Chapter 4.5
Piece–Mold–Machine Manufacturing Planning

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ABSTRACT

This chapter studies a manufacturing process of pieces. These pieces are produced with molds which are mounted on machines. The authors describe this process as an optimization problem using an integer linear programming formulation which integrates the most important features of the system, and determines the quantities of pieces to produce, including the allocation of molds to machines. The objective function is to maximize the weighted production since the authors seek to minimize the non-fulfilled demand. First they show that the addressed problem belongs to the NP-hard class. After observing that solving the problem in an exact way is time consuming, they propose a solution methodology based on an Iterated Local Search Algorithm. Through computational experimentation they make conclusions about the difficulty of the decisions determined in this manufacturing planning.

INTRODUCTION

Automated planning is a branch of artificial intelligence which deals with the computation of the best strategies of action sequences, typically for execution by machines or robots (Russell & Norvig, 2003). In general, the automated planning solutions are complex, combinatory and have to be searched in a multidimensional space. Solutions usually resort to iterative trial and error processes commonly seen in artificial intelligence as the Iterated Local Search metaheuristic that we implement in this work.

More precisely, this chapter examines a real manufacturing system with molds and machines requirements for the production of pieces. These characteristics include, for example, plastic injection systems. Such an enterprise has a certain

demand of pieces to fulfill. To produce a piece on a machine it is necessary to use a mold, and if it is decided to produce another type of piece in that machine with the same mold, a preprocessing time or setup time should be considered. This setup can reflect, for example, a change of color. Furthermore, each mold can make a certain number of pieces with a certain production rate. As for the type of pieces, molds changes involve a setup time (usually larger than for the pieces). In addition, there are limitations on the machines with molds with which to work, besides having a certain time availability. As a manufacturing process with these requirements increases (e.g., more types of pieces to produce, more molds, or more machines), one loses the ability to identify the type of pieces, and the quantities to produce as well as the optimal allocation of molds to machines. It is then important to implement formulations and solution methods to meet the planned objectives.

We consider the objective of maximizing the weighted fulfilled demand. Indeed, when a company fails to meet its demand, it is often forced to buy products to other companies so as not to lose customers. The objective function we propose deals with this issue since it can be viewed as minimizing the weighted non-fulfilled demand. Thus, the pieces to buy to other companies will be, less expensive.

With this chapter we show that the decisions of production flow (the type of pieces and the quantities to produce) is simple to operate, while the piece-mold assignments are mostly affecting the complexity of the problem. In Section 2, the characteristics of the system are presented together with some related scientific literature. To the best of our knowledge, there is not yet a model for this type of system. In Section 3, the problem is modeled by an integer lineal programming formulation covering most of the features present in these types of manufacturing processes. In Section 3.2 we prove that the studied problem belongs to the NP-hard class. Given the complexity of the problem and the computational time used to exactly

solve large instances, we propose in Section 4 an Iterated Local Search algorithm to obtain "good" solutions in a short computational time. In Section 5 we present computational results obtained by the proposed methodology on random instances cases based on real data.

RELATED RESEARCH

Scheduling problems often consider setup times between the executions of different type of jobs (in our problem jobs can be considered as a type of piece). Moreover, there are cases where the setup times depend, besides the previous scheduled task, on the task to be executed. These are known as sequence dependent setup times (s_{ij} denotes the setup time between job i and job j). The latter is our case, where the change of type of piece to produce, induces a setup time. Scheduling problems with sequence-dependent setup times are, generally NP-hard (Brucker, 2001) and there exist several solution methods. However, these methodologies are focused on the single machine case (Eren, 2007; Eren & Güner, 2005; Sourd, 2006; Stecco, Cordeau, & Moretti, 2008). We can particularly cite Lou and Chu (2006) who worked in the minimization of the total tardiness scheduling problem on a single machine and sequence-dependent setup times. By using a branch and bound method (B&B) based on permutation schemes, they find exact solutions within reasonable time. This scheduling problem has the characteristic of being non preemptive which prevents a task to be interrupted during its execution. This assumption is not consistent with the characteristics of our problem, besides the use of a single machine.

Generally the articles dealing with the parallel machine case and setup times (Shim & Kim, 2006; Weng, Lu, & Ren, 2001) do not considered the use of an auxiliary equipment such as molds. Shim and Kim (2006) propose a B&B method for minimizing total tardiness where jobs are broken

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