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Application of Industrial Robots in Various Manufacturing Operations

Leonid Martovytskyi[1], Anatolii Sochava[1], Vasylii Glushko[1], Zoia Shanina[2], Roman Frolov[3], Olena Syvachuk[4]
[1] *PhD in technical science*
[2] *PhD in Mathematics and Physics*
[3]*Senior lecturer, Department of Machine Parts and Handling Equipment*
[4]*Senior lecturer, Chair of foreign languages*
Zaporizhzhia Polytechnic National University
64 Zhukovskoho str., Zaporizhzhia, Ukraine, 69063
ORCID: 0000-0002-6839-1840, 0000-0002-7640-2589

Abstract : The functionality of existing and new industrial robots and their application in various manufacturing operations can be expanded by replacing the old control system with "rigid" logic by a modern one, based on microcontrollers, as well as adding to the manipulation system other manufacturing capabilities: measuring the weight and temperature of the manipulated object, increasing the accuracy of positioning and rigidity of the manipulation system by structural methods, expansion of mobility on the principle of "robustness" of the robot.
The purpose of the study was to find a way and develop means of expanding the functionality of existing and new industrial robots and their application in various manufacturing operations while minimizing economic costs and without large-scale reconstruction of basic models.
Methods of research. The functional analysis of the three-stage industrial robot МП-9С, which is widely used in industry, is applied. At the same time, the necessary production functions that robot MP-9C should have are investigated. Functional flexibility and the possibility of transforming new proposed schemes of robots is justified.
Findings. There have been developed and experimentally investigated the efficiency and functionality of equipping the gripper of МП-9С robot with tactile sensors to record the presence of load in the gripper and measure its weight. The operation of the thermocouple in order to measure the temperature of the load in the gripper was also experimentally studied. The algorithm and scheme for transmitting information from additional sensors to the robot control system have been developed and tested, which has significantly expanded its operational functions.
Scientific novelty. The vast majority of industrial robots are designed to handle loads in a three-dimensional working space, i.e. designed to perform only transporting and unloading operations, which is functionally insufficient for modern production processes. Providing industrial robots with additional functions, as well manufacturing new robots with extensive functions beyond simple movement is a timely scientific requirement for modern industries.
Practical value. Industrial robots with the help of additional functions can independently perform an extended set of works with a limited range of industrial equipment.
Keywords: industrial robot; functionality; microcontroller system; strain gauges; thermocouples; non-supported manipulator.

Modern automated production requires a high level of functionality from the executive and service devices, machines and appliances, if not at the level then at least close to human functionality. These requirements apply to both high moving function and intellectual perfection of machines. All this is especially relevant when providing supplementary production operations, such as: transporting, loading and unloading, packaging, warehousing, etc. These operations, in contrast to the main manufacturing operations, are low-automated and high-cost.

One of the means of automation of production is robotics, i.e. automation of processes with the help of industrial robots (IR). Functionally advanced robots with artificial intelligence and with elements of sensitivity correspond well to conditions of highly automated modern production, but they are high-cost products. Under conditions of economic crisis even in highly developed countries, the main economic guideline is resources and costs saving, which corresponds to the total concept of gaining the maximum profit with minimum capital investment. That is to say, robotization by minimal and simple means, using existing cheap and simple industrial robots, which are robots such as МП-9С, with a certain level of remodelling, is one of the most justifiable trends in production automation.

In forging, there is a need for people to safely unload workpieces, heated to a certain temperature for subsequent manufacturing operations, by simple means out of the heating furnace. For this purpose it is necessary to control the guaranteed grab of the workpiece by the IR gripper and to carry out rather exact control of temperature of the workpiece. The industrial robot МП-9С appears to be such a simple and cheap tool with a high level of automation.

