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Automatic Sorting System for Educational Training

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***Abstract* - At the same time as the introduction of automated equipment in industry, production operators and maintenance workers servicing automated stations require professional training courses depending on the category and job. Depending on the particularity of the production process, these training courses can be done internally at the production unit, at external industrial partners or at universities. The paper presents an automatic tire sorting system made on a small scale. The sorting system is composed of an input stock and two output stocks of sorted tires. Tire storage in the two output stocks is done with an electro-pneumatic manipulator robot. The sorting is done according to the tire bead width, for which the system is equipped with the appropriate sensors. The structure is controlled by an Arduino Mega2560 microcontroller development system. The sorting station can also be controlled manually by the operator via a joystick and some buttons. In comparison to other sorting systems, the robot structure is simpler. It performs the transfer of the tires by only two movements, thus reducing the handling time. Also, the automatic sorting system realized corresponds to the requirements imposed on flexible production systems. The automatic system can be used both for training students from technical faculties and industrial operators in the field.**

Cuvinte cheie: *sortare, sistem automat, actionare pneumatică, microcontroler senzori, robot manipulator, pregătire educațională.*

Keywords: *sorting, automatic system, pneumatic drive, microcontroller, sensors, manipulating robot, educational training*

I. Introduction

Industry in general and in the machine construction, in particular, requires great flexibility of the manufacturing process, flexibility enabling the transition easy from the technical and cheap in terms of equipment and labor to another manufacturing. In this context, it is necessary to design and implement special equipment that will be comprised of flexible automations. An important role in this equipment you have manipulators and robots, which ensure the construction features and functional characteristics and quality indicators for flexible manufacturing [1].

Robots and manipulators are the most complex and flexible machines that have been created and used by man so far that incorporate pneumatic drives. Taking into account these considerations the paper presents an automatic sorting system using a manipulator robot and a pneumatic actuation system. Industry needs knowledgeable, skilled robotics engineers, technicians, and operators. The application enables trainers to successfully integrate robotics into programs and lab facilities [1], [2].

The automatic sorting system presented in the work represents a small scale model of an automatic tire sorting system. It can be used for the educational training of students, but also of staff in the field.

II. Descrption Of Sorting Station

A. Structure of a sorting station

The various products resulting from the manufacturing process require sorting and palletizing operations. The sorting facility is composed of an electric drive system (SAE) and an electro pneumatic one (SAEP), under the coordination of a control system (CS) which, based on the operating protocol, ensures the control laws (Fig.1) [3], [4]. The control system receives the information from the sensory system (SS) regarding the state of the system and provides the commands to the actuators in the drive structure to realize the functional diagram.

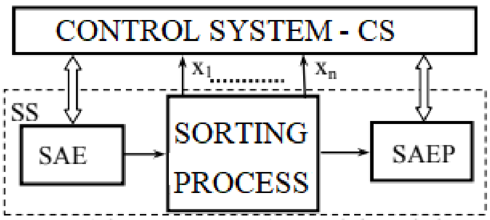


Fig. 1. Structure of sorting station.

The tire sorting station is based on a manipulator robot that sorts tires according to the program selected by the user.

The tires are brought by conveyor belts to the point of collection where they are caught with the help of a gripper, here the selection process also takes place (depending on the bar code placed on each bead, depending on the width of inches) and the tire is placed on another conveyor that transports it to the storage points [5].

Robots used in sorting operations must be equipped with guiding devices with 5-6 degrees of mobility, universal or flexible gripping devices (pincers). Most of the time, such robots are equipped with autonomous travel systems, and sometimes with remote control systems. The drive system of robots of this type can be electric, hydraulic or combined.

The control system must contain surface and/or volume evaluation programs. He must ensure the command of the peripheral devices, process the information collected by the sensors about the nature of the manipulated objects and their arrangement, and modify the behavior of the robot according to this information.

B. Design of sorting system for educational training

The educational application refers to a system for handling and sorting pieces according to their width.

Figure 2 shows the layout of the component blocks on the training board.

The manipulator has two axes, the first actuated by an electric motor and the second by a pneumatic cylinder.

The position information is taken from the sensors of each axis.

To carry out the sorting operation, the analysis of two signals generated by a distance sensor located at the end of the gripper will be considered.

At the base of the control process is the command and control unit, which manages the entire process, as well as the man-machine interface [6], [7], [8].

