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ANALYSIS OF PART SEQUENCING AND TOOL REPLACEMENT FOR AN AUTOMATED MACHINING CENTER

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ABSTRACT

This paper addresses a joint part sequencing and tool replacement problem on a machining center. The objective is to minimize the *expected* production cost subject to available tool spares. In 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. In the problem under consideration, the cost components associated with tool replacement and defective parts are *position-dependent*. That is, even if the precedence order of a pair of adjacent parts is fixed, their associated tool replacement cost and defective part cost may be different if their position relative to other parts in the sequence is changed. This, coupled with the sequence-dependent setups, precludes optimal solutions for any meaningful sized problems. To provide quick and reasonably good solutions, we propose a 'nearest neighbour heuristic' (NNH). The efficiency of the NNH algorithm is demonstrated with an example problem. The effects of tool spare level on the expected production cost are also 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 for various parts. An automated machining center, 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.

In literature, the problem of part or job sequencing has been addressed by a number of researchers (e.g., [5,10]). For an automated machining center, the problem is more complex due to the 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 the much of the current results". Having identified the importance of tooling, Bard [1] suggested a heuristic which sequences jobs with an objective of minimizin ; total number of tool switches. Along this line, several notable studies are recently reported [7,9,11]. 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. It is noticed that the term "tool replacement" has been used in [1,11]. However, "tool replacement" in [11] is defined as a problem of determining the set of tools to be placed on the machine for a fixed job sequence. While in the context of [1], "tool replacement" appears to be equivalent to the tool switch required due to job change. Random tool failures, especially in-process failures, are not considered. Some important issues, such as expected defective part cost, the effect of tool spare level on total expected production cost, the feasibility of the tool provisioning decision made in machine loading stage (if the machining center is a part of a flexible manufacturing system), can be investigated only when tool replacement decision is accommodated. Therefore, sequencing jobs without considering tool replacement is not adequate.

Studies on tool replacement are extensive (e.g., [2,4,6]). However, most of the studies, with the possible exception of [2], are limited to single-tool (type) and single-job problems. Billatos and Kendall [2] are probably the first who investigated the tool replacement problem for multi-tool and multi-job systems. However, since their focus was on the optimization of machining condition, the job sequence in their paper was assumed to be known and

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