

CONTROL SYSTEM WITH PROGRAMMABLE LOGIC CONTROLLER FOR METAL FORMING

Vasile Marinescu, Cătălina Maier, Viorel Paunoiu, Valentin
Tabacaru

"Dunărea de Jos" University of Galați, Manufacturing Engineering Department,
vasile.marinescu@ugal.ro

SUMMARY

In the metal forming process with multiple punches, distributed on different axes, it is necessary to precisely control the axial position of multiple punch processing units. In order to control the flow of material in the mold cavity it is necessary to control the punching force and the control of the holding or clamping force of the semi-finished product. This paper analyzes the possibility of implementing these control functions with PLC (Programmable Logic Controller).

Keywords: Programmable Logic Controller, metal forming with multiple punches.

1. Introduction

Programmable logic controllers are specialized systems designed to perform the following functions: data processing and storage, input-output transfer functions and control functions of the various operating parameters of the industrial installations. Although the "logic-programmable" designator clearly indicates the existence of scalar processors, these machines can also process numerical sizes, so they can directly intervene in numerical control structures of complex control loops.

The Central Unit (UC) controls and supervises all operations within CLP, internal data transfer and instructions, processing instructions, real-time retrieval of information from the process, and transmission of orders to the process.

To store the program, all CLPs use RAM, EEPROM, and FLASH-EPROM memories. The first ones are used for the initial program development that, after complete testing, is enrolled in the EEPROM. RAMs are also used to store intermediate variables to capture input / output variables and to memorize internal counting, timing, PID control, and so on.

The input-output modules form the interface between the internal structure of the CLP and the following process, ensuring at the same time the isolation of the external CLP and the electrical compatibility with the exterior, the compatibility of the input or output signals.

The instructions used in CLP programming fall within the usual range of logic instructions, plus specific features resulting from the Ladder schema diagram or Grafcet diagrams.

Next, we will analyze the structure of a multi-point deformation machine, distributed on 2 axes, and give an example of PLC control system implementation.

2. Description of the machine structure

In this chapter we analyze the structure of a machine that allows punching, marking, drilling and cutting operations. Such a machine is intended for the processing of semi-finished products of type L, I, H

In Fig.1. a schematic diagram of such a machine is presented. The semi-finished product is placed on the roller and then fixed in the trolley pliers. The trolley can travel along the roller track 1, driven by a Mx motor controlled by a speed variator. The kinematic chain associated with the trolley is made up of a reducer R and a pinion-rack mechanism.

The machine is equipped with two punching processing units (Up1, Up2) which allow two-way machining. Each unit can move in parallel with one side of the semi-finished product and can be equipped with maximum three punches. Movements can also be made with the help of motors that maintains the toggle-nut mechanisms. The processing of the punches is performed hydraulically using a controlled hydraulic cylinder.

There are also two drilling units (UB1, UB2) that are moving solitary with the units to be processed. The rotation movement of the tool is achieved by means of electric motors. The propulsion movement is performed hydraulically by means of linear hydraulic motors. Adjusting the speed rate is done using droughts.

The marking is being done by using a special unit that has four cassettes where the characters required for the operation can be entered. The operation of the marking punch is also hydraulic. The semi-finished product can be cut with a cutting unit.

Each unit shown is provided with adjustable retaining force. The evacuation of the processed leaves is made by the roller track 2.

