Int. J. Production Economics 64 (2000) 285–293

international journal of
production economics

www.elsevier.com/locate/dsw

Modeling and simulation of the control framework on a flexible manufacturing system

C. Gertosio[a,*], N. Mebarki[b], A. Dussauchoy[a]

[a]*PRISMa, Université Claude Bernard Lyon 1 Bat 710 43, Bd du 11 Novembre, 69622 Villeurbanne Cedex, France*
[b]*IRCyN, IUT de Nantes - Dépt OGP, La Chantrerie, BP 60601, 44306 Nantes Cedex 03, France*

Abstract

A flexible manufacturing system (FMS) is designed to combine high productivity and production flexibility. But the design of a FMS requires high investment. Furthermore, this preliminary phase is strategic and the decisions at this stage have to be made very carefully in order to ensure that the manufacturing system will successfully satisfy the demands of an ever-changing market. Discrete-event simulation has been widely used to design production systems such as FMSs. More particularly, it has been used to design and size the hardware part of a FMS. On the other hand, simulation is more and more used to design and evaluate decision strategies. In this paper, we propose to integrate in a single simulation model a physical model which corresponds to the hardware elements of the FMS with their physical characteristics and interactions, and a logic model which corresponds to the modeling of the computer control system and its interaction with the material part (i.e., the control framework and the network). For this, we present a methodology which allows the integration in a single simulation model of a logical layer representing the control framework and a physical layer representing the FMS elements (i.e., machines, vehicles, transportation network …) within a discrete-event simulation language. On a FMS, for example described in this paper, the results obtained show that with a high level shop congestion, the control layer does not increase the job flowtime.

Keywords: Flexible manufacturing system; Simulation model

1. Introduction

A flexible manufacturing system (FMS) is an integrated system composed of automated workstations such as computer numerically controlled (CNC) machines with tool changing capability, a hardware handling and storage system and a computer control system which controls the operations of the whole system [1]. It is designed to combine high productivity and production flexibility. But the design of a FMS requires high investment. Furthermore, this preliminary phase is strategic and the decisions at this stage have to be made very carefully in order to ensure that the manufacturing system will successfully satisfy the demands of an ever-changing market.

In a FMS, the flexibility depends, from one point of view on the technology used (e.g., machines with tool changing capability) and from another point of view, which is not the least important, on the computer control system. Moreover, the computer

* Corresponding author. Tel: 4-72-44-80-43; fax: 4-72-43-15-37.
E-mail address: gertosio@univ-lyon-1.fr (C. Gertosio)

0925-5273/00/$ - see front matter
PII: S0925-5273(99)00066-3

control system can hardly be tested without the FMS hardware part. Thus, the design of the computer control system has to be made so that the control will be flexible and easily adaptable to the configuration changes of the FMS. In fact, the computer control system is a strategic function for the optimal use of a FMS, as well as the hardware part of the FMS has to be carefully designed.

Discrete-event simulation has been widely used to design production systems such as FMSs. More particularly, it has been used to design and size the hardware part of a FMS (e.g., capacity of the buffer storage, characteristics of the hardware handling, characteristics and numbers of workstations with regard to the expected production, robots, ...) in order to optimize the parts flow or to maximize the utilization of the workstations for example. Simulation tools such as ARENA, Witness or Automod allow to model quite quickly the physical flow of parts in the FMS.

On the other hand, simulation is more and more used to design and evaluate decision strategies (e.g., sequencing of parts, machine or AGV selection). But, decision strategies in FMSs are integrated into the computer control system and depend widely on the framework of this control system and also on the way that the control system interacts with the material elements.

In this paper, we propose to integrate in a single simulation model a physical model which corresponds to the hardware elements of the FMS with their physical characteristics and interactions, and a logic model which corresponds to the modeling of the computer control system and its interaction with the material part (i.e., the control framework and the network). The first part of this paper is devoted to the presentation of different control frameworks used in FMSs. The second part will present the methodology used to integrate a logical model representing the control framework and a physical model representing the FMS elements (i.e., machines, vehicles, transportation network ...) with discrete-event simulation tools. Then, in the third part we describe, as an example of FMS, an application of this methodology. And finally in the fourth part we present and analyze the results obtained from this example which integrates the control framework and the physical part.

2. Control frameworks in FMS

Tang et al. [2] consider two kinds of decision strategies in a FMS:

- pre-release decisions which consider the study of the control framework at the design stage of the FMS. This study involves control strategies which allow us to manage, in a flexible way, the resources as well as the production parts.
- post-release decisions which deal with routing parts while the system is in operation. For this, real-time scheduling strategies are frequently proposed through simulation studies [3–5].

In this paper, we consider only pre-release decision strategies. These strategies deal with the allocation of parts to the resources which has to be made in a flexible way in order to yield better system utilization [6], and with the hazard control. Due to their flexible nature, FMS allocation decisions should be made as late as possible so that these decisions are effectively based on the real state of the system. But to achieve this objective, the control framework has to collect information about the state of the system. Moreover, it has to react efficiently (i.e., quickly and pertinently) to any change of the system. Control framework have been widely studied on automated manufacturing sy stems [2,4,7–11]. Broadly speaking, two kinds of control framework are used in FMSs:

- the centralized and hierarchical control framework, where a central controller manages all information and decisions. This kind of control is easier to implement but is not very flexible especially if there are changes in the shop configuration or in the production parameters (e.g., modifications of the routing of operations).
- the decentralized and hierarchical control framework where a central controller manages local controllers, each one supervising a function of the manufacturing system (e.g., transportation, measures control, transformation).

Due to its flexibility we have retained the latter kind of control framework shown in Fig. 1.

In a decentralized and hierarchical control framework, the control system is composed of one central control station which is in charge of the