Automatic Sorting and Handling Station Actuated by Pneumatic Drive

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Abstract **- The main path through which technical progress contributes to increasing work productivity is the automation of manufacturing processes. Applications based on robotic handling solve many problems in different areas, especially in the food, pharmaceutical, plastics, building materials, or logistics applications. The paper presents an automatic electro-pneumatic system for manipulation and sorting of parts according to color. The system is taught to sort two kinds of pieces, both white and black. Pieces of different types arrive at the input stock and are picked up by a manipulating robot, then stored in two output stocks according to color. The entire structure is integrated in an electro-pneumatic drive system with linear actuators (pneumatic cylinder) and rotary (rotary pneumatic motors), controlled by the solenoid valves. The manipulator robot consists of three modules (rotation, lifting, gripper actuation), and the output stock contains a rotating module for the sorting table provided with two parts warehouses. Both white and black pieces will be stored in the two storehouses. The structure is controlled by an Arduino Mega2560 microcontroller development system. The sorting station can also be controlled by the operator via a joystick and some buttons. The system designed, developed and tested can be used both in educational applications in electrical engineering and in industrial applications. In comparison to other handling systems, the robot structure is simpler. It performs the transfer of the pieces by only two movements, thus reducing the handling time.**

Cuvinte cheie: *sortare, manipulare, sistem automat, actionare pneumatică, microcontroler*

Keywords: *sorting, handling, automatic system, pneumatic drive, microcontroller.*

I. INTRODUCTION

The technique of handling calls means or devices, which carries the flow of material from one post to another. In the automation technique robots are used to fully automate the assembly and / or testing process. For this purpose, loading and unloading stocks are used to maintain a spare buffer [14].

The rapid pace of technology development and advances in electronics have today enabled the development of highly efficient drive equipment and a high degree of "intelligence" built into it. Thus the main direction of current research is to improve the control of pneumatic drives by incorporating "intelligence"[10].

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-handling 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.

II. DESCRPTION OF SORTING STATION

A. *Structure of sorting station*

The sorting station consists of a stock of input pieces, a manipulator robot (MR) and a sorted pieces output stock (Fig. 1).

The entire structure is integrated in an electro-pneumatic drive system with linear actuators (pneumatic cylinder) and rotary (rotary pneumatic motors), controlled by the solenoid valves [1].

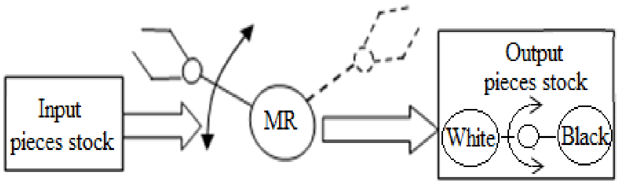


Fig. 1. Structure of sorting station

Thus, the manipulator robot MR consists of three modules (rotation, lifting, gripper actuation) [4], and the output stock contains a rotating module for the sorting table provided with two parts warehouses. Both white and black pieces will be stored in the two storehouses.

B. *The operating protocol*

In the initial phase the system must be in the following state:

Robot arm is up, the robot is rotate to the right, the gripper is open.

After positioning the boom in the initial state, the automatic start sequence is confirmed from the keyboard button, in which the arm moves to the left position.

If no pieces are detected on the input stock, the robot arm returns to the initial position until the piece presence sensor detects parts in stock.

If there are pieces on the tape, the system goes into the next decision phase where the object color is detected and decides the position of the rotating table. In this phase it is determined in which position the table should rotate so that the arm correctly positions the pieces on the output stock. After rotation of the table, the robot descends, catches the piece, rises, rotates, lowers, opens the gripper, and stacks the piece in the proper location.

After these operations, the robot returns to the initial position and the cycle resumes until an external, voluntary or accidental interruption.

C. *Structure of pneumatic drive*

FluidSIM Pneumatics dedicated software has been used to design the pneumatic drive, due to the many advantages it offers [9]. The model of the pneumatic part of the sorting-handling station was divided into three blocks (Fig. 2):

B1 - the compressed air preparation unit block;

B2 - the manipulator block;

B3- the sorting pieces block.