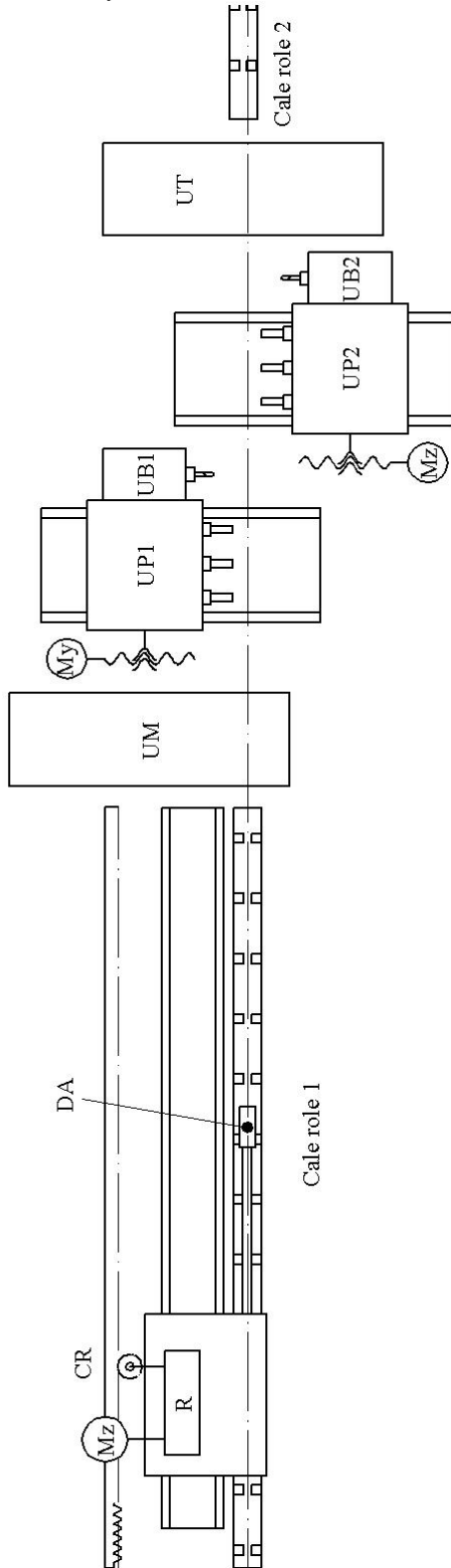


Fig. 1. The principle of the machine

From a hydraulic point of view, the machine has two main circuits (figure 2): a low pressure circuit B which is supplied by the pump P2 and a high pressure circuit A, supplied with the pump P1. The two pumps are driven by different electric motors.

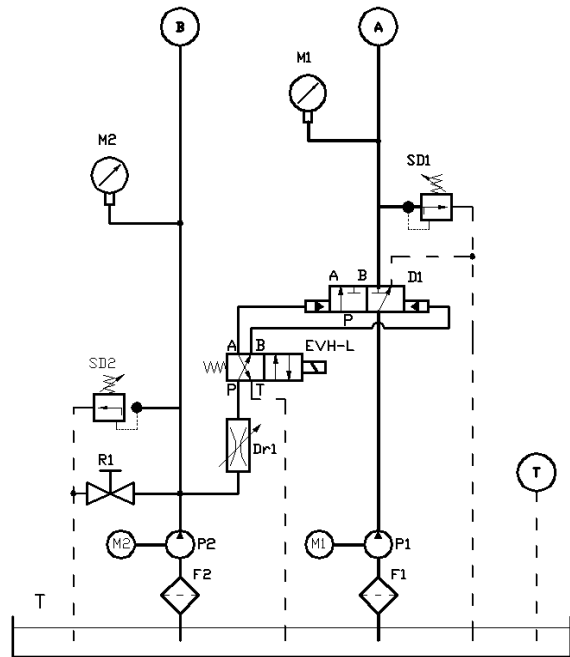


Fig. 2. Hydraulic plant diagram

Circuit A allows getting hundreds of bar pressure, required for deformation, punching, marking and cutting operations. If no processing is performed, circuit A is not supplied with oil. When supplying this circuit, it acts on the EVH-L solenoid valve that drives the hydraulically controlled distributor D1.

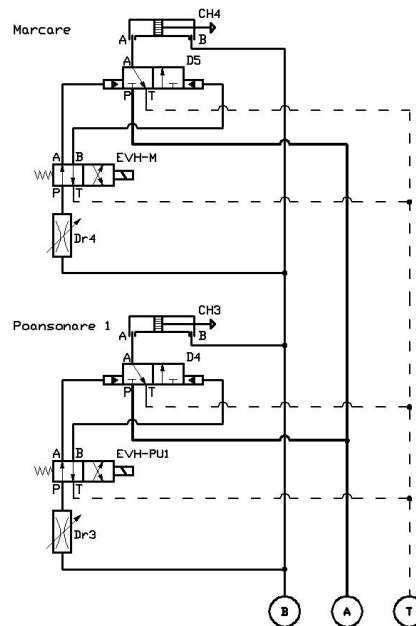


Fig. 3. Actuating the punching unit 1 and the marking unit

In Figures 3 and 4 we present the elements through which the marking, punching and cutting operations are carried out. To achieve this, the electrovalves: EVH-TP, EVH-PU2, EVH-PU1 and EVH-M are processed. These solenoid valves pilot the D2, D3, D4, D5 manifolds that allow the high pressure engine to enter the hydraulic clutches Ch1, Ch2, Ch3, Ch4. After executing the operation, the powering of the pilot valve solenoids is interrupted and the force cylinders return to the initial position under the action of the hydraulic agent in the hydraulic circuit B.

