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MONITORING AND SIMULATION IN THE MODEL OF THE COMPUTER TURNING CELL

Summary. Computer model of the robotized turning cell is presented. Monitoring algorithm has been developed based on the cell model. Tasks of the particular system's modules are presented.

1. Introduction

The Institute of Machine Technology has been involved in developing the industrial applications of robots since many years [1],[2],[3]. Functioning of the robot in a cell has called for the special supervisory systems. The following hardware has been employed in the cells being used until now [4],[5]:

a) simple, hardware panel duplicating some of the robot's functions,
b) dedicated, programmable, computer based system equipped with the additional panel capable of carrying out some of the operator's decisions,
c) computer based supervisory system, overseeing the functioning of the cell and carrying out of the operator's decisions according to a previously developed program. Starting from 1991 the main activity is being exerted for the development of the software for monitoring and controlling of the robotized manufacturing cells [6],[7].

2. Model of the Robotized Cell

The technological components of the flexible robotized turning cell (FRTC) dedicated for the components machined by turning are shown in Figure 1. Testing of the software and following investigations called for a robotized machining cell with components connected to the control computer. The numerical control systems of the machine tools employed in the robotized turning cell in the Institute of Machine Technology are obsolete. It has been decided, taking into consideration the costs of modernization or buying a new turning cell with robot, to develop a computer model of FRTC. This less expensive solution has made it possible to carry out testing of the control and monitoring software.

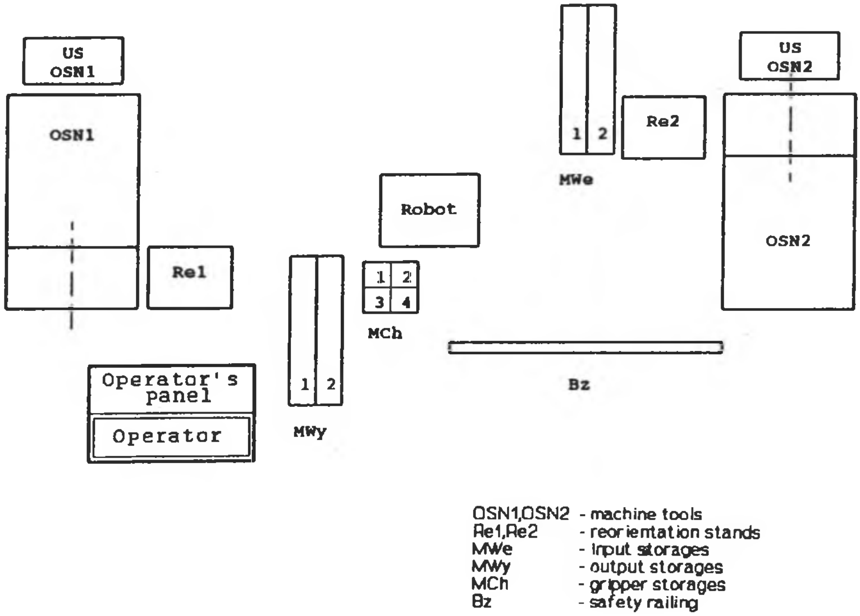

Figure 1. Components of the flexible turning cell (FRTC)

The outline of the FRTC control system is shown in Figure 2. There are three PC486 computers simulating machine tools with a robot and a supervisory computer controlling the operation of the cell. The information between these computers is being circulated by means of the Ethernet network. Moreover, the system comprises the DIP switches set simulating other cell elements like input/output storages, gripper storage and safety railing. Each one of the DIP switches set has one input and two digital outputs. The input is being controlled by the computer of the robot an one of each module's outputs is may be set by hand. The possibility of manual setting of the states' of the technological components of the cell is very useful at the testing stage of various software modules. This DIP switches set is connected to the supervisory computer by means of the two digital data acquisition boards and with a computer simulating functioning of a robot by means of another digital output board. This model system is assembled in the Institute of Machine Technology of the Silesian Technical University.

