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Optimisation of intelligent FMS using the data flow matrix method

J. Balic*, I. Pahole

Faculty of Mechanical Engineering, Smetanova 17, SI-2000 Maribor, Slovenia

Abstract

This paper deals with the development of a data flow matrix method for the monitoring and control of flexible manufacturing systems (FMS) taking into account the intelligent behaviour and disturbances within the system. The methods and concepts for solving the problems are described. Especially, the ''data flow matrix'' and computer-aided methods for the designing of an FMS control system are introduced.

Keywords: Flexible manufacturing systems; Data flow matrix; Optimisation

1. Introduction

In the industrial states nowadays production trends are oriented to the:

- functional characteristics of the products;
- quality and reliability of the products;
- variety of the products;
- customer oriented products;
- competitive production with optimal production cost.

In all mentioned orientations the growth of quality is present. The result is production on better machine-tools. With the growth of machining accuracy the costs of machine-tools are greater [1]. The production machine must be turned to the maximal advantage in its life cycle. If we limit ourselves to machining time reduction, we have the following choices:

- Reduction of the main machining time: this reduction is limited with technological properties of machining procedure, physical properties of the raw materials and cutting tools [2].
- Reduction of the auxiliary times with higher degree of the automation.
- Reduction of the preparatory-finishing time is the area of great interest, specially in the last few years when new methods for production data acquisition in real time are possible.

2. Monitoring and control of FMS

The efficiency of use of the machine-tools depends on the level of automation. Efficiency of conventional machine-tools is between 15 and 30%, with NC machine-tools it is 50%, with machining centres it is up to 75% and with FMS it is up to 90% (according to the machine-tools manufacturers Gildemeister, Fastems, Valmet, Fritz Werner). Making all-purpose mathematical model for FMS control is not possible. For the control and operating of flexible manufacturing systems (FMSs) the intelligent behaviour of the system is of significant importance and corresponds to the following:

The efficiency of FMS is very high, but if we take the economical aspects and cost-effectiveness into account, the total efficiency is low [3].

For the effective use of the FMS the following conditions must be met. FMS the production must be greater and cheaper than with separated machine-tools. If FMS must satisfy this requirement, the problem of FMS controlling must be general enough in case of:

- disturbances within FMS, and
- troubles from environment feed to FMS through orders.

If unpredictable events are introduced into the control system, each solution of the problem is registered ''the system learns''. In this case the number of unpredictable events decreases asymptotically, but it is never zero.

Nowadays, the methods and concepts, which more or less successfully solve the problems described, have been developed for the control of FMS. The main concepts and methods, derived from them, to control the FMS are

* Corresponding author.

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- conventional methods of dynamic network planning [4];
- methods of waiting rows [5];
- bar charts (mainly for graphic representation of state of the system);
- methods of artificial intelligence (IF THEN logic, methods of rules, methods of learning, etc.) [6];
- control according to theories of networks (Petri networks, neurone networks);
- use of temporal logic;
- use of genetic algorithm.

3. Data flow matrix

All these concepts and methods are mainly based on program packages; they solve the problems generally or they are completely adapted for some configuration of the FMS. In such a form they are too expensive for a large number of users.

In 1995 the concept of ‘‘data flow matrix’’ was developed. This concept is described in the matrix and vectors form and thus it controls the production. In the data flow matrix the links between individual model points (FMS units) in the FMS are precisely defined and also the technological database is connected to the data flow matrix. Thus the matrix is a basis for further connection of inputs and outputs from individual model points or FMS units. The concept of ‘‘data flow matrix’’ is able to perceive and execute every event in each unit of FMS in real time. Execution of events is separate in three levels:

- 1st level—planning;
- 2nd level—prognosticating;
- 3rd level—manual intervention in the conflicting situation.

The created vectors describe readiness and conditions for all FMS units during operation.

At the start point the vectors are initialised and put into the system. During the operation updating of the vectors is made automatically via DNC control. After that, the input vectors are simulated according to ‘‘triangle method’’, and describe very good the operation of real manufacturing system.

The created vectors which describe the behaviour of FMS units, are now ready for processing in the information data flow matrix and they represent the actual connection between the FMS units and the matrix. After each change on FMS units the vector becomes a new value on the point which represents this changes. Multiplication of the vectors by data flow matrix occurs if the vectors are changed. This process is an accordance with mathematical laws. The matrix defines precisely the connection between the nodes in FMS and the technological database. The method for creating the input vectors provides insight into in the operation of FMS to particular customer order.

The information data matrix was upgraded with the information shell which ensures:

- synchronisation;
- time and topological dependent sharing of information and control data between the nodes in FMS;
- connection with computer-aided process planning system.

The operation in information shell occurs according to these steps:

- collection of information from the FMS units;
- identification of information;
- arrangement and filtering of the information;
- processing of the information in database;
- sharing and sending the information from the functional modules.

4. Characteristics of the system

The basic direction for development of the system was

- general modules architecture;
- technologically oriented system;
- automation of FMS units;
- only machine-tools for cutting machining are included;
- use of existing program modules and systems;
- testing of the system in real production environment;
- testing of the system with simulation, according to ‘‘triangle method’’ for describing the real manufacturing system;
- devices and procedure could be aided to the system.

The basic assumptions for start of the system are given by the computer-aided process planning module. These assumptions are

- listing of orders with priority settings;
- sequence of manufacturing on FMS units for particular order;
- number of input parts and theirs conditions;
- NC control programs for all parts;
- the basic data on machining time used for each part.

On this basis it is possible to determinate the first scenario for start-up of the FMS system (could start). During the exploitation of the system disturbances and conflict situations occur, and a new alternative scenario has to be worked out. This means that the alternative production units within the FMS have to be set. The standard criterion for classification of type of machining is used. At this point the manual intervention of expert could be used to avoid troubles and run the system optimally.

Computer-aided methods for design of the FMS control system consist of actual design of informational shell and nine functional groups with following modules:

- initial and set-up modules;
- modules for generation of data flow matrix and integration shell;
- data backup modules;
- modules for protection and priority;