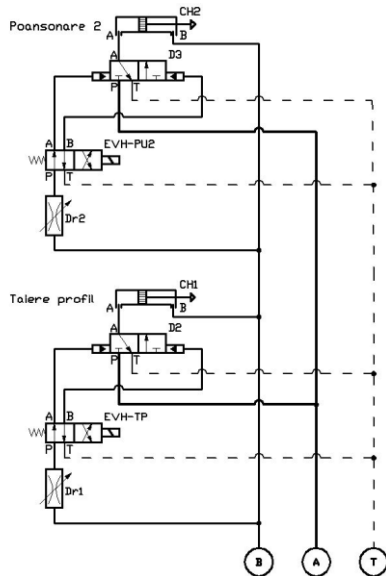


Fig. 4. Operating the punching unit 2 and the cutting unit

Each work unit has a number of elements to fix the semi-finished product. These elements are operated by hydraulic cylinders CH5, CH6, CH7, CH8. To stabilize the profile, the EVV-FP1, EVH-FP2, EVH-FP3, EVH-FP4 electrovalves coils are supplied. The hydraulic scheme associated with these fasteners is shown in Figure 5.

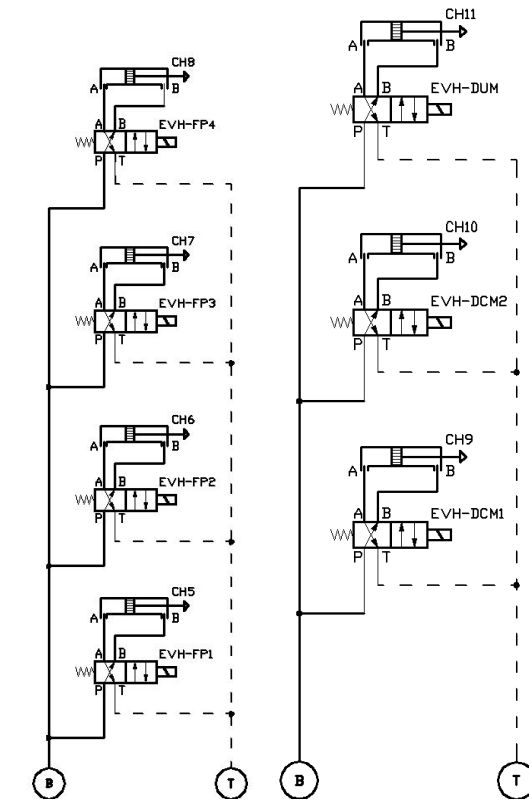


Fig. 5. Fix the profile

Fig. 6. Marking

In Figure 6, we show how to operate on the marker unit elements. For achieving the proximity of the semi-finished product through out the EVH-DUM solenoid valve, the marketing unit must be moved. Also, this unit is equipped with four cassettes with up to twelve characters. Selecting the box containing the characters to be printed on the semi-finished product is done by actuating the EVH-DCM1 and EVH-DCM2 solenoid valves. Hydraulic cylinders CH9 and CH10 are schematically represented, but it is noteworthy that they actually form a telescopic hydromotor.

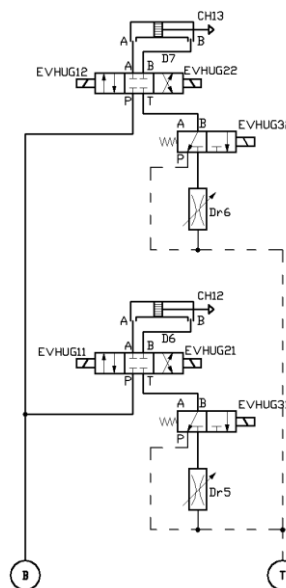


Fig. 7. Actuating of drilling unit elements

Each drill unit is equipped with a hydraulic cylinder for the advance movements. Considering the analysis of the operation scheme presented in Figure 7, the making of a fast-working-retreat with drosel on the drain pipe, it's possible. The fast advanced movement is performed by supplying the EVHUG11 or EVHUG12 coils when the EVHUG31 and EVHUG32 solenoid valves are not operated. This movement is used for proximiting the semi-finished product and the cutting tool. When the tool comes near the semi-finished product, it acts on the solenoid valve EVHUG31 or EVHUG32 corresponding to the drilling unit on which the movement will be performed. This will result in the slow advance movement required for processing.