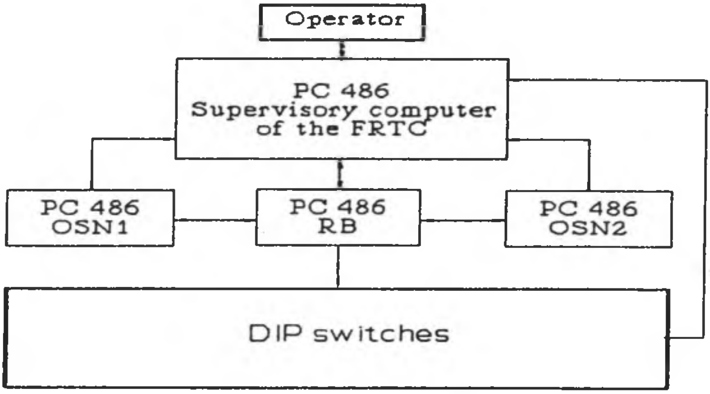

Figure 2. The FRTC modelling system

3. Structure of the System

The main tasks of the control and monitoring system are:

- supervisory control of the manufacturing process in the FRTC by controlling functioning of its technological components and labour power, taking decisions about the necessity of replacing the worn out cutting tools and notifying the break-downs of the FRTC components,
- controlling the replacement of equipment of the FRTC components,
- generation of the production flow reports.

The cell work schedule and technological data feature the input data to the system. The system includes:

- cell work control module (CWCM),
- production flow database module (PFDM),
- cell state monitoring module (CSMM).

Links between the system elements and the simulation programs are shown in Figure 3.

3.1. Cell work control module

The task of the CWCM module is supervisory control of the cell functioning and managing the use of tools and other technological equipment. This module controls the FRTC functioning by running

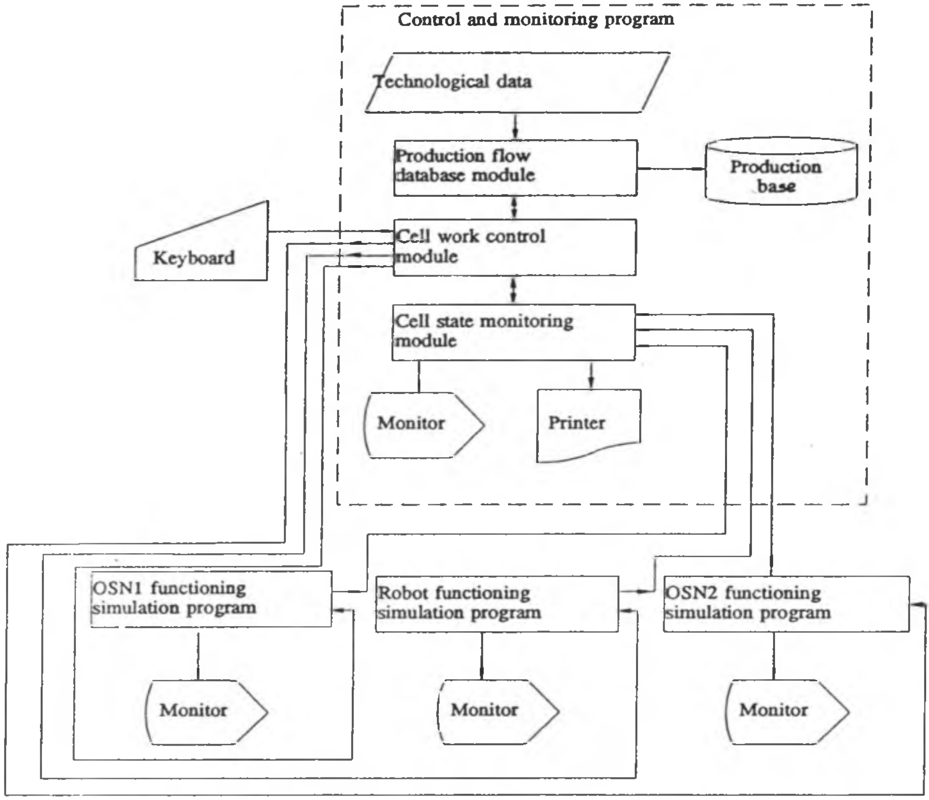

Figure 3. Links of the control and monitoring program with the simulation programs

and suspending the programs of machine tools and the robot, supervising the process of replacement of the cell equipment for the set necessary to carry out the next job. The supervisory managing of the tools is reduced to notifying the operator the next planned time of the tools' replacement, generating a list of the tools for a preplanned replacement and during the FRTC down time and the time necessary for its repair, notifying the supervisory level of the additional requirements for the tools that were prematurely worn out and listing the equipment items to be replaced in case of the production spectre change. This module collects the cell production flow data and prepares the data necessary for reports.

