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SCIENCE DIRECT

Computers & Industrial Engineering 45 (2003) 61–73

computers & industrial engineering

www.elsevier.com/locate/dsw

Operation sequence and tool selection in flexible manufacturing systems under dynamic tool allocation

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Accepted 4 February 2003

Abstract

In order to adapt to a rapid changes of manufacturing orders, flexible manufacturing systems (FMS) advances into the direction that machines become further versatile functionally and that tools are controlled by fast tool delivery device. Versatile machine can perform a variety of operations when it is supplied with the required tools. Tool management is among the essential elements in the successful operation of the FMS studied in this research. In this research, we propose an integrated model that performs operation sequence and tool selection simultaneously into the direction that minimizes tool waiting time when the tool is absent. The effectiveness of the model is demonstrated through a series of simulation experiments, and interpretations of the results are also presented.

Keywords: Dynamic tool allocation strategy; Tool movement; Tool waiting time; Operation sequence

1. Introduction

To cope with manufacturing orders which are characterized by varieties of products, high quality and short production lead time, a recent trend in flexible manufacturing systems (FMS) is to utilize versatile machines with fast tool delivery devices. Because versatile machine can perform a variety of operations when it is supplied with the required tools, tool management is critical for smooth flow of tools in this

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0360-8352/03/$ - see front matter
doi:10.1016/S0360-8352(03)00019-6

FMS (Amoko, Meredith, & Raturi, 1992; Koo, 1993; Lee, Kim, & Rho, 1999). Also, one important tool-related issue that has not been adequately addressed in FMS literature is planning for the tool's availability (Chung, 1991).

The tool allocation for FMS can be divided into two categories: static (Cuppan, 1986; Hankins & Rovito, 1984; Mason, 1986) and dynamic (Gaalman, Nawjin, & Platzer, 1987; Zeleny, 1981). In the static tool allocation, tools are assigned to the machines at the beginning of a planning horizon or a production batch, and the assigned tools remain unchanged during the period or the processing of the batch. With a dynamic tool allocation, the assignment of tools is not necessary at the beginning since tools are delivered when they are needed, and therefore, parts remain on the same machine until the required machining is completed. This strategy is possible when the system is equipped with fast tool delivery devices and an efficient tool control model.

There are two major entities of material flow in manufacturing systems: parts and tools. The former was called part movement and the latter tool movement. Traditionally, tools are assigned to a limited set of machines and parts follow a rigid route because of the static tool allocation (part movement policy). Even in systems with highly versatile machine, a part on a machine is often moved to another machine after an operation is finished, because the required tools may not be available. The conventional way of solving this problem is to increase the capacity of tool magazines and allocate as many tools to the tool magazines as possible. This approach, however, requires very high tool inventory and tooling cost. In addition, the capacity of the tool magazines cannot be increased beyond modification of its design. To keep high flexibility with low tooling cost, the idea of dynamic tool allocation has been introduced (Gaalman et al., 1987; Zeleny, 1981). Technological evolution in tool handling systems and shop floor information systems allows the tools to be dynamically shared by machines. Dynamic tool allocation virtually increases the capacity of tool magazines, and eliminates the need of moving the parts from machine to machine in searching for the tools. Once a part is loaded on a machine, all its operations can be performed on the machine without part movement. In the manufacturing systems of this type, a part visits only one machine and its required tools are delivered in time of requirements. This flow concept is completely inverted from part movement in conventional manufacturing systems: tools travel around the machines while parts stay on a machine (tool movement policy (Grieco, Semararo, Tolio, & Toma, 1995)). When the required tool is unavailable under tool movement policy, part is waiting on a machine until the required tool is available. This waiting time is tool waiting time. The tool waiting time can occur because of absence of the required tool. Therefore for high system performance under dynamic tool allocation, minimizing tool waiting time is critical.

This paper proposes operation sequence and tool selection to minimize tool waiting time. As the related research Grieco et al. (1995), proved that, when a system adopted a dynamic tool allocation strategy with a smaller number of tools, the same level of tool idle time could be maintained as for the same FMS possessing a larger number of tools and operating under a static strategy. Koo (1996) proposed a part release model that used a forecast of the degree of competition in the use of tools between the part to be loaded (candidate) and loaded parts in the system under dynamic tool allocation. In their studies, decision point of tool selection is after finishing an operation by a tool. If decision point shifts just after machining a part, tool waiting time is further minimized by changing operation sequence. In this research, we propose an integrated model that performs operation sequence and tool selection simultaneously in the direction that minimizes tool waiting time by considering schedules of tools under dynamic tool allocation strategy.