A GENERALIZED METHODOLOGY FOR COMPUTER SIMULATION OF NUMERICALLY CONTROLLED PRODUCTION SYSTEMS

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Summary

Due to the complex nature of numerically controlled production systems, analytical methods alone are not sufficient to evaluate new system design concepts or modes of operation. To assist in the study of problems of this nature, a computer-based generalized simulation methodology for numerically controlled production has been developed. The methodology provides means of identifying the components of a computer-based numerically controlled production system and of specifying its structural arrangement.

Component sub-systems are identified as the Numerical Control Data Processing System, the Physical Processing System, the Emergency Maintenance Supporting System, and the Production Information System. Within these subsystems, generalized functions such as part programming, computer processing, tape proofing, machine center processing and machine repair, are discussed for purposes of computer simulation.

Within the system concept and with the use of a systems engineering approach, the generalized functions and their interrelationships are organized in a Numerical Control Production System Simulator. The simulation output obtained through the Production Information System can provide a variety of information to estimate flow times of job orders through the production system and to analyze effects of changes in work schedules, manpower levels, machine center capacities, and job order configuration.

Introduction

Numerical control (N/C) is generally acclaimed as the largest single advance made in the techniques of industrial production in the last decade. The basis of these new production systems is the numerically controlled machine tool. This revolutionary new machine is an electromechanical system that has controls which guide a manufacturing process according to a specific program of instructions. The direction in which the tool moves, its speeds and feeds, type of operation-together with auxiliary machine tool commands-are directed by digital instructions read from a punched tape or a magnetic tape.

At present, a variety of N/C machines are encountered in various industries, all of them requiring data processing services of various complexity and frequency. In the metalworking machine tool area, N/C machines such as turret drills, jig borers, lathes, multi-axis milling machines, engine lathes and multi-purpose machining centers are most common in large manufacturing companies, but are also found in medium and small machine shops. Other N/C devices that are being used extensively are drafting machines, flame cutting machines, riveters, tube benders, welding machines and inspection machines. Figure 1 shows one of the general purpose N/C machine tools considered in the simulation model discussed in this paper.

Formulation of the Generalized Model

A simulation methodology in numerical control requires the definition of a framework aiming at the integration of physical and information handling processes. Figure 2 shows a simplified representation of such process integration. There are essentially four component systems considered in the modelling philosophy presented here. They are the N/C Data Processing System, the Physical Processing System the Emergency Repair Support System and a Production Information System.

The N/C Data Processing System has the function of generating machine tool control information from engineering drawings and process planning data.

The Physical Processing System covers the production processes carried out by the N/C machine tools and the Emergency Repair Support System provides the services needed for repair of machine tool breakdowns.

The Production Information System encompasses all activities of the three principal systems mentioned previously. Sensing elements report to this information system events that take place in the subsystems.

The generalized model treats the N/C plant as a man-machine system within a discrete-type production environment. It recognizes the dynamic aspects of these production systems as it includes feedback links within each subsystem and between the subsystems themselves. The basic schematic diagram of the N/C production system is shown in Figure 3, as a detailed representation of the operations and flows illustrated in elemental form in Figure 2.

The flows as indicated in the diagram are of four distinct types. The solid-black line network shows the materials flow from raw material storage to finished part storage, going through the numerical control machining operation. The double-line network provides the carrier for all information issued from the arrival point of the engineering drawings to the issuance of numerical control tapes for the production process, going through various points for processing of the numerical control programs. The broken lines indicate the flow of information between the repair dispatching center and the machine tool sites. The thin-line network links all the other three networks and their stations to an information center designed for the control of operations and for the measurement of system performance during the simulation. The Production Information System is therefore an instrument for the evaluation of performance as a result of manipulations on the model. Data on system dynamics or utilization of facilities allows such an evaluation.

Production orders entering the system are routed to the N/C part programming function which handles all the operations necessary to code, process, validate and machine tool test the information necessary to run the N/C machines.

The computer processing operation simulated in the model produces families of tapes representing the major routings considered in the model. N/C tapes are released to the machining centers for tape proofing prior to final release for production.

The highly aggregated function blocks in the general schematic, as well as the various linkages of direct flow and feedback loops, may be broken down to a level of detail represented by the simulation logic used by the General Purpose Systems Simulator Program (GPSS). Flows through the N/C parts programming function, for example, can be detailed in the sub-functions of Part Programming proper, Computer Processing, Automatic Drafting and Control Tape Proofing. Within the Breakdown Repair Function boundary there are logical blocks representing sources of break-down events, blocks representing repair functions and sinks representing the termination of the repair operation.

The N/C Machining Centers may have one or more machines of the same type. Parameters affecting the center operations are the number of shifts per day, the length of the individual shift and the number of working days per manufacturing week. Wide flexibility exists in programming shifts for the various centers up to the point of assigning centers to different shifts of varied duration.