3.2. Production flow database module

This module is designed to manage the cell production flow data. The information concerned include: cell work-flow schedule, technological data (operation data, tool data, robot program data), robot and machine tools control programs. The abovementioned data is going to be introduced to the database system by the company's external production planning department. The task of the PFDM are running and modification of databases. This module is capable of selecting from the database (based on the order number, workpiece name and the operation number) information needed by the supervisory level like: NC operation unit times, time of completion of the robot programs, lead times due to the machine tool and robot, equipment and tools' symbols, tools' life under cut and tools' work times during the machining operations according to the machine tools' programs.

3.3. Cell state monitoring module

The tasks of the cell state monitoring module are: determining the states of the cell components, logging the components' state changes, counting the number of workpieces machined on the machine tools, totalling the work time of tools, summing up the time losses due to the machine tools' down times, registration of the robot and machine tools equipment symbols, generation of the screen messages to the system operator, generation and printing the technological documents. The monitoring module algorithm analyses in turn the states of the input/output storages, reorientation stands, gripper storage and of the safety railing. The states of the machine tools and robot are recognized based on the information supplied by the programs simulating the functioning of these components and by comparing the state of the safety railing with the data supplied by the simulation programs. OSN machine tool shall be reported as ready to work, for instance, when the transmission of the control program to its numerical control has been completed succesfully and when the safety railing is secured.

The state of the cell components is stored in the state table "K" comprising the states of the following components: OSN1, OSN2, robot, input storage 1, input storage 2, output storage 1, output storage 2, reorientation stand 1, reorientation stand 2, safety railing and the cell operator. The particular table elements defining the sates of the components may have the following values:

a) notification of the state of the machine tools

0 - not set for production (no equipment)

1 - control program transmission

2 - machine tool ready.

3 - busy - working

4 - break down simulated by hand or generated by the random numbers generator

5 - repair

6 - equipment set up by the operator

7 - replacement of the worn out tools

8 - stop of the control program

9 - end of the control program

b) notification of the state of the robot

0 - unequipped (no adapter)

1 - control program transmission

2 - robot ready

3 - busy - working

4 - break down simulated by hand or generated by the random numbers generator

5 - repair

6 - equipment set up by the operator

7 - stop of the control program

8 - end of the control program

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OSN 1 - OPRZ1             OSN 2 - OPRZ2             ROBOT - CH2
busy                      busy                      break down

PROGRAM ID - POT21        PROGRAM ID - POT31        PROGRAM ID - ROB5
NO OF PIECES - 2          NO OF PIECES - 6

     M W E 1                   M W E 2                   M W Y 1
     full                      full                      empty

     M W Y 2                   R E 1                     R E 2
     empty                     empty                     empty
                                                         MCH1 - full
  SAFETY RAILING            OPERATOR                     MCH2 - empty
  secured                   idle                         MCH3 - empty
                                                         MCH4 - full

                Date: 13-07-93          Time: 13:13:13

MESSAGE : Repair the robot

F1 state of machine tools and robot                  F2 cutting tools
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Figure 4. Monitor screen - states of the cell technological components

c) notification of the states of the input/output storages and of the reorientation stands

0 - empty

1 - full

d) notification of the state of the safety railing

0 - open

1 - secured

O S N 1

BLOCK - 1 **WORK TIME** - 0.2

TOOL - 1 **MT STATE** - 3

Tool no	Work time [min]	Tool life [min]
1	1.8	15.0
2	0.0	15.0
3	0.0	15.0
4	0.0	15.0
5	0.0	15.0
6	0.0	15.0
7	0.0	15.0
8	0.0	15.0
9	0.0	0.0
10	0.0	0.0