The meaning of the elements used in the model is the following:

D1 ... D4 - pneumatic valve;

C1 ... C2 - pneumatic cylinders;

MP1, MP2 - rotary pneumatic motors;

DC1 ... DC7 - track droop;

S1 ... S8 - sensors of position;

Y1 ... Y4 – solenoid valve.

The modeling of the pneumatic actuator consists of two parts: shaping the power (pneumatic) part and shaping the electrical and control part. Both parts of system modeling mainly involve choosing components in the Component Library, placing them on the design sheet, setting parameters, and making connections between components [9].

If the component library is not visible in the workspace, it can be displayed by choosing Total View from the Library menu.

The state diagram generated by the FluidSim program for the pneumatic actuators of the sorting station (Fig. 3) shows a correct operation of the pneumatic installation according to the required operating protocol.

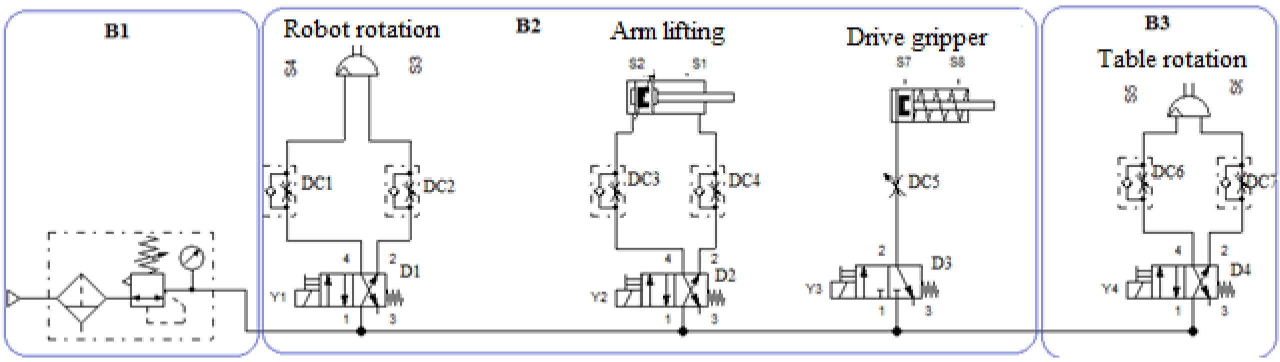


Fig. 2. Structure of pneumatic drive for sorting station

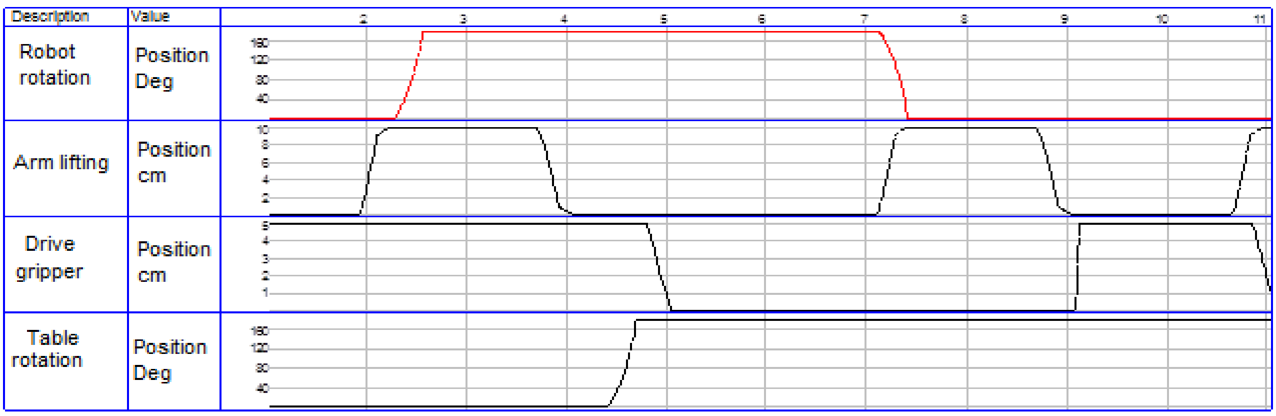


Fig. 3. State diagrams of pneumatic actuator in a work cycle obtained with FluidSim software

The state diagram highlights the operating sequences of the execution elements in the pneumatic drive.

