Ryszard SAWWA, Stanisław DWOJAK, Jerzy GRZEŚLAK
Industrial Research Institute
for Automation and Measurements PIAP.
W a r s a w, Poland

Jerzy SIKORA, Witold SIKORA
FIAT-Auto Poland
T y c h y

THE FLEXIBLE ROBOTIZATION OF THE MEDIUM PRESS LINE AT THE CAR FACTORY. THE RESULTS OBTAINED

The paper presents the results obtained on the robotization-automation of the medium size press line (300 T), for the press forming of the cars parts. The main solutions applied for fulfilling the factory requirements are described.

1. Introduction.

The robotized spot welding lines of car bodies and other car parts are used from a long time in the car industry.

As for the press forming technology, the level of robotization in this technology is presently much lower and therefore the robotization of it is actual task. Automation of the press forming technology is also necessary due to the hard and hazardous working conditions and to increase and stabilize the production quality.

Presently there are known some general solutions of the press line robotization. One of them bases on the use of the special, quick, electrically driven, cartesian coordinates robots, placed on traverses between the presses, above the level of the press tools. The main movement of these robots is linear, along the axis of the press line. Such automation introduced by Mecfond, Italy, works now at the heavy press line in FIAT-Auto Poland (former FSM-Tychy) car factory, which produces the cars under the licence to Fiat.

Another solution bases on the use of universal robots positioned on the level of the press base and on the press line axis. It is also known in such solution the use of the special, additional and quick rotation of the whole robots. The a/m, additional, quick rotating drive of the whole robots is introduced to meet the requirements of the press line output. Such automation is proposed by the Comau of Italy, which is the known producer of the robots for car industry.

Generally, some additional special solutions are necesary when the use of the robots with the main rotation speed of the order of 90° per sec. is planned.

The FSM-Tychy factory has introduced automation and robotization of production in the various technologies and in that in the press forming technology. The factory press forming department consists of a number of medium press lines and the heavy press lines (400 ÷ 1200 T). The medium press lines consist of 6 or 10 presses and are served, without robotization, directly by 7 and 11 workers. The project of medium press line robotization, for the FSM-Tychy car factory, was performed by Industrial Research Institute for Automation and Measurements, PIAP, Warsaw, with the cooperation of the factory staff and completed in 1991. The project was included into and was supported financially by the Governmental R & D Programme "Industrial Robots". Some support for project was granted by UNDP and UNIDO, which established the short project for that purpose.

2. The main requirements for the press line robotization.

The robotized line had to meet the following main requirements:

- instantaneous output — min. 8 pcs/min,
- flexibility — ability to produce 1 ÷ 3 different kind of drawpieces at the same time; for this purpose the line may be divided into the 2 ÷ 3 sublines, with separate inputs and outputs,
- the time of changing the production (beside the press tools change) — max. 1 hour,
- automation technical availability — min. 0.9,
- working staff — max. 2 persons,
- parts in the press positioning by robots grippers accuracy in x, y, z axis — max. ± 1mm,
- control system:
  - — easy reprogrammable,
  - — providing flexibility and diagnostics (presses, auxiliary, robots, grippers).
- during the changing of the press tools, the robots have to be retracted from the working area of the press line into the parking positions.

  Due to the a/m requirements and the fact that presses are founded on the steel truss, which conducts the vibrations to the robot manipulators, the test cell was built to examine first of all the vibrations influence. The test cell had to allow checking of:
- the practical robots shock-resistance,
- the robots positioning accuracy in the vibrations presence,
- the attainable instantaneous output of the line.

3. The investigations results at the test cell.

The test cell consisted of:

- 2 presses, first and second in the line,
- input module with the magazine-feeder of blanks and the IRb-6 loading robot,
- the IRb-60 robot, between the two first presses,
- the rack shedder and shute at the press 2 output,
- the safety barriers,
- the control desk,
- the pneumatically driven rail-tracks and the robots base with the rubber cushion on which the robots were positioned.

