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Parallel machines scheduling with machine preference via agent-based approach

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ABSTRACT

This paper deals with parallel machines scheduling for electro-etching in the manufacturing processes of aluminum foil. Due to the attributes of the machines and the fitness of jobs to each, the processing time and setup time for a job depends on the machine on which the job is processed. In this paper, the application of agent-based multi-negotiation mechanism is developed for this manufacturing environment and for further scheduling uncertainty research. To support the dynamic negotiation mechanism between jobs and machines, three categories of agents are currently employed by the system. They are job agents, machine agents and supervisor agent. To establish job allocations, job agents and machine agents have to bid interactively in accordance with the decision model embedded in. Supervisor agent is designed to manage negotiation process between job agents and machine agents to ensure the global bi-objective of system are being observed. Experiments were conducted to evaluate the performance of the proposed architecture. Computational experiences demonstrate that the proposed architecture can work more efficiently and is capable of obtaining better solutions to the heuristic based on earliest-due-date rule applied by enterprise practice on case company.

1. Introduction

This paper deals with a scheduling problem of the electro-etching in the manufacturing processes of aluminum foil. There are seven main steps that often included in the manufacturing processes of aluminum foil and the electro-etching is the critical step. The equipments for electro-etching are classified into three grade specialized equipments used to produce three grades' products such as high voltage, medium voltage, or low voltage aluminum foil. For convenience, this paper views the equipment for producing high, medium, and low voltage aluminum foil as the first, second, and third grade equipments, respectively. Due to the product's physical characteristic and specification, each grade product has its 'preference' machine which possesses the fittest operation condition [1].

In industrial practice, in addition to the third grade equipments, the first and second grade ones can be used to produce the first (high voltage) and second (medium voltage) grade products alternatively. However, when product is not processed on its preferred machines, longer processing time is required. Furthermore, a longer setup time is incurred in the electro-etching process whenever there is a changeover from a job in one grade to another job in different grade. To reduce the setup time, the jobs in same grade are scheduled to process successively. However, scheduling all the same grade jobs to

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process successively may cause inventory increase and job tardiness, and hence there is a trade-off between grouping and splitting jobs in the same grade.

Because of the incompatibility of the third grade equipment, it can merely process the third grade job. This paper focuses on the scheduling of the first and second grade equipments. The addressed problem can be classified as a scheduling problem of parallel-machine and its choices of eligibility.

Parallel machines scheduling problems with jobs sequence-dependent setup time have been reviewed in Allahverdi et al. [2]. This kind of scheduling problems are generally NP-hard/NP-complete, i.e. it is unlikely to find an optimal solution without the use of an essentially enumerative algorithm and computational time increases exponentially with problem size [3–5]. As machine eligibility constraint is considered, the solutions are even more complicated.

Over the last two decades, a concerted effort has been directed at a variety of parallel-machine scheduling problems by many workers [6]. The application of agent-based systems based on the concept of distributed artificial intelligence paves a novel way of thinking about many complex systems and overcoming the complexity problem. Zhang et al. [7], Usher [8], and Wong et al. [9,10] present multi-agent system to develop integrated process planning and scheduling in job shop. The computational results show that the performance is significant superiority.

In this paper, considering the industrial practice and further requirement of solving scheduling uncertainty problems such as the situation of unexpected machine failure and urgent order, an agent-based multi-negotiation mechanism (AMN) was constructed to deal with parallel machines scheduling with preference of machine. The multi-agent system is developed based on the JADE (Java Agent DEvelopment framework) platform [11]. In the proposed AMN, three categories of agents are currently employed by the system. They are job agents, machine agents and supervisor agent. Each job/machine has a corresponding job/machine agent. And supervisor agent was added to manage negotiation process between job agents and machine agents. To support the dynamic negotiation mechanism between jobs and machines, a communication protocol based on FIPA (Foundation for Intelligent Physical Agent) ACL (agent communication language) message [12] is developed for negotiation between job agents and machine agents to ensure the better global bi-objectives can be reached.

In order to establish job allocations, job agents and machine agents have to bid interactively round by round in accordance with the decision model embedded in each agent. When all jobs are assigned to machines, the supervisor agent will record the parameters, job sequence for each machine, and process data, and the single job–machine-matching process is done.

This paper also constructs multi-negotiation mechanism to overcome the correlation existing between bi-objective. Eventually, the supervisor agent will save the Pareto optimal solutions and compare with those of the heuristic adopted by the case company.

In the remainder of the paper, we briefly mention a number of existing algorithms in solving parallel machines scheduling problems and agent-based approach applications in Section 2. Thereafter, in Section 3, the considered problem applied in real enterprise practice is described. Section 4 presents the proposed agent-based multi-negotiation approach in details. The next section constructs the experiments and compares the results with those of the scheduling algorithms applied in case company. Finally, the conclusions of this paper are outlined.

2. Related works

2.1. Parallel-machine scheduling problems

Recently, a great deal of meta-heuristic has been proposed to solve practical parallel machines scheduling problems [6]. These methods are all centralized approaches that assign each job to a machine and make a sequence [13].

A recent survey of the literature on parallel machines scheduling problems can be found in Mokotoff [14], Cheng and Sin [15], and Pfund et al. [16]. Most researches on parallel machines scheduling assume that a job can be processed on any machine. The machines can be identical, uniform, or unrelated. Identical machines have the same speed for all jobs; uniform machines have different speeds which are independent of jobs; unrelated machines have different speeds which are dependent on jobs.

Omar and Teo [17] developed an improved mixed integer programming (MIP) model to solve the sum of earliness/tardiness in identical parallel machines with incompatible job families. The model provided optimal solutions for up to 18 jobs that originate from up to four families. Eren [18] and Xu et al. [19] proposed MIP models to solve minimizing maximum lateness in identical parallel-machine scheduling problem with a learning effect. Wang and Wei [20] considered identical parallel-machine scheduling problems with a deteriorating maintenance activity. In the problem, each machine has a rate-modifying maintenance activity and two objectives separately to be solved by binary integer programming (BIP) models.

Dunstall and Wirth [3] studied the identical parallel machines with independent setup time. The paper proposed several efficient branch-and-bound algorithms to minimize total weighted completion time. It is able to solve problems with up to 25 jobs and eight families. For solving larger problems, Dunstall and Wirth [21] also developed effective heuristics to solve the same problems.

Weng et al. [22] proposed seven heuristics for unrelated parallel machines. Chen and Wu [4] proposed a heuristic based on threshold accepting methods and Tabu lists and the performance is better than an existed SA method.

As for the problem related to the presence of machine eligibility on parallel machines, where a job can only be processed on a subset of the parallel machines, Chuang et al. [1] has done on parallel machines with longer processing time required when jobs are not processed on their preferred machines. The scheduling problem described in Chuang et al. [1]