O S N 2

BLOCK - 8 **WORK TIME** - 0.3

Tool - 1 **STAN OSN** - 3

Tool no	Work time [min]	Tool life [min]
1	1.8	15.0
2	0.0	15.0
3	0.0	15.0
4	0.0	15.0
5	0.0	15.0
6	0.0	15.0
7	0.0	15.0
8	0.0	15.0
9	0.0	0.0
10	0.0	0.0

MESSAGE: Repair the robot

F1 state of machine tools **F2** cutting tools

Figure 5. Monitor screen - state of the machine tools

e) notification of the state of the cell operator

0 - idle

1 - reapiring the cell component

2 - machine tool equipment replacement

3 - worn out tool replacement

4 - robot equipment replacement

All information about the technological components are reported to the operator on the screen shown in Figure 4.One may find ID symbols of the equipment set on the machine tools and robot as well as the ID numbers of the robot and machine tools' programs executed at the moment. The messages displayed at the bottom of the screen inform the operator about the necessity of: replacement of the worn out tools, replacement of the robot and machine tools' equipment necessary for the new job, repair of the machine tool or the robot. Operator is supplied the computer listings that, in case of replacement of the worn out tools on a machine tool state the tools' ID and their appropriate holder position numbers. Should the equipment replacement be necessary then the listing includes the symbols of the equipment components of the machine tools, robot and symbols of the robot grippers. The message saying "F1 state of machine tools and robot", "F2 cutting tools" displayed in the bottom line of the monitor is related to the F1 and F2 function keys. Pressing the F1 key is connected to the screen resented above whereas pressing the F2 key causes the shift to the lower level of the components' state - Figure 5. One may find the following information connected with the machine tools: program block number, number of the tool utilized at the moment, total work time of this tool, overall state of the machine tool, tool lifes and the extent of wearing out of the tools mounted. The CSMM module is being called by the supervisory program frequently enough to enable monitoring the system components' states in the real time. The cell state monitoring module (CSMM) and the production flow database module (PFDM) are ready by now. The work is going on to complete the system software as a whole.

4. Simulation of the Functioning of the Machine Tool and Robot

In order to make the computer model of FRTC run properly it was necessary to develop programs simulating functioning of the machine tools and robot. All of them run under control of the CWCM module.

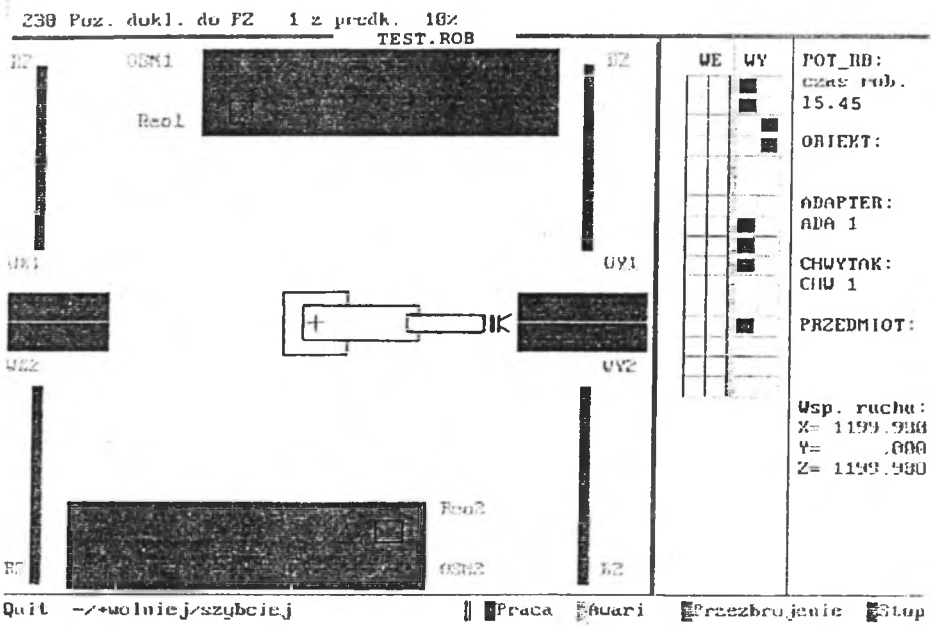

Figure 6. Picture of the graphical simulation of the functioning of robot

The aim of the robot work simulation program is the graphical simulation of its functioning in the FTRC, namely the graphical presentation of its state to check the correctness of the previously generated robot programs. Graphical presentation of the robot program is being carried out by a SYRB program module on a background representing the FTRC layout (Figure 6). This simulation