The IRb robots were produced by PIAP and were equipped with the shakeproof lock-washers.

The vibrations in the test cell were measured at many points during the press activity. There were measured: the vibration frequency, effective acceleration amplitude and displacement values.

The results of measurements proved that the vibrations acceleration did not exceed the permissible values for the IRb robots.

The displacements of the vacuum cap-lifter grippers ends caused by vibrations, being 0.05 mm for the IRb-60 and 0.04 mm for the IRb-6, were of an order less than the requirements for positioning repeatability of robots, which is ± 0.4 mm for the IRb-60 robot. So, the vibrations didn't cause the negative influence for the positioning accuracy of robots.

The control units of the robots were positioned outside of the truss, on the steady basement. The operation of the test cell proved generally the satisfactory stability, productional reliability and accuracy of the robots under the vibration conditions, at the medium press line.

At the beginning of the test cell operation the output equal to approx. 4 pieces per minute was attained, that is much less than required.

In order to increase the output, there were made the investigations in three ways:

- adjustments of the robots user work programmes,
- increasing of the maximal speed of robots,
- limitation of the main rotation angle of the second robot i.e. the IRb-60.

During the robots user programmes adjustments, for decreasing the press serving time by robots, there were also made some changes in the presses. As the examples may by cited:

— taking away some bars, which strongly complicated the robots trajectory,

— equalizing the level of the tools at the both presses.

After the adjustments and press changes the output of 6 pcs/min was attained.