After executing the operation, the fast retraction movement will be performed only by supplying the EVHUG21 or EVHUG22.

The magnitude of the displacement is determined by using cams which position can be adjusted and which are detected by position electric limiters.

The machine is also comprised of pneumatically operated elements. Pneumatic cylinders (Figure 8) CP1, CP2, CP3, CP4, CP5, CP6 are used to select the punch by with the processing operation will be performed.

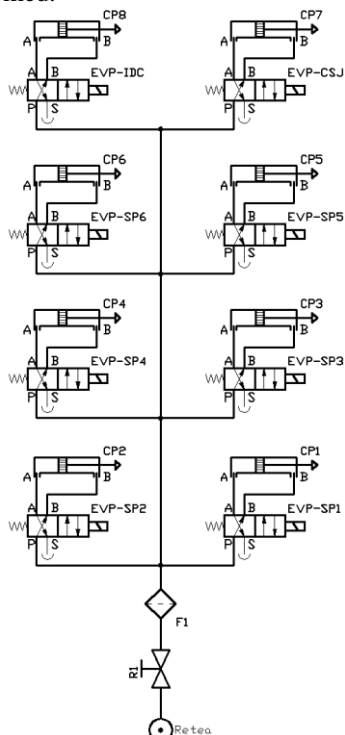


Fig. 8. Pneumatic scheme

In order to select a particular punch, one of the EVP-SP1, EVP-SP2, EVP-SP3, EVP-SP4, EVP-SP5, EVP-SP6 electrovalves will be supplied.

The CP7 pneumatic cylinder is used to raise or lower the blanking pliers of the semi-finished product. The CP8 pneumatic cylinder is used to operate the closing or opening of the tongue.

3. The implementation of the PLC control system

The machine control system was implemented on two levels: a superior level consisting of an industrial computer and a lower level consisting of a Programmable Logic Controller (CLP), which controls the execution elements and positioning systems of the moving parts of the machine.

In the computer, there is a software application running in Visual C ++ which creates the interface between the operator and the machine. This program takes the information needed to perform a technological cycle, process it and pass it on to CLP.

The communication between the computer and the PLC, which is necessary for the exchange of information, is accomplished by using OPC data server, which is based on OLE Automation technology. "OPC" allows real-time communication with CLP. For this reason, the computer program is the only one that controls the data transfer to / from CLP.

Through the application which creates the interface between the operator and the machine, the operator generates one or more *part programs* that can be saved in a database (DB).

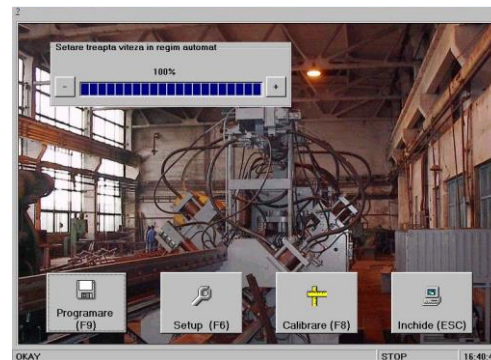


Fig. 9. Example of human-machine interaction

By *part program* (Fig. 9) it is meant a task string (more precisely punching, drilling, or marking), each task being assigned a program line. As the operator enters the program lines, the changes are displayed graphically in real time.

LINIA	TIP	PARTI	DIAMETRU X	Y/Z	DETALIU
>> 0001	LIN	DA*DB	21,5	30	60 PUNCH
0002	LIN	DA*DB	21,5	60	110 PUNCH
0003	LIN	DA*DB	21,5	885	60 PUNCH
0004	LIN	DA*DB	21,5	825	110 PUNCH
0005	LIN	DA*DB	21,5	1495	60 PUNCH

Fig. 10. Window for part program generation

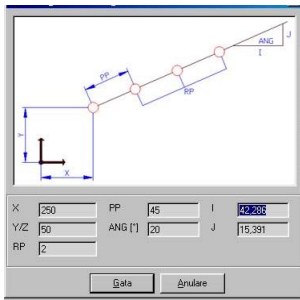


Fig. 11. LIN -
- Inline processing

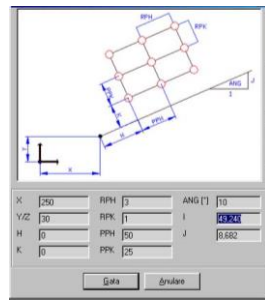


Fig. 12. MAT -
- Matrix processing

For each task it is necessary to specify how the operation (marking / punching / drilling) will be performed, the corresponding parameters for the complex instructions (LIN-Fig 11, MAT-Fig 12, FLA-Fig 13), the dimensions of the material, the features of the tool.

