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SOLVING THE COMBINED PART SEQUENCING AND TOOL REPLACEMENT PROBLEM FOR AN AUTOMATED MACHINING CENTER: A TABU SEARCH APPROACH

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Abstract—This paper addresses a joint part sequencing and tool replacement problem on an automated machining center. The objective is to minimize the *expected* production cost subject to available spare tools. In the literature, it has been shown that the sequencing problems with sequence-dependent setups are equivalent to the "travelling salesman problem" (TSP) and thus are NP-complete. The problem under consideration is further complicated by the *position-dependent* cost components associated with tool replacement decisions. To provide an efficient planning tool for shop floor decision making, a tabu search approach is proposed. The application of the proposed approach is demonstrated using an example problem. Our computational experience shows that good solutions can be found within a relatively short search time. The impact of tool spare level on the performance of the machining center is also examined. Finally, the effects of tabu-list size and path diversification are discussed.

1. INTRODUCTION

Automated machining centers have been widely used over the years. The popularity of machining centers is mostly due to their high flexibility and efficiency in processing a range of operations of various parts. An automated machining centre, however, represents heavy capital investment, which can be justified only when the machining center is effectively operated. Operational decisions such as part sequencing and tool replacement have significant impact on operation effectiveness.

Single machine sequencing problem has been addressed by a number of researchers (e.g. [12, 15, 16, 18]). For an automated machining centre, the problem is more complex due to tooling decisions and tool magazine capacity constraint. As indicated by Bard [1], "Although the single machine scheduling problem has been studied extensively, the added complication of tool loading undermines the usefulness of much of the current results". Having identified the importance of tooling, Bard [1] suggested a heuristic which sequences jobs with an objective of minimizing the total number of tool switches. Along this line, several notable studies are recently reported [10, 11, 17]. However, an important issue which, to the best of our knowledge, has not yet been addressed in the literature pertinent to sequencing is the tool replacement problem. In the literature, tool replacement has been specified as a problem of determining optimal time for tool changes due to tool wear or breakage [9, 20]. Although Bard [1] and Tang and Denardo [17] used the term "tool replacement", it was used to address different issues. In Bard's paper, "tool replacement" appears to be equivalent to the tool switch required by job changes. While in the context of Tang and Denardo [17], tool replacement is regarded as a problem of determining a set of tools to be placed on a machine for a fixed job sequence. Random tool failures, especially in-process failures, are not considered. Some important issues, such as the expected defective part cost, the effect of tool spare level on total expected production cost, and the feasibility of the tool provisioning decision made in the machine loading stage (if the machining center is a part of a flexible manufacturing system), can be precisely investigated only when a tool replacement decision is incorporated. Therefore, sequencing jobs without considering tool replacement is not adequate.

Studies of tool replacement are extensive. However, most of the studies, with the possible exception of Billatos and Kendall [3], are limited to single-tool-type and single-part-type problems.