The status chart is very useful for tracking and analyzing the operating cycle [2]. Based on this, anomalies, defects, irregularities can be identified in the sorting station's operating cycle. Optimization of the sorting process can also be done.

D. *Structure of the control system*

At the core of the control process lays the command and control unit that manages the entire process as well as the human-machine interface [5].

Based on the operating principle of a closed-loop control system [3], the command and control unit takes over the position information of the system sensors from the position sensors and the color information of the part gripped by the color sensor.

After processing the information, after a predetermined schedule, control signals are generated to the pneumatic actuators (Fig.4).

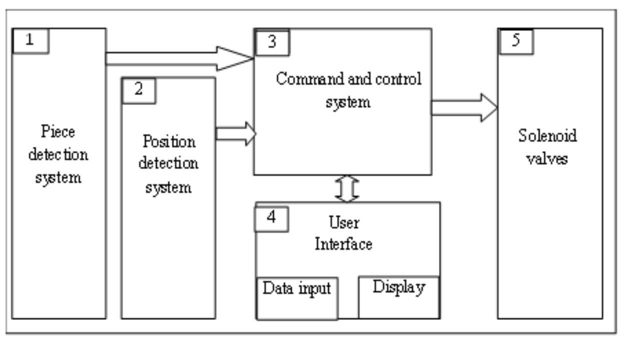


Fig. 4. Block schema of the control system

The parameters of the adjustment process can be viewed and modified via the user interface.

The structure contains 6 blocks:

- Block no. 1: contains sensors that identify the presence and color of the pieces on the inclined plane.
- Sensor 8- Identifies the color of the pieces;
- Sensor 9- Identifies the presence of the pieces.
- Block no. 2 consists of the 7 sensors of handling robot (MR).
- Block no 3, the command and control block, is the part of the application that handles the output input signals and decides to run the application after a set auto-cycle or manually executing commands.
- Block no. 4 is the user interface. This is made up of:

- from an LCD that displays the current status of the system and the state of the manual controls;

- a 6 button plate used in the rotating table manual controls, microprocessor reset, and Automatic Position Confirmation

- a 5 position joystick used for robot manual controls;

- a 3 position button used to activate the states: Automatic / Off / Manual of the system

- Block no. 5 is the pneumatic solenoid valve. There are 4 solenoid valves for each movement for a distinct part of the pneumatic control. Solenoid valves receive electrical signal from the microcontroller and operated distributes air pressure to each pneumatic actuator [7].

All 5 blocks work after a set schedule.

The electronic handling system consists of three main subsystems:

The position determination subsystem, present as a group of sensors located at the rotation ends of the robot joints pneumatic actuators, and the sorted table of color-sorted objects in different containers.

The subsystem of signal adapting. Position signals generated by the sensors are 24V signals that are converted to 5V signals through a block of 9 relays.

Movement of the moving parts of the system is accomplished by means of three pneumatic actuators: two rotators used to rotate the manipulator and the device for rotating the objects collecting objects according to color.

The solenoid valve control subsystem. Adaptation between the signals generated by the control and control block, the 5V signal generated by the microcontroller output pins and the supply voltages of the cylinder control electro-valves is achieved by means of a relay block that is activated generating a 24V signal.