Based on the operating principle of a closed-loop control system, the command and control block takes the information about the positions of the system elements from the position sensors, and the information about the width of the piece gripped in the gripper from the distance sensor.

Following the processing of this information, according to a pre-established program, command signals are generated to the pneumatic actuators [9], [10] (Fig. 2).

Sorting process parameters can be viewed and modified through the user interface.

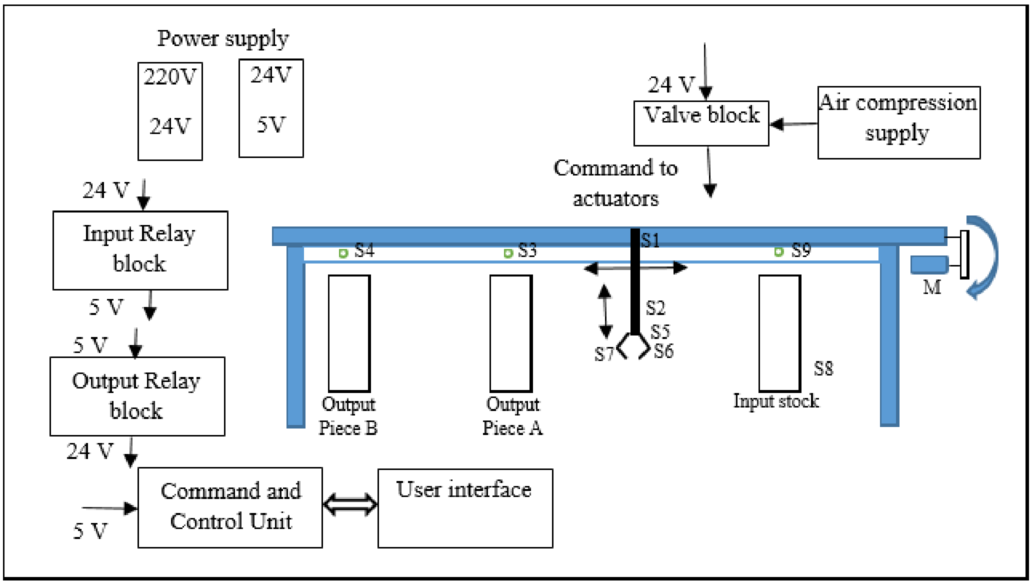


Fig. 2. Training board of sorting system - the layout of the components.

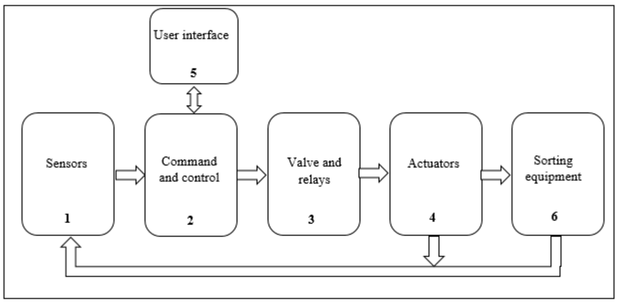


Fig. 3. Block diagram of a sorting system.

The block diagram of the system (Fig. 3) contains 6 blocks:

➢ Block number 1: it is made up of the 9 sensors of the sorting robot:

Sensor 1 - arm up position;

Sensor 2 - lower arm position;

Sensor 3 - center robot position (piece A);

Sensor 4 - left robot position (piece B);

Sensor 5 – detection of type A piece;

Sensor 6 - detection of type B piece;

Sensor 7 - gripper status;

Sensor 8 - piece presence sensor;

Sensor 9 - right robot position (initial position).

➢ Block number 2 – the command and control block, is the part of the application that deals with the management of input and output signals and decides the operation of the application after an established automatic cycle or the execution of commands manually. It operates in two modes: in closed-loop (control) and also with a human operator in the loop.

➢ Block number 3 represents the part of pneumatic solenoid valves [11] and the four motor control relays:

Relays RQ3, RQ4- left motor rotation;

Relays RQ5, RQ6- right motor rotation.

Individual solenoid valves are used for each movement of the manipulator:

Solenoid valve 1 – Up arm control;

Solenoid valve 2 - Down arm control;

Solenoid valve 3 - Gripper control.

Solenoid valves receive the command signal from the microcontroller and distribute the air pressure to each pneumatic actuator.

Block number 4 contains pneumatic and electric actuators:

Cylinder 1- Actuates the arm on the vertical axis;

Cylinder 2 - Closes/opens the gripper;

The motor – Moves the manipulator horizontally.