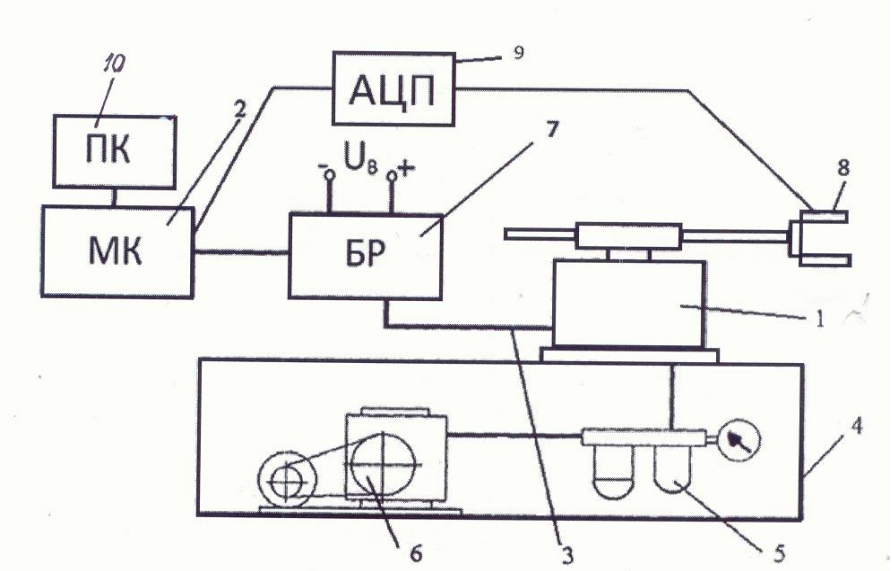
The simplicity of design of this manipulator and its high operational reliability determined its wide use in production. But over the years, along with a reliable and easy-to-maintain mechanical part of the manipulator, the computerized digital device ЕЦПП-6030 has become obsolescent. The device is built on the basis of chips with "rigid" logic and is designed to control only the movements of elements of the manipulation system (MS). For this reason, there is an uppermost need to redesign the old control system using programmable microcontrollers МП-9С with microcontroller system AVRATmega R20 (Fig. 1).

The robot consists of a manipulator with pneumatic actuators and an computerized digital device ЕЦПП-6030 with a cyclic control system. The robot operates in a cylindrical coordinate system, has three degrees of mobility and a drive to open the gripper. The maximum positioning error is ± 0.1 mm. The maximum capacity of programs is 30 steps, which are performed one by one.

The manipulator is put in motion by seven electropneumatic valves. Each movement is performed by the corresponding pneumatic cylinder except for closing of the gripper. The manipulator gripper is closed by means of a spring. For switching of electric valves the direct current with a voltage of 24V is used, and power supply of the microcontroller is 5V. Therefore, a unit of 7 low voltage electromagnetic relays was used to control electric valves. The control signals from the microcontroller alternately turn on the appropriate electromagnetic relays, which close the power supply circuit from an external source for 24V.

The ready-made Arduino Nano board based on ATmega328 was used as a microcontroller, due to a number of advantages:

- compactness, the size of the circuit board allows placing it in the case of the manipulator;
- the presence of a large number of digital outputs, which allows you to connect a large number of sensors and relays;
- built-in software downloader;
- a simple and common programming language C++.



1 – manipulator; 2 – microcontroller; 3 – connecting cable; 4 – base; 5 – air filter; 6 – compressor; 7 – relay unit; 8 – gripper with strain gauges and a thermocouple; 9 – analog-to-digital converter (HX711 and MAX6675); 10 – PC – personal computer

Figure 1 – Schematic diagram of the robot МП-9С with a microcontroller

The Arduino development environment is used to program the microcontroller, after which the cycle program is downloaded from the computer to the microcontroller.. Since all controls are connected in parallel and the power for electropneumatic valves comes from an external source, it remains possible to control the manipulator from both the ЕЦПП-6030 and the microcontroller.

Strain gauges are mounted on the fingers (lips) of the gripper to create sensitivity functions, which helps to determine the presence of the object to be manipulated in the gripper and to determine its weight. In addition, a hot junction of a standard chromel-alumel thermocouple is mounted here, which allows determining its temperature in contact with the heated workpiece in the gripper. (Fig. 2).

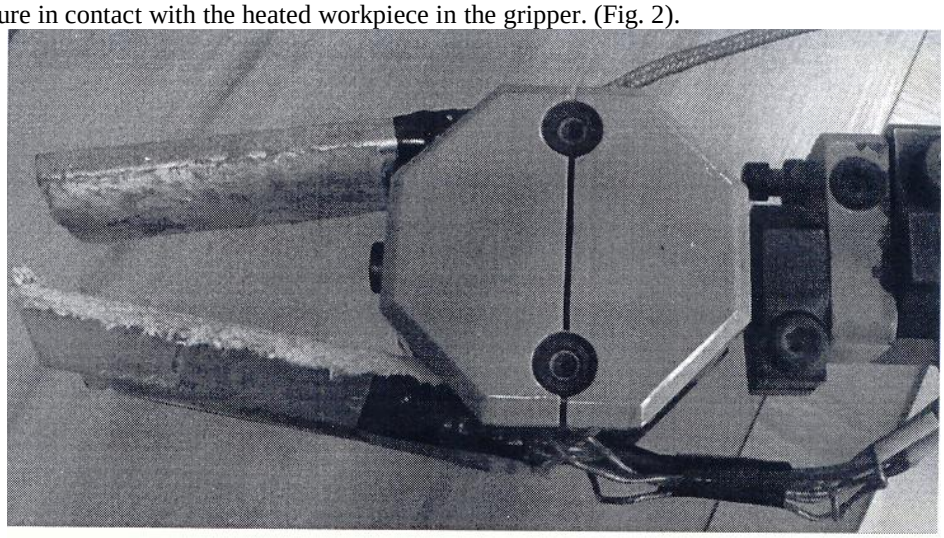


Figure 2 – Gripper with strain gauges and a thermocouple

The PR manipulator in which functional advantages are both the increased rigidity and accuracy of positioning is offered. The manipulator (Fig. 3) includes a base 1, functional units made in the form of eccentric platforms 2-4. Engines 5-7 and gears 8-13 are used to ensure the rotation of the platforms. The platforms are