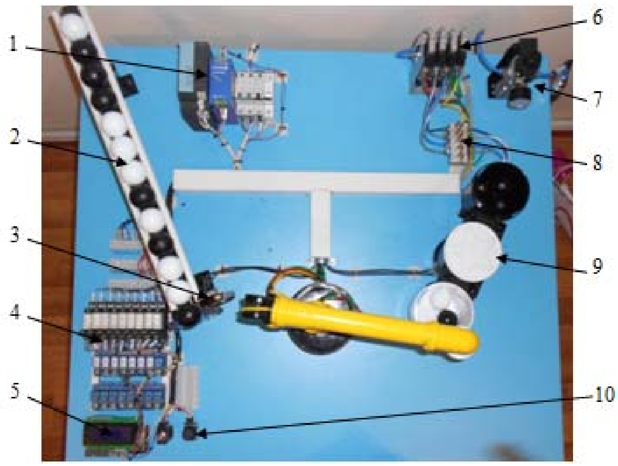
III. Implementation Of Automatic Handling And Sorting Station

A. *Implementation of hardware part*

Validation of the proposed system operation was done by numerical simulation using the dedicated FluidSim program (Fig. 3). Another 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- pieces input stock;
3- sensors detecting the presence and color piece;
4- relay module;
5- development system with microcontroller;
6- pneumatic valves;
7- group of compressed air preparation elements;
8- track walkers;
9- rotating table;
10- joystick for manual control;
11 - handling robot;
12- pieces output stocks.



a) Top view

b) Front view

Fig. 5. Experimental model of the automatic handling and sorting system

The air preparation group is FR type produced by SMC with the coding: AW20-F02-C-X64. This combination minimizes space and pipelines by integrating the two units into one [11].

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 rotation, lifting arm and rotating table it used three bistable solenoid valve Festo [12] 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 [9].

Rotary actuators of type DSM-8-180-P-A-FF-FW are used for rotation of the robot and the table.

• For the operation of the arm on the vertical axis was used a double-acting cylinder type: UNSD-12-25-P-A

• A single-effect cylinder type EGZ-6 was used to drive the gripper.

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).

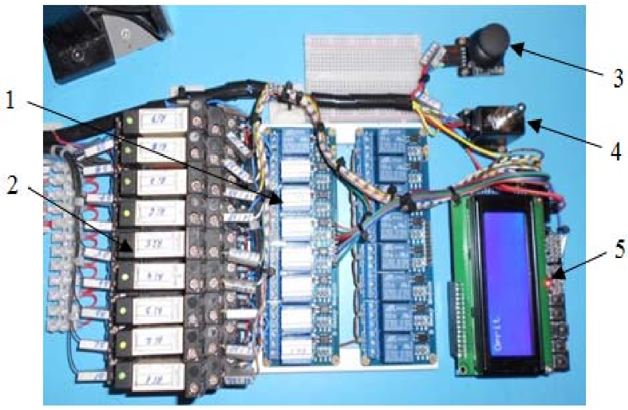


Fig. 6. Command and control system: 1- output relay module; 2- input relay module; 3- joystick; 4- operation mode selection switch; 5- microcontroller development system.

For this purpose, the Arduino Mega 2560 microcontroller has been chosen [13].

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 color determination stage.

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 color of objects grabbed by the gripper, which is the sorting criterion.

To determine the rotation position of the robot and rotary table, the sensors of the type Baluff BMF214K-PS-C-2A-SA2-S49-00,3 were selected.

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 pressostat 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.

The electrical schemes elaborated for each module of the sorting station were grouped into a single general scheme of the whole sorting station (Fig.7). To protect the development system with a microcontroller both on the input side and on the output side were relays connected.

In order for the signals received at the input port to be as clear as possible, the noise voltages were eliminated by pull-up resistors (Fig. 8). As long as there is a ground connection through a resistance, the state of the input is stable. If there is no grounding, parasitic voltages may occur in the circuit.