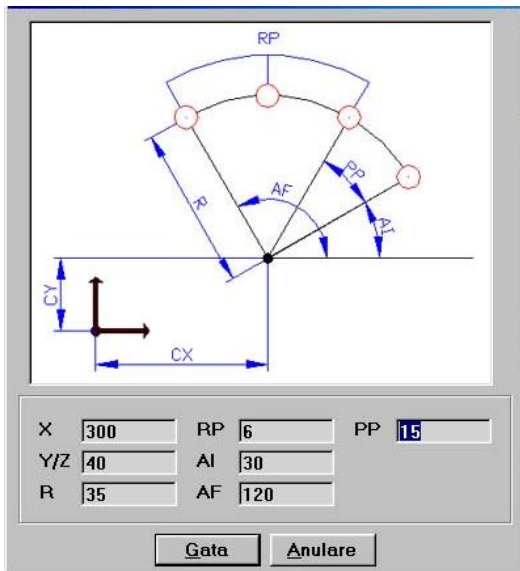


Fig. 13. FLA- On a circle processing

Subsequently, after the completion of the part program generation, the operator makes a selection (inclusion) of the piece programs to be executed from a semi-finished product.

3. Programming of Programmable Logic Controller (PLC)

The CLP program consists of 4 sections: a Ladder programmed section dealing with the analysis of the operating conditions (Generation_error), a main section programmed in Grafcet that handles the machine (Main), a programmed Ladder section handles manual handwriting from the programming panel and machine control panel buttons (Manual Commands) and a programming Ladder section dealing with the machine's manual mode (Regim_manual).

The "Main" program section performs the machine's command during an automatic work cycle,

as well as its command for calibration of the axes. Below we will present the Grafcet command diagram.

When the machine is started, Grafcet step 0 is activated, a step where a series of initializations of some variables are made, it will begin when the starting application of the automatic cycle is expected. Activating this step means disabling the program variables in the computer that make requests for running an automatic cycle, therefore calibrating the axes.

From step 0, it is possible to start executing the axis calibration branch of the M5 macro-step or starting an automatic cycle if the program in the computer activates the corresponding variable and there is no error. Macro-step M5 through which the machine axes are calibrated contains three execution branches separated by a divergence of type "Sau".

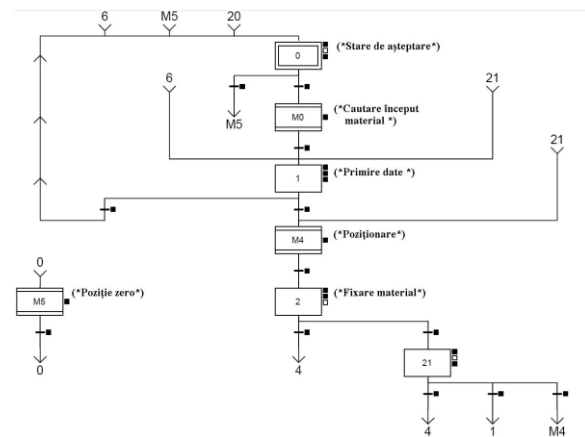


Fig. 14. Grafcet-pregatire pentru prelucrare

In Fig. 14 is the first part of the command Grafcet where is made the preparation for processing: "0" - Initial; "M5" – Macropas for making the zero positions of the axes; "M0" - Macropas to detect the beginning of the material; "1" - UC communication step for receiving data; "M4" - The positioning of the mobile axes according to the data received from the UC in the previous state; "2" -Staff where bending force is achieved.

In a calibration branch the following steps are performed: activate the channel of the movement module corresponding to the axis needed to be calibrated, force the value of the current position to the maximum value of the respective axis, command a negative movement of the axis which stop to the event, generates the event on the respective axis when the limit end is reached, the current value of the position is forced to a value representing the measured position of the end stop limiter that has been reached on the respective axis and finally command a move of the mobile part to a preset standby position.