connected to each other and to the base by circular movable rolling bearings 14-16. The gripper 17 is attached to the inner platform with the possibility of rotation from the engine 18 through gears 19-20 and longitudinal movement from the engine 21 through the bevel 22-23 and rack 24-25 gears.

Longitudinal movement of the gripper, i.e. its positioning in direction perpendicular to the platforms, is carried out from the engine 21 through the bevel 22-23 and rack 24-25 gears.

The manipulator works as follows. When the signal for processing comes, eccentric platforms 2, 3, 4 receive rotational motion from the respective engines through the gear pairs 8-9, 10-11, 12-13. The platforms rotate relative to the base 1 and relative to each other. Since the platforms 2 and 3 have eccentricities e_1 and e_2, while the gripper is attached to the platform 4 with its eccentricity e_3, the rotation of the platforms leads to the movement (positioning) of the gripper 17 in the plane.

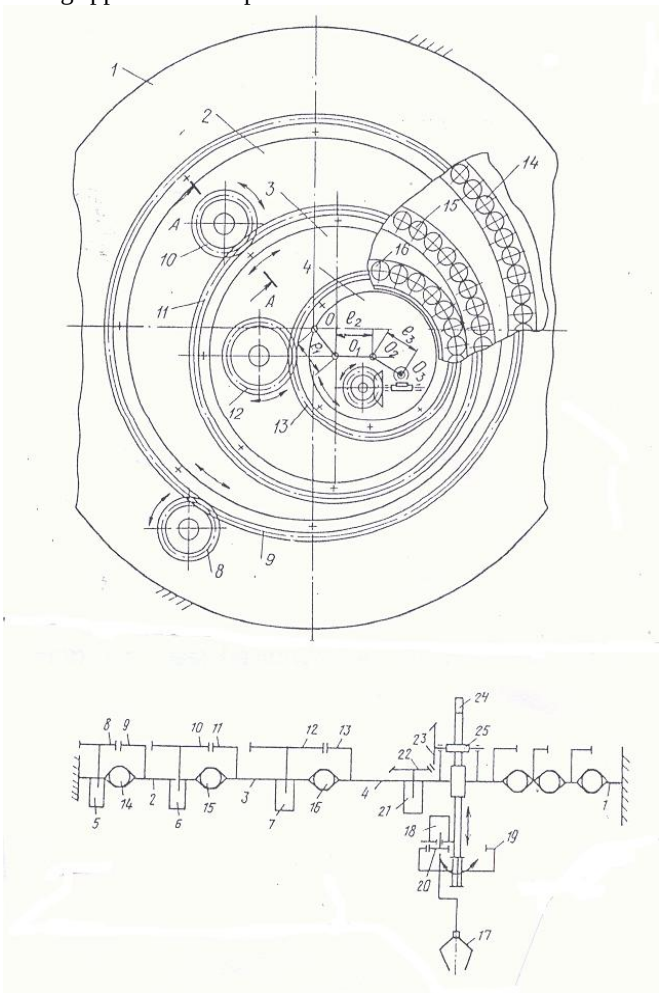
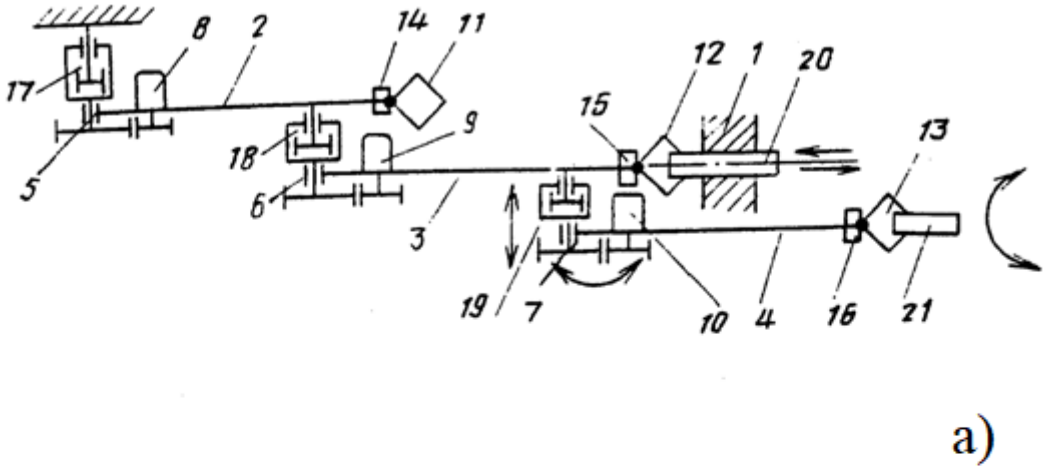