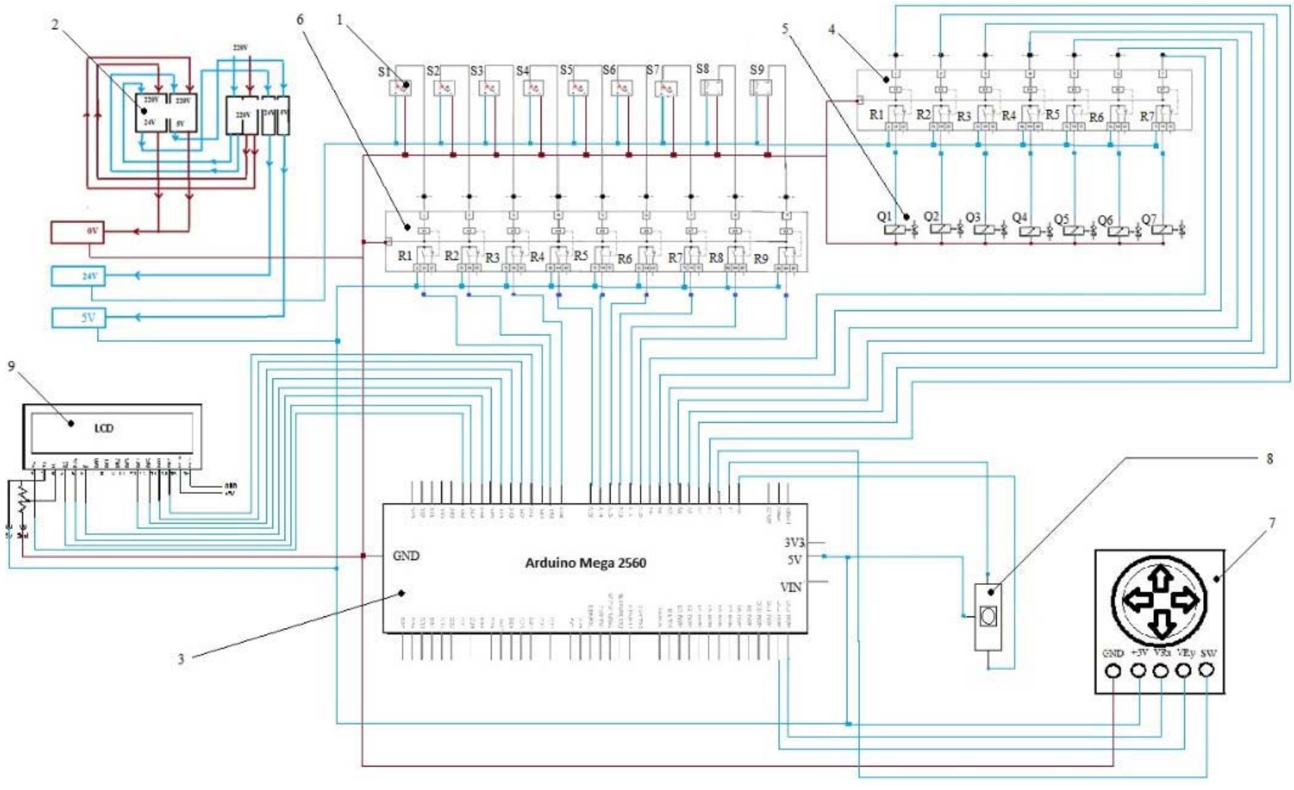


Fig. 7. Electrical schemes of the command and control system: 1- sensors; 2- DC voltage sources; 3- Arduino Mega2560 microcontroller; 4-output module relays; 5- solenoid valves; 6- input module relays; 7- joystick; 8- work mode selection switch; 9- display

When designing the pull-up resistors, it is necessary to limit the value of the current flowing between Vcc (+ 5V) and the ground. Usually this current is limited to around 0,5mA.

$$R = U / I = 5V / 0{,}5mA = 10k\Omega \qquad (1)$$

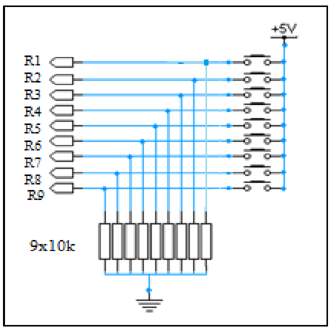


Fig.8. Wiring diagram of pull-up resistors

C. Making the user communication system

The user communication system consists of a six-key keyboard, a joystick, a three-way button, and a display system.