To increase the maximal robots speed a change was introduced into routines for

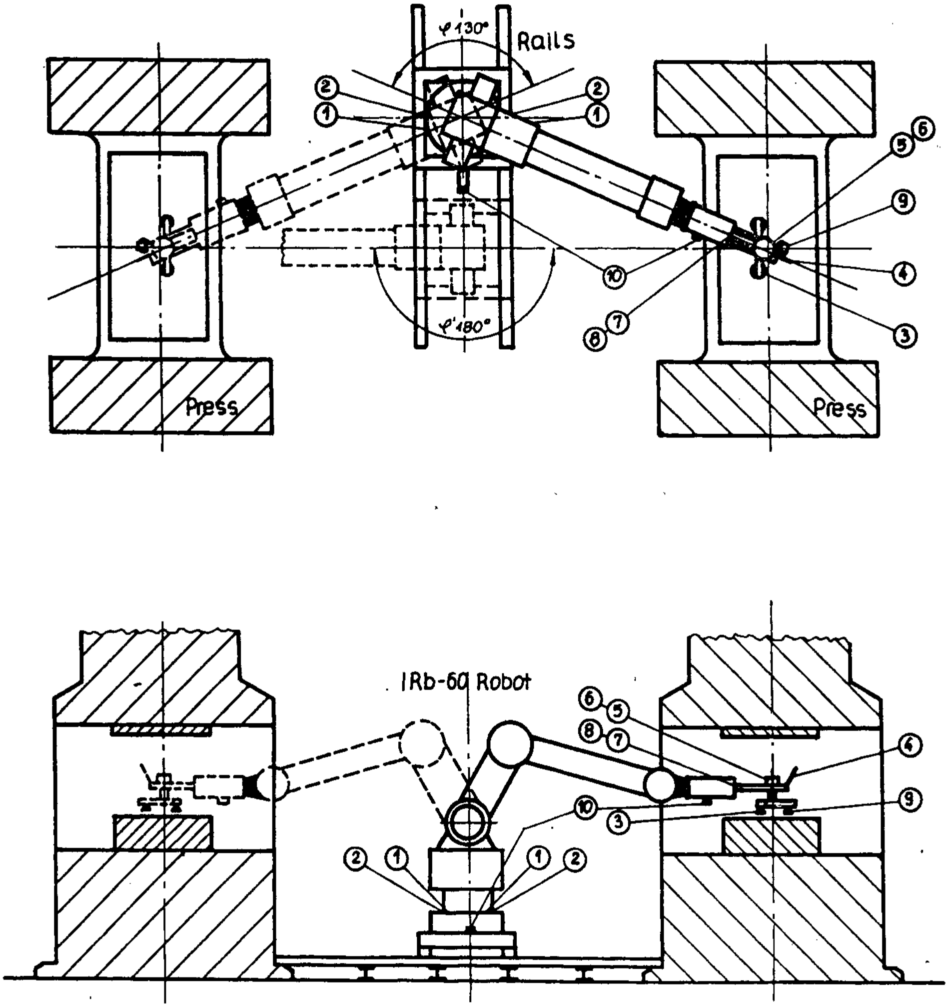

Fig. 1. Gripper Solution & Sensors. 1. Manipulator Anti-Colision Sensor (φ ⩽ 130°C); 2. Manipulator Anti-Colision Sensor (φ ⩽ 180°C); 3. Vaccum Caplifter Anti-Colision Sensor; 4. Gripper Anti-Colision Sensor; 5. Turn-Right Gripper Sensor; 6. Turn-Left Gripper Sensor; 7. Cylinder — Out Gripper Sensor; 8. Cylinder-In Gripper Sensor; 9. Drawpiece Presence Sensor, 10. Master-Position Sensor.

controlling the robots servos. Namely, the maximal value of increment for a new position setpoint of the servos was increased in every data transfer cycle. Also the electrical power suppliers of the servos were forced. All this was made after the calculation and practical analysis of the static and dynamic load of the robots. Moreover, the calculations performed on the basis of the robot design constraints proved that forcing the servos was permissible. These changes enabled to increase the maximum speed of robots as follows: the IRb-6 by 15% and by IRb-60 by 10%. The resulting practical output of 6.6 pcs/min was attained.

The limitation of the main rotation angle was achieved by retracting the IRb-60 robot manipulator from the press line axis and by using the gripper equipped with the pneumatic linear cylinder and pneumatic rotating motor. The maximal robot main rotation angle was reduced from 180° to 130° (Fig. 1). As the result, the instantaneous output higher than 8 pcs/min was attained.

4. The equipment and layout of the line.

The layout of the robotized medium press line 300 T is outlined in Fig. 2. The IRb-60 robots control units, the industrial host (PLC) controller with display, keyboard and printer and the line operator control desk, consisting of only the push-buttons and lights, are situated outside of the vibrating truss. The robots manipulators are retracted from the press line axis in order to provide the required output by limiting the angle of the main rotation. The IRb-6 press line input robot is situated at the press line axis, and it does not limit the whole line working cycle. All manipulators are located on the rail-tracks with robots base plate with the rubber cushions. Rail tracks enable the quick change of tools at the press line, by moving the robots out of working area to the parking position, with the aid of the pneumatic drive.

The flexibility of the line is the result of using the additional blank inputs and piece outputs, if needed. For example they are ahown in Fig. 2 as located between the 4th and 5th presses.

5. The line host PLC controller tasks

The industrial host (PLC) controller of the line, Simatic S5 155U of Siemens provides:

- the coordination of presses-robots interaction, including the press starting and the robots press loading /unloading movements permissions,
- the diagnostics of the line equipment with emergency stopping of the presses and

