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Evolutionary algorithm for advanced process planning and scheduling in a multi-plant☆

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Abstract

Integration of process planning and scheduling is one of the most important functions to support flexible planning in a multi-plant. The planning and scheduling are actually interrelated and should be solved simultaneously. In this paper, we propose an advanced process planning and scheduling model for the multi-plant. The objective of the model is to decide the schedules for minimizing makespan and operation sequences with machine selections considering precedence constraints, flexible sequences, and alternative machines. The problem is formulated as a mathematical model, and an evolutionary algorithm is developed to solve the model. Numerous experiments are carried out to demonstrate the efficiency of the proposed approach.

Keywords: Process planning and scheduling; Multi-plant chain; TSP with precedence constraint; Evolutionary algorithm

1. Introduction

Many manufacturers now try to optimize the total system to cope with a global manufacturing. This trend brings the idea of supply chain, which is to optimize not only the plant operations but also the whole activities from a supplier to a customer. As a result, manufacturing companies nowadays are migrating from separated planning processes toward the more coordinated and integrated planning processes to provide high quality products at lower cost.

Integration of process planning and scheduling is one of the most important problems for supporting the total optimization. The two functions are interrelated because both of them take part in the assignment of factory machines to production tasks. Hence, the actual process planning and scheduling

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problem should be solved concurrently, but the problem has more complexities due to the alternative machines and alternative operations sequences. We define the problem as an advanced process planning and scheduling problem (APPS). Therefore, the APPS should focus upon the following issues: (1) How to make a flexible process plan considering shop floor status and design information? (2) How to make an efficient schedule considering the job shop's dynamic situations and the complexity of the machine constraints? (3) How to make an appropriate integrated model which includes various constraints?

In the traditional approaches, process planning and scheduling are done sequentially, where the process plan is determined before the actual scheduling is performed. But, this simple approach ignores the relationship between scheduling and process planning.

Recently, some research results for the integrated process planning and scheduling are presented. Tan (2000) presents a review of the research in the process planning and scheduling area and discusses the extent of applicability of various approaches. Hankins, Wysk, and Fox (1984) discuss the advantages of using alternative operations sequences to improve the productivity of the shop floor. They show that the efficient planning considering the alternative machines results in reduced lead-time and in improved overall machine utilization. Nasr and Elsayed (1990) present two heuristics to determine an efficient schedule for the n jobs, m machines problem with alternative machine routings for each operation. The objective they adopted is to minimize the mean flow time. Palmer (1996) and Sundaram and Fu (1988) solve the IPPS problem using a simulated annealing. Brandimarte and Calderini (1995) develop a two-phase hierarchical tabu search. Saygin and Kilic (1999) propose a frame for IPPS with the objective of reducing the completion time. To solve the problem, a heuristic method is proposed. Morad and Zalzala (1999) develop an evolutionary algorithm (EA)-based method to tackle the IPPS problem.

However, the major weakness of the models so far introduced lies in that they consider the alternative machines for each operation with a fixed sequence or the non-constraint operational sequence when constructing a schedule. In this paper, we consider an APPS problem for a multi-plant composed of a network of production facilities, and of multiple products flow through manufacturers. The multi-plant means extending the integration concept beyond on production site by means of stronger distribution management capabilities, electronic data interchange, and coordinated multiple plant management. We develop a model incorporating the alternative machines in the chain. The alternative machines have different capabilities and require unequal processing time for an operation. The operations sequences for each job include precedence constraints. In order to obtain good approximate solutions, we develop an EA-based heuristic approach.

2. Problem definition

In a customized manufacturing environment, most jobs have a different sequence of operation steps and may have a set of alternative process plans. Fig. 1 shows an example of the general structure of the network for a customized manufacturing. This kind of structure is common in heavy industries, e.g. turbine manufacturing, generator manufacturing, and ship engine manufacturing. The production cycle in this chain consists of three main units: with the supplier, raw materials are transformed into specified workpieces; with the manufacturers, machining processes—drilling, milling, boring and grinding—are executed to remove pieces of the workpiece; and with the assembler, final products are produced. Among the units of supply chain in Fig. 1, the manufacturer plays the main role because it is a bottleneck unit. Therefore, the manufacturer unit is usually represented as a network of plants.