The keyboard must allow rotating table movement, microcontroller reset as well as automatic command validation.

The three-way button is used to activate the three states of the stem "Automatic", "Off" and "Manual".

To switch from Automatic to Manual, the system must be Off.

The Joystick is made up of a two-way Phillips resistor of 10 K, its strength varies by moving the joystick in different directions.

This module is powered at 5V when pushing the joystick in one direction the voltage can reach up to 5V, pressing in the opposite direction can reach 0V.

The display will provide information about the current system status in real time and displays the current movement of the robot.

Entering the working parameters of the system and select sizes to be displayed is done through a system of six buttons of a joystick and a button with three positions scanned by the processor software.

In order for the signals received at the keyboard input port to be as clear as possible, we have eliminated the noise voltages through pull resistors.

Many microcontroller devices use smart LCDs to display visual information (Fig. 9).

Fig. 9. Liquid Crystal Display

LCD displays are not expensive and are easy to use, even being able to check the data displayed using the 8x80 pixels of the display.

LCD displays contain a set of ASCII characters plus Japanese, Greek and mathematical symbols.

The HD44780U LCD Controller and the LSI Driver display alphanumeric characters, Japanese kana characters and symbols (Fig. 9).

D. Implementation of Software Part

Arduino Mega can be programmed with Arduino AT-mega2560 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.

The general structure of software for microcontroller is shown in Figure 10.

The program starts with microcontroller initialization and variables used [6], [8]. Implementation of various timings is possible by using a sequence of decrement of all counters used. Then follows purchase of analog-digital signals, execution of algorithm, then transmitting the synthesized commands.

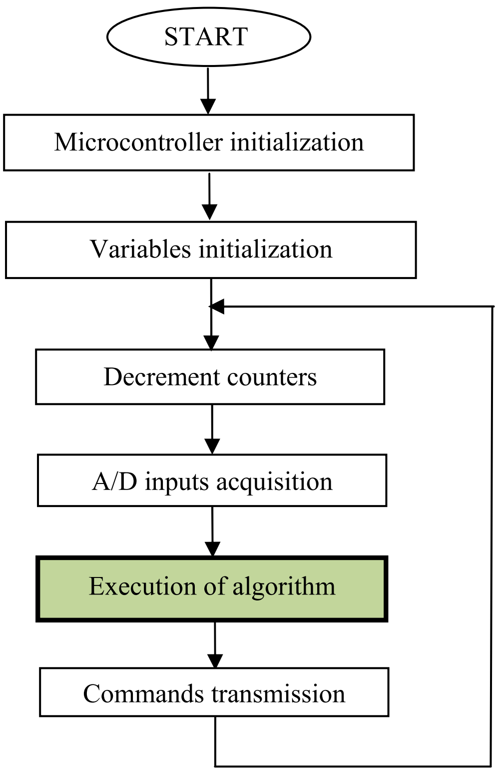


Fig. 10. Flow diagram of microcontroller program.

The main program algorithm for the automatic sorting station cycle is shown in Figure 11.

During the automatic sequence, the user cannot execute manual commands, so manual operation is selected.