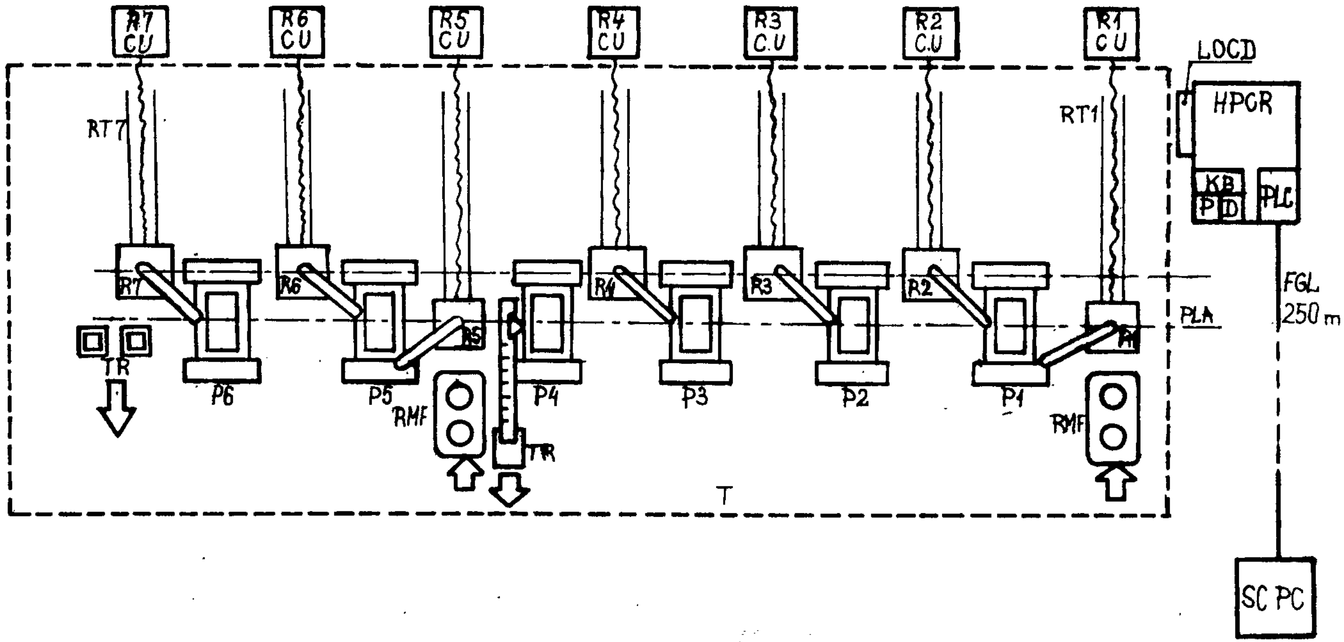

Fig. 2. Robotized Press Line Schematic Diagram. P1 ÷ P6 — Medium Size Presses; R1 ÷ R7 — Robots Manipulators — IRb-60; RT1 ÷ 7 — Rail Tracks; R1CU. ÷ R7.CU. — Robots Control Units; LOCD — Line Operator Control Desk; HPCR — Host PLC Controller Room (D — Display, KB — Key-Board, P — Printer); PLA — Press Line Axis; RMF — Rotary Magazine-Feeder; TR — Trays; T — Steel Truss; FGL — Fiber GlassLine; SC PC— Supervising Computer.

robots as well as the host control of the automatic testing programmes of the robots,

- the production data processing, i.e. mainly: supervision of the instantaneous output, counting the shift output and downtimes for different time periods and calculation of the actual utilization coefficient for the whole line and the technical availability coefficients for the three groups of the equipment, namely:
  - — automatics (robots, PLC controller),
  - — presses,
  - — others.

Due to the restricted visibility of the line operation, the PLC controller also provides the visualization of the line work at its monitor.

The controller performs all these tasks with the possibility of using the production flexibility of the line.

Due to the necessity of providing the required output and the diagnostics through reading "continuously" of many points, some of the sensors groups in the system are monitored directly by the controller.

6. The robots programmes.

The user programmes of the robots consist of the 3 main parts:

- the automatic tests of the robots inputs/outputs and auxiliary,
- the service tests — specific routines for finding the failure during service work,
- the user working programme, identical for every robot, diferentiating only in positioning points.