Block number 5 represents the user interface. It is composed of:

- an LCD that displays the current status of the system and the status of commands in manual mode;
- a joystick with 5 positions used for the manual controls of the robot;
- a safety power supply button, which interrupts the supply;
- a button with 3 positions used to activate the states: Automatic/Off/Manual of the system.

All 5 blocks work according to a set schedule.

The electronic handling system consists of three main subsystems:

The subsystem for determining the position, present in the form of a group of sensors related to each axis. For the y-axis, the sensors are mounted along the electric axis used to actuate the manipulator horizontally, for the z-axis, the sensors are mounted at the stroke ends of the cylinder.

The adaptation subsystem. The position signals generated by the sensors are 24V signals which are converted to 5V signals by a block of 9 relays.

The movement of the mobile elements of the system is carried out with of an electromechanical linear actuator and a pneumatic actuator, the tool is a pneumatic gripper.

Solenoid valve control subsystem

The adaptation between the signals generated by the command and control block, the 5V signal generated by the output pins of the microcontroller and the supply voltages of the cylinder control solenoid valves is carried out by means of a block of relays which, when activated, generate a 24V signal**.**

The command and control block receives the signal from the position sensors and from the differentiation sensor and presents the part by means of an input signal receiving module, consisting of a block of nine relays that, when activated, generate a signal of 5V.

The processing unit takes the results from the input port, equivalent to the values of the positions and the tire type, which it processes based on a program written in a memory block.

After processing, through the control signal generation module, the activation signals of the electro valve coils that control the pneumatic actuators and the electromechanical actuator are provided at the output [12].

The user interface system has a 20x4 character LCD display necessary for displaying internal and external parameters and for accessing the menu.

The data entry system consists of a 5-position joystick used for manual robot controls and a three-position button used to select the three system states: Manual, Off, Automatic.

In order to reduce the number of components as well as to benefit from the flexibility of programmable systems [13], the system is designed around an Arduino Mega 2560 microcontroller produced by the Arduino Company [14], which coordinates its entire operation.

The block diagram of the system based on a microcontroller is presented in figure 4.

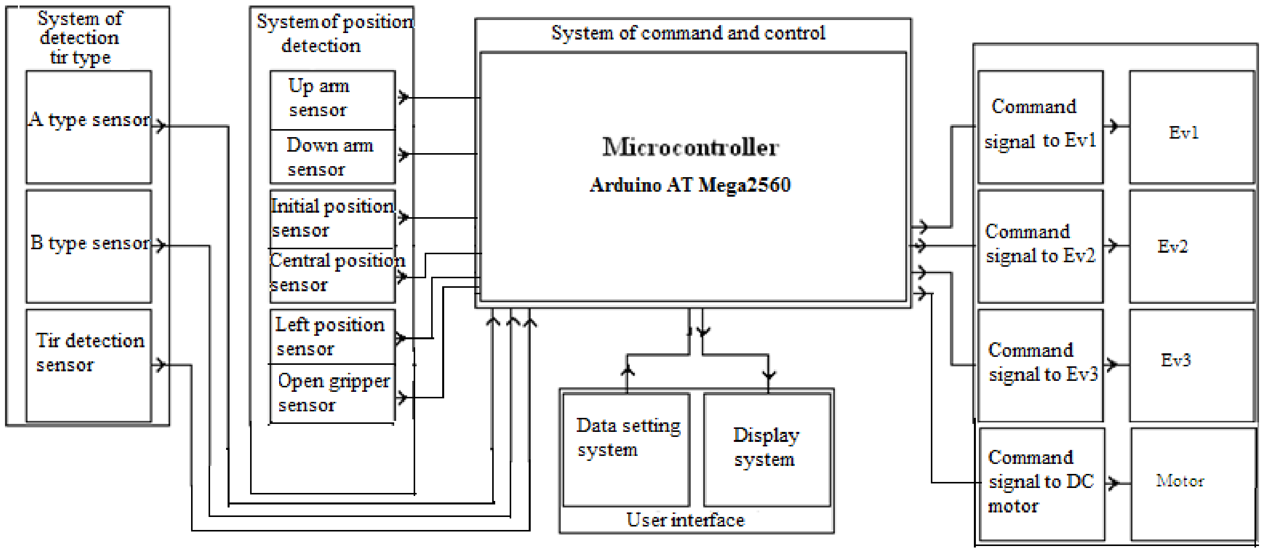


Fig. 4. Detailed block diagram of a educational sorting system.