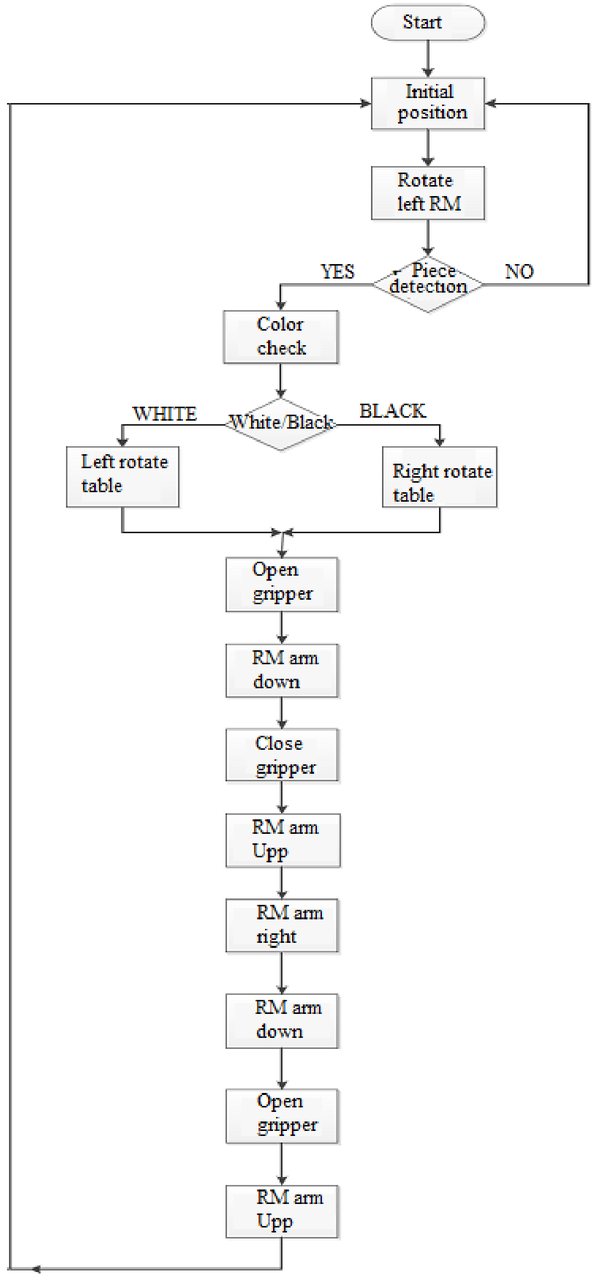


Fig. 11. Flow diagram of proper algorithm – automatic operation mode.

IV. Testing of Automatic Handling And Sorting Station

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

In figure12 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 for the purpose of verification and easier debugging.

The 4 states of operation are highlighted in the figure by the positions occupied by the manipulating robot - RM and the sorting table, respectively.