The scheduling program requires a description of available facilities per center in terms of a facility identification, number of shifts of operation, number of machine hours of capacity. The scheduling function operates on the given information to calculate for each job the probable number of manufacturing days needed to process the job and the manufacturing week number in which the job processing will start at the machining center. It determines the load that would exist at each machining center according to the over-all job lot processing time and to the frequency of job lot and tape arrivals.

Data Outputs from the Model

Extensive output information on the performance of virtually all basic functions of the model can be provided by a single GPSS simulation run. Selected measures of performance have been grouped into five categories to illustrate the main capabilities of the model.

Output Data on Queues forming at Processing Centers

- Distribution of queue delay times at N/C processing centers and N/C data processing centers.
- Maximum and average contents of queues at processing centers.
- Average length of time spent by production order in queue of specific processing center.
- Record of queue lengths as a function of time taken at selected queues of the system.

Output Data on Facilities Control

- Time covering period of operation of facilities.
- Average utilization of each facility based on period of operation. This also constitutes the loading factor of the facility.
- Total loading levels and capacity levels

at each N/C machine center, over period of operation considered.

Output Data on Production Order Control

- Total number of job-lot orders accepted and completed by system during period of operation considered.
- Average flow time of new orders through N/C data processing system and through total production system, including physical processing system.
- Average flow time of reorders through physical system and average flow time of reorders and new orders combined through total system.

Output Data on Operating Schedule Control

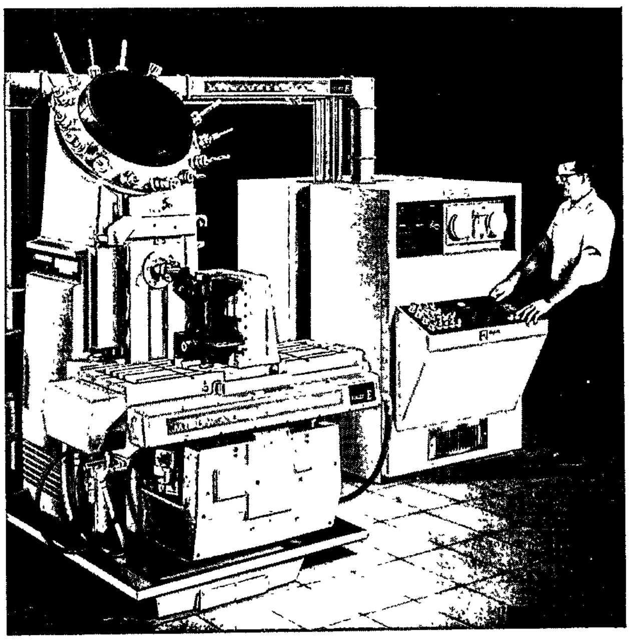
- Number of manufacturing days and manufacturing weeks covered by scheduling.

Number of manufacturing days expected to process specific new order or reorder and number of manufacturing week when specific new order or reorder is expected to be processed at machine center.

Output Data on Breakdown Repair Control

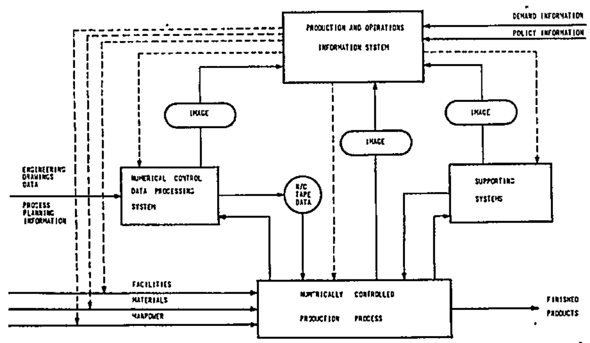
- Distribution of queue delay times at machine center for the handling of repair orders.
- Total number of breakdowns occurred at specific machine center.
- Maximum and average contents of queue for handling of repairs at machine center.
- Average time spent for repairs at machine center.
- Average utilization of repair technicians assigned to machine center.

Fig. 1



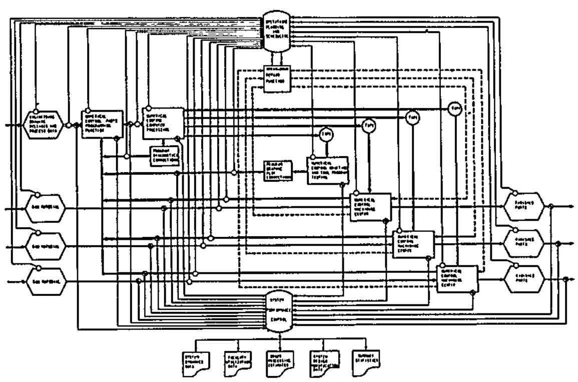
Numerically Controlled Machining Center

Fig. 2



General Model for N/C Production Systems - Basic Schematic Diagram

Fig. 3



General Model for N/C Production Systems - Complete Model Diagram