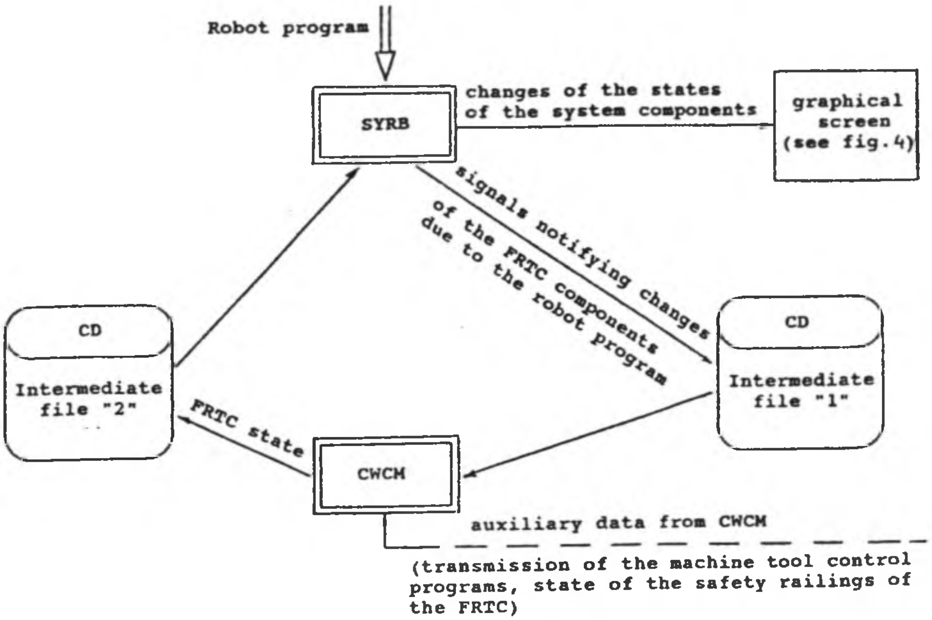

Figure 7. Links of the SYRB module with CWCM

program works in real time resulting from the real cell components' tending times according to the robot program. This program is generated by means of the robot programming computer based system SPMT-R/PC for the simulation purposes [9].Simulation of the robot's work makes it possible to represent the real state of the cell being modelled, it also enables the user to verify the logical interdependencies among the system components and evaluation of the real production cycle in the FRTC. The graphical screen presents al information necessary for obtaining the full control of the state of the FRTC modelled, e.g. symbol of the robot program being carried out, current coordinates of the robot trajectory, succesively executed robot program instructions and the input/output states of the robot numerical control system (Figure 6) through which it communicates with its FRTC surrounding. The abovementioned I/O system enables the robot to monitor and change the state of the binary state components like input and output storages, gripper storage and the reorientation stands. Changes of the states of these components caused by the robot functioning, i.e. by taking a workpiece from a storage, change of grippers and others are being noticed by the CWCM module and all changes occurring are illustrated in the simulated FRTC model by the SYRB module. Links of the SYRB module with the CWCM one are shown in Figure 7.

Program simulating functioning of the NC machine tools is designed in the same manner and it mimics carrying out of all the NC machine tool technological tasks being a component of the modelled cell, e.g. notifies succesful transmission of the machining control program for a given workpiece, starts the machining cycle upon obtaining the relevant signal from the CWCM module (when the machine tending task by the robot is completed), simulates graphically current stage of the machining program, interrupts the simulation process upon a signal from the CWCM and generates randomly or due to the keypress a machine tool breakdown. The graphical screen of the machine tool activity simulation presents all data necessary for monitoring of the current state and stage of realisation of the machining program: IDs of the machine tool program, workpiece, tools involved and times relating to the machining program, information about the equipment employed, etc.

5. Recapitulation

The control and production monitoring system will, in case of the computer model, enable the user to investigate the various disturbances on the FRTC throughput. When the system is installed in the real production cell cutting down of the down times of the cell shall occur - both in the break down situations as well as during the prescheduled worn out tools' replacement and change of the equipment for the new job.

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