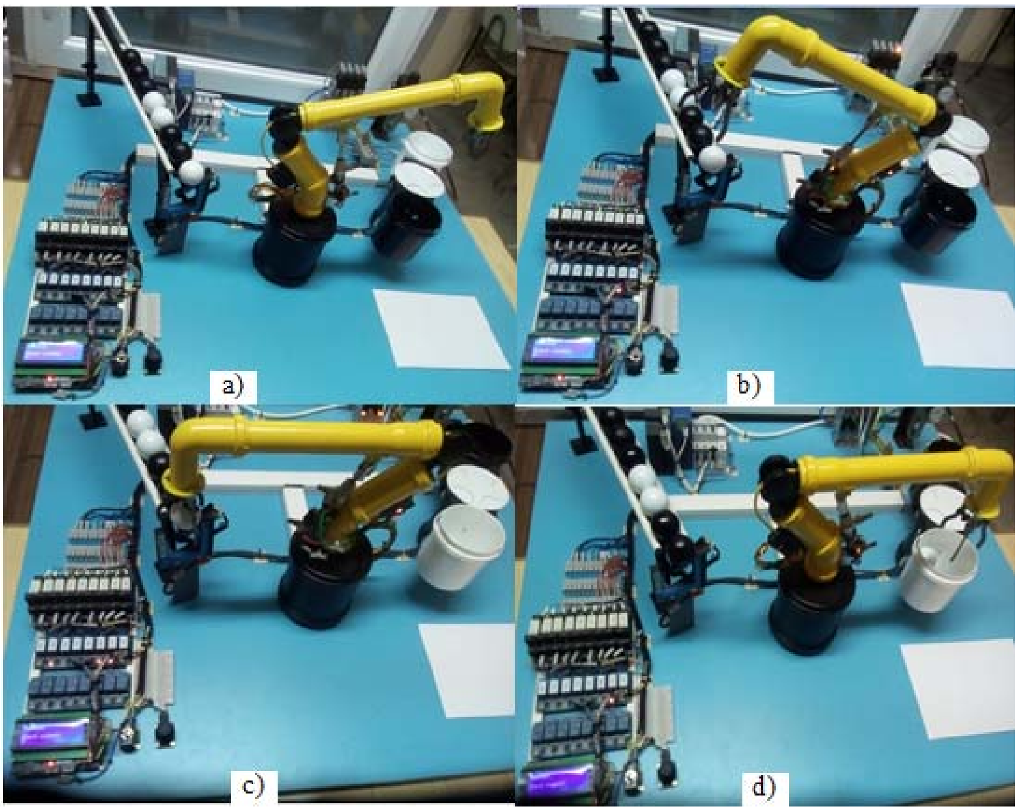


Fig. 12. Testing of experimental handling-sorting system

The states captured in the figure have the following meaning:

- State 1- the RM is in the initial position (Fig. 12 a);
- State 2 - the detection of piece presence in the input stock, RM displacement for piece pickup (Fig. 12 b);
- State 3 - the piece color detection, rotating the collecting table (Fig. 12 c);
- State 4- the RM displacement for storing the piece in the output stock (Fig. 12. d).

Experimental tests have demonstrated the precision of gripping and maintaining parts in the gripper due to the use of a high-performance pressure sensor. The pressure sensor is a cost effective alternative for simple and quick pressure monitoring. The “intelligent fitting” delivers instant information about the current pressure and is an equally effective device for object detection via back pressure as it is for pressure, regulation and vacuum detection.

Also, a high positioning accuracy of the manipulator robot and rotating table for collecting the parts has also been observed. Sensors that detect position also have good accuracy and a high response speed.

As you can see from the simulation results with the FluidSim software, manipulator positioning is achieved in minimum time due to the simplified structure developed (minimum number of actuators).

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. Conclusion

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.

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

Infrastructure hardware and software used allows monitoring and control of a handling-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:

Firs author – 60%

First coauthor – 20%

Second coauthor – 20%

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REFERENCES

[1] L. Alboteanu, “Modeling an Automatic Processing Station Using Fluidsim Software”, Hydraulica-Magazine of Hydraulics, Pneumatics, Tribology, Ecology, Sensorics, Mechatronics, No. 3/2017, ISSN 145-7303, pp. 27-30;

[2] L. Alboteanu, ″Pneumatic Tracking System for Photovoltaic Panel″, ″ Hydraulica″, No. 1/2015, ISSN 145-7303, pp. 32-39;

[3] M. Avram , C. Bucşan ,V. Banu , ″Innovative Systems for Incremental Positioning in Pneumatics″, ″ Hydraulica″, No. 2/2015, ISSN 145-7303, pp. 52-56;

[4] M.A. Drighiciu M.A., “Hydro pneumatic drive and automation”, Publishing House of University of Craiova, Craiova, 2003.

[5] C. Lazăr, O. Păstrăvanu, F. Schonberger, “Computer-assisted management of technical processes”, Matrix Rom Publishing House, Bucharest, 1996;

[6] W. Nawrocki, “Measurement Systems and Sensors”, London, ARTECH HOUSE, 2005.

[7] B. Robert, van Varseveld and G. M. Bone, ″Accurate Position Control of a Pneumatic Actuator Using On/Off Solenoid Valves″, ″IEEE/ASME Transactions on mechatronics″, vol. 2, no. 3, september, 1997, pp. 195-204;

[8] Toma L., “Acquisition systems and digital signal processing, . “Vest” Publsher , Timişoara, 1996.

[9] *** FESTO FluidSIM Pneumatic 4.2, Software, User manual;

[10] *** “About flexible production systems and complex automation”, Plant Engineering, XIII Year, no. 11 (118), 2013, pp. 42-45

[11] *** http://www.smcromania.ro/

[12] *** http://www.festo.com/net/startpage/

[13] *** https://www.arduino.cc/

[14] *** https://www.buettelundmarx.de/