The following functions will be implemented on the designed system:

- carrying out the cycle entered in the program automatically;
- interruption of the automatic cycle, with the possibility of its continuation;
- movement of robot by manual controls;
- displaying the position of the moving elements;
- determination of the width of the part gripped by the gripper;
- storage of objects in different areas (one for each implemented width);
- training the system regarding the association between the width of the piece and the area where it will be positioned;

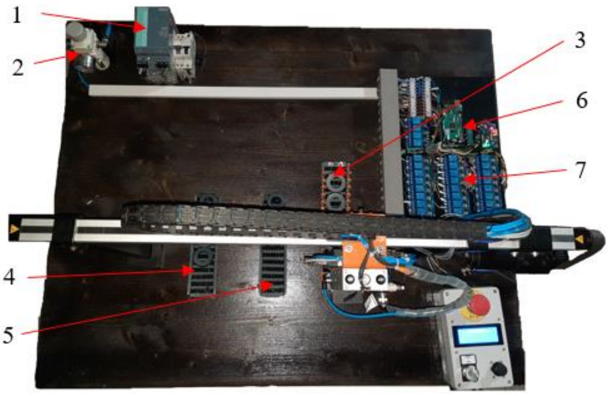
III. Implementation Of Automatic Sorting System

A. *Implementation of hardware part*

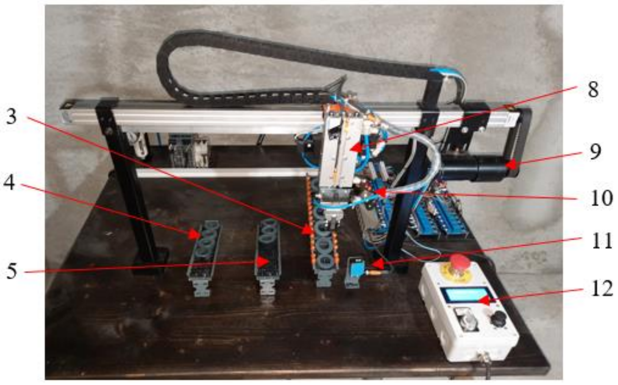
One method of verifying the proposed solution is to achieve an experimental model. Based on the structure presented above, an experimental model of the automatic handling and sorting system was developed. System components are represented in figure 5.

The components shown in the figure have the following meanings:

1- DC voltage sources; 2- group of compressed air preparation elements; 3- pieces input stock; 4- sorted pieces of type A; 5- sorted pieces of type B; 6- development system with microcontroller; 7- relay module; 8- handling robot; 9- DC motor for the translation of the robot; 10- sensor of position; 11 - sensor of detecting the presence piece; 12- operator console.



a) Top view



b) Front view

Fig. 5. Experimental model of the automatic sorting system

Within the designed system, the drive is performed by three actuators:

- a C3 linear electromechanical actuator for the translation of the arm;

- a C1 double-acting linear pneumatic actuator for actuating the up-down arm;

- a C2 single-effect pneumatic actuator to actuate the gripper.

The air preparation group is FR type produced by SMC [15] with the coding: AW20-F02-C-X64. This combination minimizes space and pipelines by integrating the two units into one.

Standard features include a regulator that can be quickly locked by pushing the adjustment knob down.

A pressure gauge is mounted on the control group. The filter cartridge provides a filtration rate of up to 5 microns/m.

For the distribution of compressed air to actuators, two types of solenoid valves were used:

• To actuate of the cylinders for robot, lifting and ro arm it used three bistable solenoid valve Festo [16] type: CPE14-M1BH-5J-Q-8;

• For the control of the cylinder that closes / opens the gripper, a Festo type XCPE14-M1BH-3GLS-1/8 monostable solenoid valve is used.

The actuators used to operate the robot and the collecting table is manufactured by Festo [16].

The feed rate is achieved by the pneumatic energy transmitted by the actuating valve; the return is done by eliminating pressure from the circuit and with the help of the spring return.

Waircon URG 5/8 type regulators have been used to control actuator speed. The "URG" series flow regulators are produced in in-line, unidirectional versions.

The "URG" model has a built-in control valve to control the flow in one direction, while the reverse flow is free. They are high precision regulators and can provide a high flow rate ratio and are very compact.