The sets of robots programmes:

- **Automatic Testing Programmes, executed automatically under the host (PLC) controller supervision:**
  - — Robots/Controller I/O Exchange,
  - — Grippers Test,
  - — Manipulators Master Positions Test,
  - — Test of Working Programme Numbers & Drawpieces Numbers
  - — Test of Vacuum Caplifters & Drawpieces Presence,
  - — Presses Tools Positions Test.
- **Service Programmes.**
- **User Working Programmes.**

The necessity to equip the robots with various types of sensors and tests is caused by small room inside and nearby the presses and due to the requirement of the very quick movement of the robot between the presses. The system of the sensors is really protecting the robots against the possible collisions which might occure during programming, testing or working activity.

7. The connection of the press line with supervising computer.

The robotized press line was connected, to the remote (approx. 250 m) IBM PC AT computer, located at the press working shop management office by the fiber optic line. The Simatic S5 155U line host controller was connected with PC, with the aid of the RS 232 interface. The PC is equipped with the following programmes: RTM (Real Time Monitor), IMI/PIM (Intelligent Multichannel Interface/Process Image Manager). It is working in the real time and its user program enables to:

— collect the information on the actual state of the press line and on the production data, emergencies and downtimes,
— visualize at the monitor and print the above mentioned informations concerning the present day, the day chosen in a month, the chosen month in a year,
— visualize and/or print the information on the most frequent downtimes caused by chosen specific reasons,
— visualize and/or print the information on the summarized downtimes caused by the chosen specific reasons,
— calculate the technical availability coefficients for the various groups of reasons causing the downtimes: press tools, quality control procedure time, productional department, material delivery, rotary magazine feeder, presses, grippers, output equipment, robots failures and other reasons.

8. Conclusions.

- The vibrations of the truss on which the robots manipulators are situated at the medium press line do not jeopardize the standard, universal robots as the IRb-60 and the IRb-6 operation.
- The most difficult requirement to meet by robotization in the press forming technology, especially lines, is the line output requirement.
- In order to meet this requirement it is necessary to use the specific solutions, as described in this paper and in more details in [1].
- Substantial reduction of personel serving the line, from 7 to 1 ÷ 2 person was attained (for every shift).
- Preparing a design of the press line robotization, however, it is necessary to support the robots with some system of various types of sensors (in order to enable the

preliminary tests and proper movement control, diagnostics and emergencies).

- The accomplished robotization project of the medium press line has solved the basic problems of medium press line automatization and can serve as a good example for the next robotization of the press lines and their information link to the higher level integrating data system.
- The experience collected during the project of medium press line robotization was wider than robotization/automation itself. In order to evaluáte properly the actual utilization coefficients of the line as a whole, and technical availability coefficients of the various groups of equipment, and other reasons causing the downtimes, the investigation on various kinds of such coefficients has been performed and some new ones were formulated, proposed for use.

This last problem is essential for the press forming technology and also for such the systems, where the normal, average actual utilization coefficient is close to 0.5. The results obtained were presented in the paper "On the Operational Performance Evaluation of the Automated-Robotized Productional Systems" [in Polish] [2]. The practical experience on the robotized medium press line implementation were presented in the paper "The Experience on the Robotized Press Line Implementation at the FSM Tychy". [in Polish] [3].

References:

[1] R. Sawwa, St. Dwojak. The Flexible Robotization of the Press Line at the Car Factory using the Industrial Controller. Biuletyn MERA-PIAP Nr 1-153/91. Also as the paper at the IEEE International Workshop on Intelligent Motion Control, Turkey, Istambuł, August 1990.

[2] R. Sawwa, St. Dwojak. O ocenie eksploatacyjnej zautomatyzowanych-zrobotyzowanych systemów produkcyjnych. Biuletyn PIAP Nr 6-158/91.

[3] J. Grześlak, E. Łukasik, R. Sawwa, S. Świder. Doświadczenia z wdrożenia zrobotyzowanej linii pras w FSM Tychy. Zeszyty Naukowe Politechniki Śląskiej. Automatyka. Z. 110. Gliwice. VIII Krajowa Konferencja Automatyzacji Dyskretnych Procesów Przemysłowych. Kozubnik k. Porąbki 1992.09.16÷19.