Figure 3 – Manipulator with eccentric mutually movable platforms

The use of functional elements in the form of eccentric fully-turning platforms allows to increase manufacturing capabilities, accuracy of positioning of the manipulator, at the expense of complete reach and reduction of approach increment in relation to discrete of turning platforms, i.e. positioning errors of the gripper. In addition, the coupling of the units with circular movable supports provides static rigidity on the gripper, which further increases the accuracy of positioning.

It is possible to improve the positioning accuracy by increasing the rigidity in dynamic modes for the well-known articulated element manipulator. The redesigned manipulator in stretched and drawn states is shown in Fig. 4. The manipulator includes a base 1 and final control elements 2-4, which are interconnected by rotating

pairs 5-7. Each element has basic independent drives 8-10 of their relative rotation, and are also provided with grippers 11-13, accordingly.



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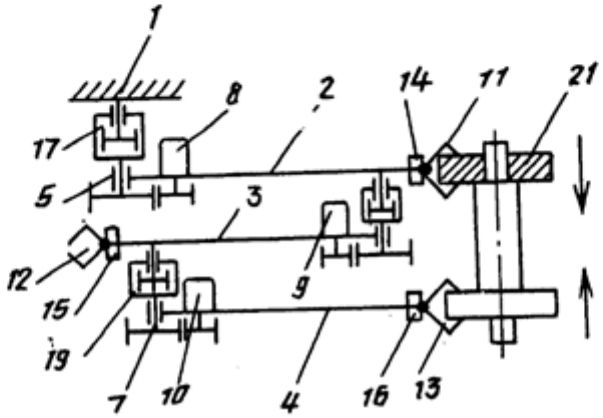

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Figure 4 – Redesigned manipulator in the stretched *а)*and drawn *б)*states

The grippers are made with the possibility of rotation from the drives 14-16 and additional translational movements from the drives 17-19 perpendicular to the axis of the previous elements. On the base 1 of the manipulator there can be installed sliding or other temporary supports 20 for possible fixation of grippers 11-13 onto them.

The manipulator works as follows. Final control elements 2-4 rotate on the base 1 and relative to each other, from the drives 8-10 and progressively move from the additional drives 17-19. Grippers 11-13, which are installed on each element, have the ability to rotate from drives 14-16. Any of the grippers can take and move the object 21 or be fixed on the sliding temporary support 20.

Due to the latter, the rigidity of the manipulator increases and the positioning accuracy rises. The simultaneous use of several grippers also increases the productivity of the industrial robot.

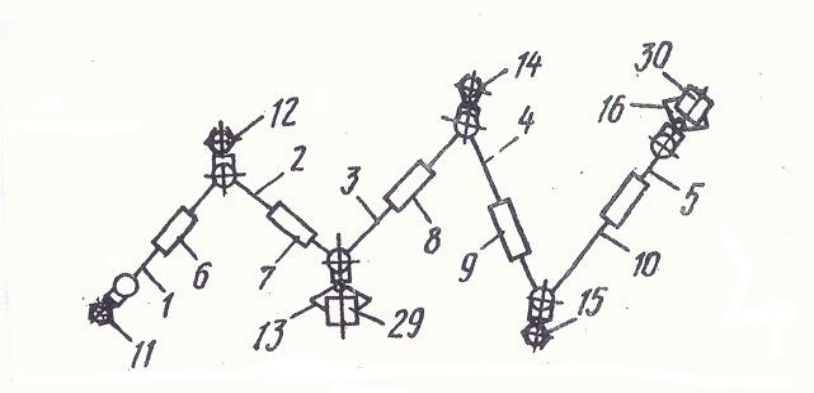

Figure 5 – Diagram of non-supported manipulator

Further expansion of manufacturing functionality of industrial robots may enable abandonment of traditional immovable support stands towards non-supported manipulators (Fig. 5). Grippers 11-15 are installed on temporary supports, as on racks. The grippers 13, 16 move the objects of load 29, 30. Temporary supports can be replaceable, portable, stationary or sliding. Portable supports serve as "legs" when moving the manipulator. The manipulator can also move based on a system of fixed supports, the configuration of which will determine the trajectory of the manipulator.

Conclusion

The appropriate level of functionality of industrial robots can be achieved not only by developing and manufacturing new industrial robots of higher levels, which is expensive and costly, but also by redesigning and equipping existing robots with supplementary devices as well as replacing old control systems with "rigid" software by modern microcontrollers.

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