B. *Implementation of the command and control system*

In the implementation of the command and control system, the following aspects were taken into account:

- simplifying the hardware part and using as few components as possible;
- the possibility of easy system programming;
- providing internal and external parameters to the user interface.

To meet the above-mentioned requirements, a microcontroller development system was developed (Fig. 6).

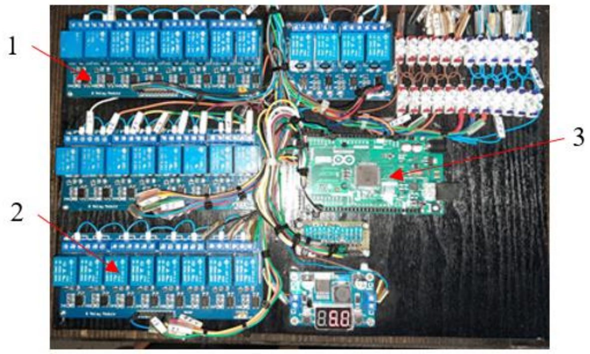


Fig. 6. Command and control system: 1- output relay module; 2- input relay module; 3- microcontroller development system.

For this purpose, the Arduino Mega 2560 microcontroller has been chosen [14].

The Mega 2560 is a development system built around the Atmega2560 microcontroller, which is equipped with numerous communication pins, analogs and PWM, useful for connecting with various elements: monitoring, control, control, etc. (sensors, relays).

It offers a number of facilities including:

- requires a small number of external components;

- has analogue inputs needed to connect the sensors;
- allows direct connection of an LCD display.
- can perform arithmetic and logical operations required in the sorting pieces process.

Arduino Mega 2560 is a ATmega2560 based microcontroller board. It has 54 digital inputs / outputs (of which 14 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), 16MHz oscillator crystal, a USB connection, a power jack, a ICSP header and a reset button. It contains everything it takes to operate the microcontroller. Simply connects to a computer with a USB cable or AC / DC adapter or battery.

The ATmega2560 has 256 KB flash memory for storing the code (of which 8 KB is used for Bootloader), 8 KB of SRAM and 4 KB of EEPROM (readable and written with the EEPROM Library). Arduino boards have a 1024 byte EEPROM space.

The Arduino Mega2560 has a host of facilities for communicating with a computer, with another Arduino or other microcontrollers. The ATmega2560 offers four hardware UARTs for TTL 5V serial communication.

A Software Serial library allows serial communication on any of the Mega2560's digital systems.

The ATmega2560 also supports I2C (TWI) and SPI communication. The Arduino software includes a Wire library to simplify the use of the I2C bus.

To obtain the 5V input signal in the microcontroller, the 24V sensor signal is passed through a relay block powered at 5V, and which is activated by the sensor signal sends a 5V signal to the input port of the microcontroller.

The sensors system of sorting station enables the acquisition of two distinct types of information:

- information on the internal parameters of the system (the position of each element);
- information about external parameters, in particular the dimension of objects grabbed by the gripper, which is the sorting criterion.

Two MK5100 IFM sensors were used to determine the two positions of the robot arm.

Closed open positions of the gripper are given by a pressure switch type: Festo SDE5-D10-O-Q6-P-M8 inserted into the pneumatic actuator of the gripper.

WF50-60B416 type sensor was used to detect the presence of the piece, and a contrast sensor produced by SICK K3L-P3216 was used to identify the color.

C. Implementation of Software Part

Arduino Mega can be programmed with Arduino ATmega2560 software. Arduino Mega has a preinstalled bootloader that allows you to load a new code without using an external programmer. It has an automatic reset button. It also performs overcurrent protection of the USB. Arduino Mega 2560 has a self-resetting fuse mounted to protect of the computer USB from short-circuit and overcurrent.

The Arduino program can be divided into three main parts: structure, values (variables and constants) and functions [17], [18].

The general structure of software for microcontroller is shown in figure 7.

The program starts with microcontroller initialization and variables used [6]. Implementation of various timings is possible by using a sequence of decrement of all counters used. Then follows acquisition of analog-digital signals, execution of algorithm, then transmitting the synthesized commands.

