A CONWIP model for FMS control

W. H. IP,1 K. L. YUNG,1 MIN HUANG1 and DINGWEI WANG2

1Department of Industrial and Systems Engineering, The Hong Kong Polytechnic University, Kowloon, Hong Kong
2Box 135, College of Information Science and Engineering, Northeastern University, Shenyang, Liaoning, 110006, P.R. China

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Production inventory control is one of the most important aspects of a flexible manufacturing system (FMS) design. CONstant Work In Process (CONWIP), which is a hybrid of push-and-pull type systems, offers an alternative to effective utilization of the expensive FMS equipment while still meeting customer requirements. In the selection of an FMS control method, material handling often becomes one of the capacity constraints which forms the basis of various research interests. In this paper, a structure-based model for a CONWIP-controlled FMS is proposed, and within it, the node type characteristics concept is used to describe the constraints in FMS. Furthermore, simulation is used to determine the card number based on the structure-based model. The simulation results demonstrate that the model is suitable for the design and operation of FMS. The model can be used as a manufacturing execution system of enterprise resources planning. An architecture for this integrated design based on Internet/Intranet systems is also proposed.

Keywords: FMS, production inventory control system, CONWIP, simulation, ERP, MES

1. Introduction

A flexible manufacturing system (FMS) is designed to combine the efficiency of a mass-production line and the flexibility of a job shop to produce a variety of workpieces on a group of machines and other workstations connected by an automated material handling system. The overall system is under computer control (Kazerooni et al., 1997; Košturnjak and Gregor, 1998). An FMS operates in a large variety of medium-volume production environments and is usually designed to produce a variety of high-precision parts and products. There are many issues associated with the design of an FMS. Production control is one of the most important aspects of FMS operations.

Effective production control systems are those that produce the right parts, at the right time, at a competitive cost. Production control systems can generally be divided into push systems and pull systems (Spearman et al., 1990; Gaury et al., 2000).

The best known push systems are materials requirements planning (MRP) and its successor manufacturing resources planning (MRP-II) and enterprise resources planning (ERP) (Kusiak, 2000; Rao, 2000; Holland and Light, 1999), developed in Western countries. The best known pull system is Kanban (Sugimori et al., 1977), CONstant Work In Process (CONWIP) (Spearman et al., 1990) and DBR (drum buffer rope) (Goldratt and Fox, 1986).

In a push system, production is controlled by a central planning system, that takes load forecasts as future demands. Production is initiated before the occurrence of demand, otherwise the goods cannot be delivered on time. Therefore, the production lead times have to be known or approximated.

In a pull system, production is triggered by the volume of actual demand. The production is controlled by a decentralized control system. To avoid long waiting times for customers, parts and finished products must be stored in buffers (Gstettner and Kuhn, 1996; Wang et al., 1996).
Both push systems and pull systems have different advantages and disadvantages, as has been pointed out by many researchers (Spearman et al., 1990; Delersnyder et al., 1989; Sarker and Fitzsimmons, 1989). For FMS, the most important thing is to choose a suitable strategy. MRP control ensures a high machinery utilization, but it results in high inventory and longer cycle times (Ján and Milan, 1998). Kanban is intrinsically a system for repetitive manufacturing (Hall, 1981), which is generally not the case in FMS. DBR must have a deterministic bottleneck and this is also impossible for FMS. Therefore, CONWIP being a hybrid is a suitable alternative control system for FMS.

In the FMS, a conveyor system is usually used, and this causes capacity constraints which are more complicated than the problems experienced in the job shop and transfer lines. There has been much research devoted to CONWIP (Herer and Masin, 1997; Leu, 2000; Bonvik et al., 2000), however, none of this has been concerned with the constraints in the production line.

The global market has a profound effect upon manufacturing. The move away from nationally focused business units to a global product-market focus requires an effective international co-ordination of a firm’s activities. To support a global outlook, many firms are implementing ERP systems (Pták, 2000; Gupta, 2000; Rao, 2000). Therefore, how to integrate FMS production control with other parts of ERP is becoming a key problem in manufacturing.

In this paper, a structure-based model for a CONWIP-controlled FMS is proposed. The concept of node type characteristic (NTC) is addressed to describe the constraints of FMS and simulation is used to determine the card number based on the structure-based model. The simulation results demonstrate that the model is suitable for the design of FMS. The proposed model can be used as a manufacturing execution system (MES) (Feng, 2000) of ERP. An architecture for this system based on Internet/Intranet applications is also investigated.

In the following section, the FMS model is explained first, then a structure-based model with NTC conception is proposed to describe the constraints of FMS and the CONWIP control of FMS in Section 3. The simulation analysis is given to determine the card number of CONWIP where the influence of the variant of process time is considered in Section 4. The simulation results demonstrate that the model is suitable for the flexibility of FMS. The proposed model can be used for the MES of ERP. An architecture for this system based on the Internet/Intranet is investigated in Section 5. The conclusion is given in Section 6.

2. The FMS model

The FMS model currently under consideration has been designed to manufacture engine blocks. Basically, the FMS consists of an automated storage and retrieval system (AS/RS), a material handling system, a set of computer-controlled machining centers, two inspection devices and a set of computers to control all the operations within the FMS. Figure 1 shows a schematic diagram of the FMS model.

First of all, raw materials are stored in the AS/RS which is used to accomplish a storage transaction, delivering loads from the input station into storage, or retrieving loads from storage and delivering them to the output station. Then, the stock to be processed is delivered to the output station. This conveyor runs as a loop with stops as buffers in order to transfer the stocks and parts between the AS/RS, machining centers and inspection devices. The stock is then transferred to the “Code Tag” inspection device to ensure that the correct material is being retrieved from the AS/RS. After this, the raw material is machined and processed by the NC lathe, and milling machining centers into finished components. Another inspection location uses a vision device to inspect the features of the finished components. Finally, the components are transferred back to the AS/RS by the conveyor. The sequences at which the operations are carried out for any particular job are summarized in Table 1.

In the proposed model, there are fourteen operations involved with every job. The flow of the job throughout the various operations of the FMS strictly follows a chronological order. In this view, the problem has been addressed as a flow shop problem. However, in the pure flow shop problem, where the processors are arranged in serial fashion, the operations in any processor can be taken up continuously until all the jobs in the queue become exhausted. This is not the case with the FMS model under consideration, since the limitations imposed by the conveyor restrict the continuous flow of jobs. In addition, the serial fourteen operations are carried out