Proceedings of the 1980 Winter Simulation Conference
T.I. Ören, C.M. Shub, P.F. Roth (eds.)

MANUFACTURING SYSTEM DESIGN TOOL - MAST - AN INTRODUCTION

John E. Lenz
University of Wisconsin
Oshkosh, Wisconsin

ABSTRACT: By 1990, fifty percent of all NC/DNC machine tools will be included in computerized manufacturing systems. Operation research techniques will be used extensively in the design and control of these systems. But because of the complexity of these systems, theory will only solve parts of the total system problem. Therefore, computer simulation will serve as the cornerstone on which theoretical models can be combined to study the total system.

The MAST model is a computer simulation which has the capability to simulate a wide variety of systems configurations. The user of MAST provides a data file containing the description of the system with free formated data cards and selects a set of control decision rules from existing libraries. Because of this design for system description and decision rule selection, the MAST model provides a means to study alternate control policies of existing systems or design of proposed systems with the need of the user writing computer code.

Problem Definition

Computerized Manufacturing Systems (CMS) include numerically controlled (NC) machine tools and auxiliary equipment, such as in-process storage or inspection stations, inter-connected via a material handling mechanism. The operation of the machine tools, auxiliary equipment, and material handling mechanism is controlled and coordinated by a center computer. The primary function of these systems is to produce several part types without the need to manually retool a machine or manually transport a single part between two machines. In order to achieve this level of automation, the machine tools and material handling mechanism must be flexible. More specifically, the machine tools must be capable of performing operations sequences on a variety of part types, and the material handling mechanism must be capable of transporting a number of these part types.

The Manufacturing System Design Tool (MAST) provides a methodology to study manufacturing systems. Also, the simulator provides the capability to study compatability of components and aid in designs of CMS. A more detailed description follows including the developing of the simulator, the information necessary to use, and its capability.

The Need for MAST

It has been forecasted that by 1990, 50 percent of all NC machine tools in operations will be incorporated into systems. Also by this time, over 2,000 large computerized manufacturing systems will be in operation. Whereas, less than twenty-five of these systems exist today, to reach the projected figure of 2,000, approximately 150-200 systems will need to be built each year in the late 1980's. Consequently, CMS is going to play a significant role in the future of manufacturing.

Just as significant as the role of CMS, is the need for CMS study methodologies. With each system worth several millions of dollars, and new hardware improvements produced yearly, methodologies must exist to aid in system design. Economics prevent the construction of computerized manufacturing systems without some forecast of its performance. Also, hardware configuration must be studied for compatibility with software configuration (controlling algorithms).

Because of the complexity of study requirements, computer simulation provides the most direct approach. Scheduling theory, inventory control, forecasting algorithms and other operation research tools can be incorporated with computer simulation to provide an effective design aid.

Studies of CMS must address the following questions. Which NC machine tools are right for the specific

80CH1617-0/80/0000-0299$00.75

need? In what order should they be located around the material handling mechanism? Is an addressable (such as a cart system) or non-addressable (such as a conveyor system) type of material handling mechanism optimal for the types of parts produced? What is the appropriate balance of part types simultaneously in the system? These are only a few of the many questions needed to be answered in CMS studies.

Thus, MAST provides a methodology research answer to these and other related questions.

The MAST MOdel's Development

The MAST model is a computer simulation written in the FORTRAN programming language. MAST was developed on an IBM 370 computer, and has also been used on the CDC 6500 and Amahl 470 computers. Because of its modular design, MAST could be implemented using overlay methods on computers with limited core, such as mini computers.

MAST development was based on much of the work resulting from another simulation called the GCMS simulator. The GCMS simulator was developed at Purdue University under sponsorship of the National Science Foundation and private industry. But the GCM simulator was designed as a research tool and had shortcomings with data input, execution time and size and user interface. Therefore the MAST model was developed to be more user oriented.

MAST is a highly user oriented simulation. The data necessary for a system description can be entered in free format without the need for providing default data. No FORTRAN programming is necessary to study computerized manufacturing systems and alternative system design. Decision rules are designed in a library format so rule selection is done through the data input.

User Interface with the MAST Model

The MAST model requires, as input, a data file containing the description of the system to be studied. The entire system description is included in the data file which contains three general types of information. The first type of information describes the system hardware to the MAST simulator. This includes the description of machine tools, parts, and the material handling mechanism. The second type to control the operation of the system. Such algorithms are the part introduction rule, the operation sequence rule, the machine selection rule, and others. The third type of information needed in a system description file describes the system's initial status. This includes the initial status of the parts in the system, machines in operation, and initial position of the material handling mechanism. When the system description data file is complete, the system can be studied using MAST.

