified into single and multi-machine problems in a broad sense. A parallel machines scheduling problem can be referred as a class of scheduling problems that origins from the multi-machine scheduling problems [1]. Machines may be identical, uniform, or completely unrelated and have different speeds. Each job can be performed on any of the machines. The aim of this problem is to sequence a set of n jobs on m parallel machines in order to minimize the performance indicator. In parallel machines scheduling problems, jobs can be partitioned into F families ($F \geqslant 1$) according to their similarity. In this condition and when setup time constraint is considered, the problem has family setup time, in which a machine should be set up when switching from one family to others and there is no setup time between two jobs from the same family. The family setup time can be sequence-dependent or sequence-independent. It is a sequence-dependent family setup time if its duration depends on the families of both the current and the immediately preceding batches (i.e., set of jobs of the same family). It is a sequence-independent family setup time if its duration depends solely on the family of the current batch to be processed [2].

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Many researchers have studied parallel machines scheduling problems with family or non-family setup times over the last two decades. Allahverdi et al. [2] conducted a comprehensive review on these problems. To solve these problems, various approaches are presented in the literature. Some exact methods can be studied in Schutten and Leussink [3], Cheng and Kovalyov [4], Webster and Azizoglu [5], Blazewicz and Kovalyov [6], Azizoglu and Webster [7], Chen and Powell [8], Lin and Jeng [9], Dunstall and Wirth [10], Nessah et al. [11] and Shim and Kim [12].

Additionally, many studies have applied heuristic and meta-heuristic algorithms to solve parallel machines scheduling problems with family or non-family setup times. Park et al. [13] applied a neural network approach for a parallel machines scheduling problem with sequence-dependent setup times to minimize the sum of the weighted tardiness. Weng et al. [14] propounded seven heuristic algorithms for a problem of scheduling a set of independent jobs on unrelated parallel machines with job sequence-dependent setup times in such a way that the total weighted completion time is minimized. Yi and Wang [15] proposed a tabu search (TS) algorithm for minimizing the total flow time in a parallel machines scheduling problem with sequence-independent family setup times. Mendes et al. [16] addressed the parallel machine scheduling problem with sequence-dependent setup times, in which the minimization of the completion time was considered as objective function. They proposed two meta-heuristic algorithms for solving this problem. The first algorithm was a TS-based method and the second one was a memetic algorithm, which combined a population-based method with local search procedures. Eom et al. [17] presented a three-phase heuristic for parallel machines scheduling problem with sequence-dependent family setup times to minimize the total weighted tardiness. TS algorithm is used in the final phase of the algorithm. Kim et al. [18] proposed a simulated annealing (SA) algorithm for unrelated parallel machines scheduling problem with sequence-dependent setup times to minimize the total tardiness. Monch et al. [19] attempted to minimize the total weighted tardiness on parallel batch machines with incompatible job families and unequal ready times of jobs. They proposed two different decomposition approaches and applied genetic algorithm (GA) in both approaches. Abdekhodaee et al. [20] proposed greedy heuristics and a GA for solving a parallel machines scheduling problem with sequence-independent setup times where the minimization of the completion time was considered as objective function. Armentano and Filho [21] applied GRASP versions that incorporate adaptive memory principles for the problem of scheduling jobs on uniform parallel machines with sequence-dependent setup times to minimize the total tardiness related to job due dates. Logendran et al. [22] propounded six different search algorithms based on TS for minimizing the weighted tardiness of jobs in the unrelated parallel machines scheduling problem with sequence-dependent setups.

Tavakkoli-Moghaddam and Mehdizadeh [23] presented an integer linear programming (ILP) model for an identical parallel machines scheduling problem with sequence-independent family setup times that minimizes the total weighted flow time. A meta-heuristic algorithm based on GA is applied to the given problem. Tavakkoli-Moghaddam et al. [24] proposed a GA for solving bi-objective (i.e., the number of tardy jobs and the total completion time of all the jobs) unrelated parallel machines scheduling problem with sequence-dependent setup times and precedence constraints. Behnamian et al. [25] presented a hybrid meta-heuristic algorithm to minimize the completion time in scheduling problems with parallel machines and sequence-dependent setup times and comprised three components, namely an initial population generation method based on an ant colony optimization (ACO), SA for solution evolution, and a variable neighborhood search (VNS) involving three local search procedures to improve the population. Driessel and Monsh [26] presented VNS approaches for scheduling jobs on parallel machines with sequence-dependent setup times, precedence constraints and ready times to minimize the total weighted tardiness. Chang and Chen [27] addressed the parallel machines scheduling problem with machine-dependent and sequence-dependent setup times where the minimization of the completion time was considered as objective function. They propounded a set of dominance properties including inter-machine (i.e., adjacent and non-adjacent interchange) and intra-machine switching properties as necessary conditions of job sequencing orders in an optimal schedule. In addition, a new meta-heuristic algorithm was introduced by integrating the dominance properties with GA to further improve the solution quality for larger problems. Vallada and Ruiz [28] presented a genetic algorithm for the unrelated parallel machine scheduling problem in which machine and job sequence dependent setup times are considered. The proposed genetic algorithm includes a fast local search and a local search enhanced crossover operator. Sarıcicek and Celik [29] proposed tabu search (TS) and simulated annealing (SA) meta-heuristics for identical parallel machine scheduling problem with the aim of minimizing the total tardiness of the jobs considering a job splitting property. Li et al. [30] presented a simulated annealing algorithm, named LPDT-SA for solving uniform parallel machine scheduling problem which is to minimize the maximum lateness. A heuristic algorithm LPDT is built to generate initial solutions. Lin et al. [31] considered an ant colony optimization (ACO) algorithm incorporating a number of new ideas (heuristic initial solution, machine reselection step, and local search procedure) to solve the problem of scheduling unrelated parallel machines to minimize total weighted tardiness. Ruiz-Torres et al. [32] propounded a set of list scheduling algorithms and simulated annealing meta-heuristics to solve a new unrelated parallel machine scheduling problem with deteriorating effect and the objective of makespan minimization. Wang et al. [33] investigated into the parallel machine scheduling problem with splitting jobs and objective of makespan minimization. Differential evolution was employed as a solution approach due to its distinctive feature, and a new crossover method and a new mutation method was brought forward in the global search procedure, according to the job splitting constraint. A specific local search method was further designed to gain a better performance, based on the analytical result from the single product problem.

In this paper, we study the identical parallel machines scheduling problem with sequence-independent family setup times. The objective function of this problem is to minimize the total weighted completion time. This problem is noted by three fields as $P/ST_{si,b}/\sum W_iC_i$ where these fields describe the shop environment (i.e., P = parallel machines), setup time