Tool Requirements Planning in a Flexible Manufacturing System with an Automatic Tool Transporter

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Abstract

A flexible manufacturing system (FMS) can be defined as an automated manufacturing system, which consists of multi-functional machines that can be numerically controlled, an automated material handling system, and all controlled by a computer. There are two types of FMSs, part-movement systems and tool-movement systems. In part-movement FMSs, parts are moved among the machines to have their operations processed, after operations are allocated to the machines and tools for operations are loaded on the tool magazines. Here, routes of the parts are determined by the operation allocation decisions. In these systems, once a tool is loaded onto a tool magazine, the tool is not removed from the tool magazine until the next tool changeover time unless it is broken or worn out. On the contrary, in tool-movement FMSs, each part visits only one machine for its entire processing. That is, a part is not moved among the machines once it is released into the FMS and loaded on a machine. Instead of the parts, tools are moved among the machines. If some tools required for a part are not loaded on the tool magazine of the machine on which the part is loaded, they are borrowed from other machines or transported from the tool crib. Tool-movement FMSs have potential advantages over part-movement FMSs, in that the number of tools needed in the system is usually smaller and there is no need to reposition workpieces or recalibrate the position of the tool head, which may deteriorate cutting precision.

Because of characteristics of tool movement systems, tools must be moved frequently, which may cause tool delay. Tool delay time consists of tool transportation time and tool waiting time.

Tool transportation time is time required to bring a tool from a machine (or the tool crib) to an other machine (or the tool crib), while tool waiting time is time that a machine must wait until a tool of required tool type becomes available. When more than one machine require the same tool type at the same time, tool waiting time occurs. In most systems, tool transportation time is very shorter than part processing time and tool waiting time. Therefore, it is important to minimize tool delay for better system performance. Tool waiting time, which accounts for most part of tool delay time, is largely affected by tool availability, and tool availability is affected by the number of copies for each tool type in an FMS, called the tool copy configuration. Consequently, for better system performance, a tool copy configuration should be determined carefully.

In this paper, we consider tool requirements planning problems in a flexible manufacturing system with an automatic tool transporter. Tool requirements planning problem (TRPP) is the problem of the determining the number of tool copies maintained within an FMS. We solve two problems, defined by two different objectives, i.e. the problems of determining the number of tool copies of each tool type with the objective of minimizing total tool purchase cost for a given makespan constraint, and with the objective of minimizing total tardiness for a limited budget. For the problems, several heuristic algorithms are developed in this paper. Suggested algorithms are composed of two parts, optimization through local search and evaluation of alternatives through simulation. Results of computational experiments done on randomly generated test problems show that the heuristic algorithms work better than an algorithm that is modified from an existing algorithm for a similar problem.