Alteration to a system design can be studied with the MAST model. The system description file can be edited to contain the desired alternation and this altered data file can be studied using MAST. Thus in describing a system to the MAST model through the use of a data file, changes to the system description can easily be included and studied.

This completes the discussion of an overview of the system description data file used to represent systems to the MAST model. A more detailed discussion of the data file follows, including the list attributes of each hardware component needed for input, the procedure for selection of hardware component needed for input, the the procedure for selection of software algorithms. But, before a detailed discussion of the system description data file, the reader must become familiar with some MAST terminology. The term "station" when referring to the MAST model is either a NC machine tool, an inspection station, inprocess storage, or loan'unload equipment. Each has the same set of attributes, but their attribute values describe the different uses. So as to condense the number of representations needed, each is considered as a station. The term "operation" refers to one completed tool sequence, more commonly described as a part program. Thus, a part will only have one operation performed at a station at a time. The term "pallet" refers to the fixture that allows consistent handling of different part types. In MAST, pallets are used as a limited facility in which to monitor the number of part types in the system. The term "cart" is used to describe any type of material handling mechanism which can transport one or more parts via specific assignments. Therefore, a conveyor type of material handling mechanism would not contain any carts in the MAST model representation. Finally, a "decision point" in MAST terminology is defined as a point within the material handling mechanism) can stop to unload or load a part, wait, or change directions.

The hardware system information contains the data needed to completely describe stations and their operations, part types, cart types, pallet types, and the material handling mechanism layout. Each station's description is represented by a STATION data card. With each station, a queue may be associated. The number of queue positions can be varied from station to station with each queue position designated as an on-shuttle or an off-shuttle position. If there is no designation, then the queue position can be used for either an on- or off-shuttle as it is needed (this is called a generalized shuttle). Also, in the station's description, a cart to shuttle movement time and a shuttle to machine movement time needed to be specified. It is assumed that the time from cart to shuttle is the same as the shuttle to cart time. This assumption also holds for the machine to shuttle time. Further, required input for the station's description is the decision point(s) where parts arrive and depart the station.

Each part type description is represented by a PART data card, and includes the maximum allowed in the system at one time, a relative priority, and total desired production. The station-operation sequence or route is represented by ROUTE data cards. The route includes an operation number and the list of stations and operation time for each. Thus, different part types having the same operation can have a different station or set of stations where it can be performed and also have different operation times.

Each cart type description is represented by a CART data card and includes the number existing of that type of its number of pallet positions. Note, if a conveyor type of material handling mechanism is used, then there is no need for a description of cart types. The speed it moves along the track, and a list of decision points it can pass over are necessary data. This allows the capability to restrict carts to certain sections of the material handling mechanism and allow a different type of material handling mechanism for other sections of the track.

Each pallet type description is represented by a PALLET data card and consists of the number that exists and a list of the possible part types it can carry. The pallet is most frequently used in studies as a limited resource to control the part balance in a system.

To complete the system hardware description, the material handling mechanism layout or configuration is included in the data file. The configuration is specified via decision points and each decision point is represented by a TRACK data card. The decision point description includes the station (only if one exists at the point), and a list of all successor decision points. The list of successors only include those decision points directly linked to the decision point that is being described. Also included in each decision point's description is the distance to each of its successors.

The system data file also contains the system's software configuration which is referred to as decision rules. A library of algorithms exist for each decision rule and the user specifies a reference identifying the desired rule. This reference is inserted in the data file and no FORTRAN programming is necessary provided the rule exists in the library, otherwise a user function must be written and the reference included in the data file would indicate that a user function is to be used. The user function is a FORTRAN subroutine which includes the specific algorithm for the decision rule. The library for the decision rule includes several common algorithms and often user functions are only needed for special system design.

In the MAST, six decision rules are required. The first rule identifies the part introduction rule. The function of this rule is to determine the part balance of the system. Whenever a part can be introduced, this rule is invoked to identify which part type is specified. The second decision rule identifies the next operation selection rule. The third decision of this rule is to determine the next operation for a given part. Often the operation sequence for parts is static, but the generality of MAST allows for dynamic operations sequences. The fourth rule identifies the next station selection rule. The function of this rule is to select a station for which a given operation needs to be performed. This rule is always invoked immediately following the operation selection rule so these two rules are easily combined so that operation selection is influenced by station availability. The fifth decision rule identifies the cart selection rule. If a conveyor type of material handling mechanism is used, then a specific algorithm included in the library must be referenced to eliminate the need for cart selection. The last rule identifies the scheduling of the carts. The function of this rule is to schedule the movements of the carts to avoid interferences and transport the parts according to assignments.