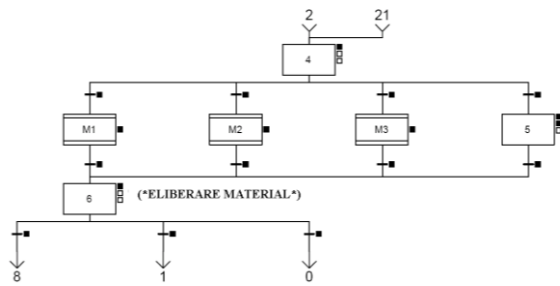


Fig. 15. Grafcet- processing operations

In Fig. 15 shows the Grafcet, which performs the processing of the operations: "M1" - Macropas by punching operation; "M2" - Macropas marking; "M3" - Macropas for drilling; "5" - Condition corresponding to the cutting operation; "4" - The corresponding condition where analyses of the operation must be executed; "6" - Status for deactivating the elements of the semi-finished product.

At the time of finalizing the execution of the last program, the track displays a message informing the operator of the completion of all operations and giving it an opportunity to decide what happens to the rest of the material. Thus, the operator may decide that the material be discharged and the carriage withdrawn, a decision communicated by the computer program to the CLP program by activating a bit, or decide that the material remains locked in the pliers and the carriage remains in the current position for later manipulations, a decision communicated by the computer program to the CLP program by activating another bit.

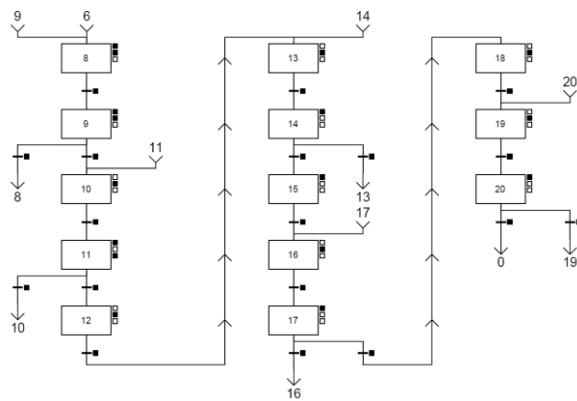


Fig. 16. Grafcet - Automatic material discharge cycle

If the operator decides to keep the material fixed in the pliers, it goes to the execution of Grafcet step 0. If the operator decides to evacuate the rest of the

material then proceed to the steps 8 to 20 of Grafcet. On this branch is ordered the lifting of the punching units, the lifting of the marking unit and the marking boxes, the movement of the carriage in the evacuation area, the release of the material by cutting off the clamping pin, the raising of the arm the retraction of the carriage to a predetermined coordinate, after which Grafcet- goes to step 0 to resume the entire cycle.

4. CONCLUSIONS

The research presented in this article enables to open perspectives in the field of control implementation of the metal working process with multiples punches distributed over several axes.

Modular structure of the PLC comande program and use of subroutines (macropas) that have a general valability, such as:

- the communication cycle with the upper hierarchical central unit,
- the positioning cycle of the moving parts at the zero point,
- moving cycle of moving parts during processing
- machining cycles through punching, drilling, cutting, marking, etc

determines the possibility of easily adapting the PLC program to different multi-axis punching machine structures.

REFERENCES

- [1] R. David and H. Alla. *Petri Nets & Grafcet*. Prentice Hall, 1992
- [2] International Electrotechnical Commission, Technical Committee No. 65. *Programmable Controllers – Programming Languages*, IEC 61131-3, second edition, November 1998. Committee draft..
- [3] SCHNEIDER ELECTRIC, *PL7 Micro/Junior/Pro Detailed description of Instructions and Functions*. 2011.
- [4] V. Marinescu, *Management of flexible processing systems*, Ed. University Foundation "The Lower Danube", Galați,
- [5] V. Marinescu - Numerical control systems and equipment- Volume 1-Programmable Logic Controllers, University book publishing house, Bucharest, ISBN 973-7956-14-1, 2004
- [6] V. Marinescu - Numerical control systems and equipment- Volume 2-control of stamping machines, University book publishing house, Bucharest, ISBN 973-7956-15-X, 2004
- [7] A. Ramirez Serrano, S.C. ZHU, S.K.H. Chan *A hybrid PC/PLC architecture for manufacturing system control- theory and implementation*, *Journal of Intelligent Manufacturing*,13, 261-281, Kluwer Academic Publisher, 2002