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Loading of pallets on identical CNC machines with cyclic schedules

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Abstract

Flexible manufacturing systems (FMS) are generally set up to process a wide variety of parts with low to medium volume demand. The loading problem in FMS is a short-term decision issue, which addresses the simultaneous processing of a set of different parts in an efficient manner on capital-intensive resources. This study focuses on cyclic schedules in loading pallets carrying groups of identical parts to CNC machining centers. A predefined stream of pallets fixtured for different part types is repeatedly supplied to every CNC machine in cycles. Moreover, a limited number of pallets have to be shared among the cycles of machines to keep utilization and the overall throughput rate at acceptably high levels. The solution approach is an integrated mix of optimization and simulation methodologies. The validation of the model is based on data from past 6 months of operation. Comparisons are made retrospectively. © 2002 Elsevier Science Ltd. All rights reserved.

Keywords: Flexible manufacturing systems; Loading; Mathematical programming; Simulation; Cyclic schedule

1. Introduction

Flexible manufacturing systems (FMS) is a manufacturing environment which consists of a group of numerically controlled (NC) machines connected by an automated materials handling all systems under computer control. Such arrangements are set up to process a wide variety of parts especially with low to medium volume of demand. FMS gives maximum flexibility and efficiency for production of different parts together. Shared usage of resources is commonplace to achieve such advantages. Pooling identical machines in a group and providing multiple operation/tool loading support effective ways of allowing alternate part routing practices. However, as an automated manufacturing system involves simultaneous

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machining of various part types with the availability of multiple routes for each, planning for and implementing shop procedures to support these operations become a complex task.

The difficulty is not only caused by the need to consider all parts simultaneously, but by the nature of flexible automation. System components (machines, fixturing and defixturing stations, material handling equipment, tooling, etc.) are highly integrated in their operation hence congestion or a delay in one causes starvation or waiting in others. Moreover, due to the high level of automation, to relieve the system off problems human interference is kept to a minimum. Hence operations have to be planned with much care and in advance to define a structured, programmed course of part processing. Thus the planning and scheduling literature for flexible manufacturing is plentiful. Chen and Chung (1996), for example, suggest an integrated approach, incorporating *batching* of different part types for simultaneous processing, *loading* of parts on multiple machines subject to tooling restrictions on each, *routing* decisions to achieve a feasible flow of parts among the loaded machines and *dispatching* to choose a particular part type from among those waiting to be processed next on a CNC machine. Operational planning issues for FMS have also been taken in isolation. The following are typical examples in this regard. Stecke (1985) suggests the use of production ratios for simultaneous manufacturing of different part types, fixed routing versus alternative routing practices are examined in Maimon and Gershwin (1988), on line and off line dispatching are discussed in Chang, Sullivan, and Bagchi (1985) and Yamatomo and Nof (1985).

Planning for flexible systems in well defined repetitive cycles has raised some interest especially in operating robotic cells, such as in Logendran and Sriskandarajah (1996) and Blazewicz and Finke (1994). Cyclic schemes have also been addressed in AGV and AS/RS operations as retrieval and handling speeds have improved and as work-in-process (WIP) inventory carrying became much undesired, such as in Kise, Shioyama, and Ibaraki (1991) and Kogan and Levner (1997).

2. The manufacturing cell and cyclic schedules

We address integrating operational planning issues in a flexible manufacturing and cyclic routing practices in automated systems in a coherent manner in operating the flexible manufacturing cell of an automotive manufacturer. Thus the two trends mentioned earlier, coherent planning and cyclic schemes are somehow combined. The flexible manufacturing cell receives monthly work orders at the beginning of every month. However, modifications to order quantities throughout the month are not unusual. Past experience has shown that not more than one fourth of the monthly work order transactions get a modification before the end of the month. The cell is located next to a conventional job shop and consists of four identical CNC machining centers served by an automated stacker. Pallets are the units of load. They carry fixtures having one or more copies of the same part type fixture. Little uncertainty exists in processing and process time per pallet which is between 5 and 45 min depending on the standard machining needs of part types. Processed parts are defixtured from their fixtures and blanks of the same part are fixtured for the next round unless a month's order is completed. Some part types require machining in multiple passes and hence their defixturing is followed by fixturing the semi-finished form. Two identical defixture/fixture stations work in parallel on all part types. Pallets carrying blanks are stored in a waiting line for later loading by the stacker. Fig. 1 show the layout and shows an instance where CNCs 2 and 3 are processing their pallet loads, and the stacker is engaged in fetching an identically fixtured pallet as that being processed on CNC 3, from the waiting line.