All of the above six decision rules are dependent upon information contained in the description of either part types, cart types, stations, or decision points. For example, different part types need not have the same operation sequence rule, or each cart type need not have the same cart scheduling rule. This flexibility of incorporating multiple algorithms for different hardware components allows the capability to study combination cart and conveyor systems or statis operation sequences for some part types and dynamic operation sequences for other part types.

Finally, the system description data file must describe the initial status of the system. The parts which are initially in the system are described in a REWORK data card. The description includes the list of operations which have been completed and the current operation and station. The pallet and other necessary data will be assigned by MAST. If the system is to start without any parts, then no REWORK data cards are needed in the system description data file. The initial position of the carts only need to be specified if the default is to be over written and is represented by a CLOCATION data card. The initial position of a cart includes the decision point at which the cart is located.

This completes the detailed discussion of the MAST user interface. The precise data card descriptions can be found in the MAST User Manual, which is available from CMS Research. The following section covers the vast capability of MAST.

Capability of the MAST Model

A rational design procedure, incorporating simulation, has been laid out for Computerized Manufacturing Systems. Such a procedure envisions the designer starting with the class of parts to be manufactured. The machine operations necessary to produce the parts are determined in some satisfactory or even optimal manner. Given these operations in static or dynamic sequences, and a "typical" batch size, a designer can specify a number of alternative Computerized Manufacturing Systems which can feasibly produce such a set of parts. At this point, MAST with other operation research tools can be useful in evaluating these alternatives.

Below is a list of capabilities of the MAST model which enables it to provide a simulation aid to the rational design of Computerized Manufacturing Systems. MAST has the capability to:

(1) simulate various material handling configurations (e.g., one- or two-way directional movement, three or more successor branches, etc.)

(2) simulate different material handling mechanism (e.g., conveyor, cranes, cart, any combinations thereof),

(3) simulate many kinds of stations (e.g., machine tools, load/unload, inspection, in-process storage),

(4) simulate station queues (e.g., on-shuttle, off-shuttle, rotational, swivel),

(5) simulate parts (e.g., unfinished to finished process, rework pieces),

(6) simulate reliability of stations, carts, and the material handling mechanism,

(7) simulate operation sequence algorithms (e.g., static operation sequence for parts, shortest cycle times, highest priority operations, idle stations),

(8) simulate station selection algorithms (e.g., closest station, idle station, highest priority station),

(9) simulate cart selection algorithms (e.g., closes cart, highest priority cart, second available cart),

(10) simulate cart scheduling algorithms (e.g., minimize blocking, interferences),

(11) simulate part introduction algorithms, and

(12) trace all activities of the system.

Conclusion

In conclusion, because of its vast capability, MAST has been used to simulate a variety of existing Computerized Manufacturing Systems. These include conveyor and cart systems, with different part types and operation sequences. The MAST model has been used to simulate systems with a station shuttles and systems with other types of in-process storage.

Unloading/loading type operations, pallet changing operations, all types of machining operations, and inspection operations have been included in various MAST uses.

Currently, MAST is being used to study the design of several existing systems. Because of its flexibility, alternative designs to these systems are also being studied. It has already been proven from its uses that MAST provides a viable method to aid in CMS design.

REFERENCES

Cook, N.H., "Computer-Managed Parts Manufacture", Scientific American, No. 2, 1975.

"DNC for Flexibility", Production, September 1974.

"Flexible Manufacturing System Fulfills Tractor Maker's Needs", American Machinist, June 15, 1975.

Barash, M.M., "Computerized Systems in the Scheme of Thing", AIIE Conference Proceedings, November, 1979.

Hutchinson, G.K., and Synne, B.E., "A Flexible Manufacturing System", Industrial Engineering, December 1973, Volume 5, No. L2.

Lenz, J.E., "General Computerized Manufacturing Systems Simulation", Masters Thesis, May 1977.

Lenz, J.E., and Talavage, J.J., "A Generalized Simulator for Computerized Manufacturing Systems", Paper presented at the Summer Computer Simulation Conference 1977.

Lenz, J.E., "Manufacturing System Design Tool -MAST- User Manual; Computer Manual Available from CMS Research, February 1980.

"The Optimal Planning of Computerized Manufacturing Systems", Report No. 1-4, May 1975 to November 1976.