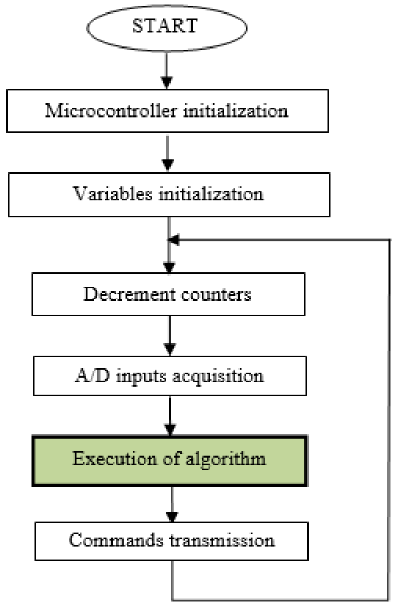


Fig. 7. Flow diagram of microcontroller program.

The main program algorithm for the automatic sorting station cycle is shown in figure 8.

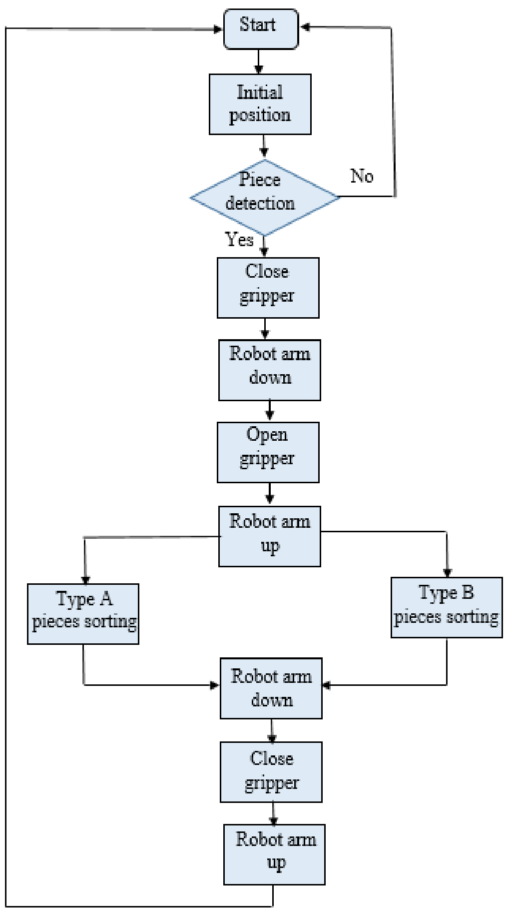


Fig. 8. Flow diagram of proper algorithm – automatic operation mode.

During the automatic sequence, the user cannot execute manual commands.

IV. TESTING OF AUTOMATIC SORTING SYSTEM

Testing actually consists of correct working verification according to the protocol and conditions imposed by design.

In figure 9 there are captured the operating states in a work cycle of handling-sorting station. These states were predefined in the design stage of automatic handling-sorting system (Fig. 8) for the purpose of verification and easier debugging.

The 6 states of operation are highlighted in the figure by the positions occupied by the manipulating robot (RM).

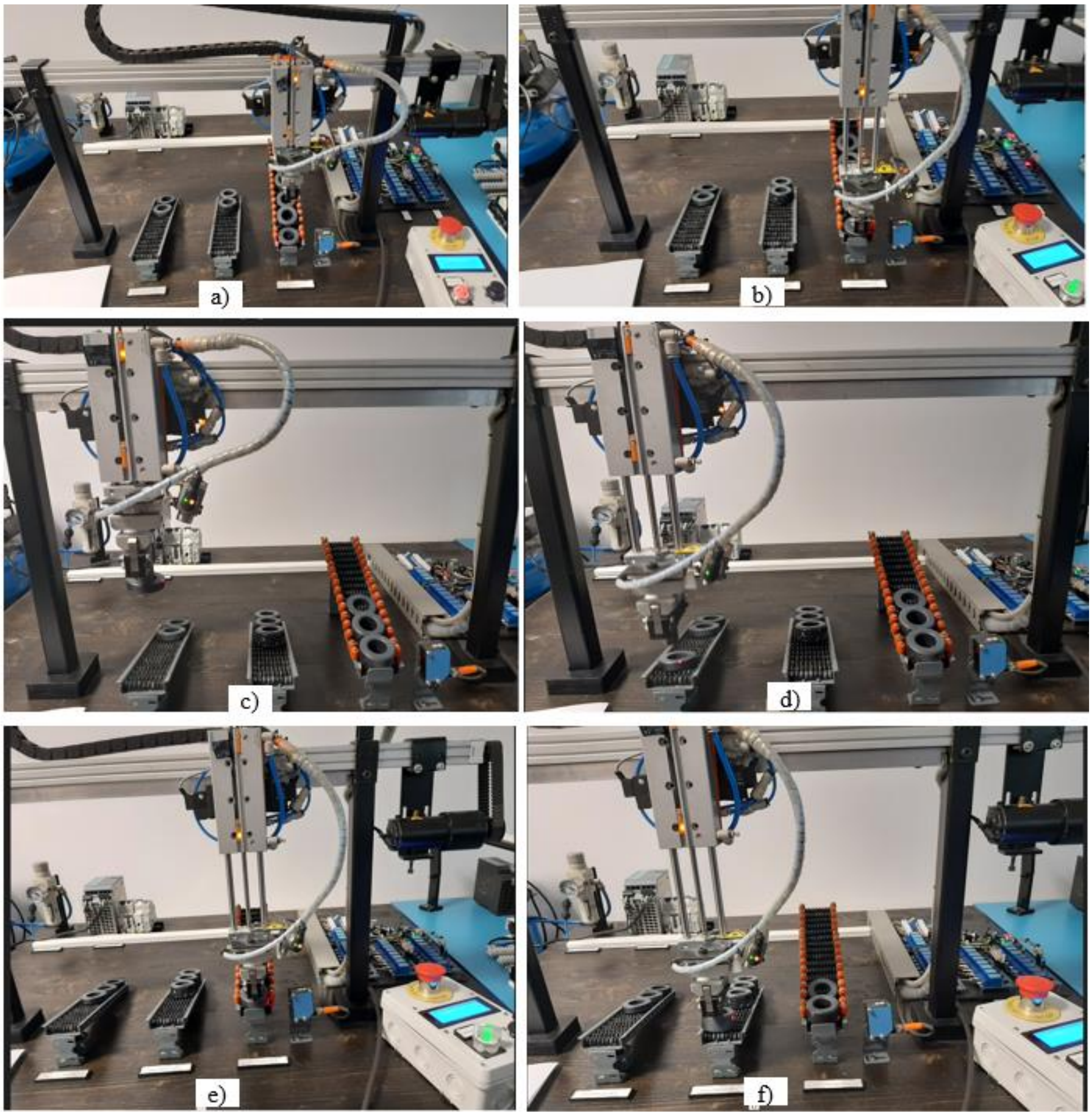


Fig. 9. Testing of experimental sorting system.

The states captured in the figure have the following meaning:

- State 1- the RM is in the initial position (Fig. 9 a);
- State 2 - the detection of B-type piece presence in the input stock, RM displacement for piece pickup (Fig. 9 b);
- State 3 - the RM displacement for storing the piece in the B type output stock (Fig. 9 c);
- State 4- depositing the piece in the B-type stock (Fig. 9. d).
- State 5- picking up the A-type piece from the input stock (Fig. 9 e).
- State 6- depositing the piece in the A-type stock (Fig. 9 f).

Experimental tests have demonstrated the precision of gripping and maintaining parts in the gripper due to the use of a high-performance sensor. Sensors that detect position also have good accuracy and a high response speed.

In the experimental tests, the correct functionality of the system for "manual operation" was checked. This mode of operation has been designed to avoid blockages in case of defects. Also in the "manual mode" the operator can execute the operations in the desired order.

The experimental tests have demonstrated the correct functioning of the system designed and realized in both automatic and manual operating mode.

V. Conclusions

The main benefits of using an automatic sorting station are:

• Presentation of specific and useful reports at user and management level;

• Exactly, real-time control of the operations carried out on the production line and in the storage area;

• Locating a product within the production flow and in the storage area;

• Real-time knowledge of the situation in the production process and in the storage area;

• Increasing the processing capacity of information and products;

• Optimizing human resources;

• Quality control.

All this benefits offered by the automatic sorting systems are intended to increase the capacity and efficiency of actions and also offer a higher level of process quality, ergonomics and optimization of customer services.

In the paper was designed and developed an automated sorting of pieces system that respond to the requirements of a flexible manufacturing system.

Infrastructure hardware and software used allows monitoring and control of a sorting station.

Sensors, electrical equipment and electronic components used for automatic system design have a high degree of accessibility and performance.

The system designed, developed and tested can be used both in educational applications in electrical engineering and in industrial applications.

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Contribution of authors:

First author – 70%

First coauthor – 30%

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