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A pneumatic conveyor robot for color detection and sorting

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ABSTRACT

Despite numerous research works on conveyor robots, few works can be found on electropneumatic conveyor belt robots with two separated lines. The unique feature of this study is a combination of various systems to develop an electropneumatic robot. In this work, an automated and intelligent mechatronic conveyor system is designed and developed for transporting and positioning circular objects that can be used in the manufacturing and packaging industries. In addition to moving and positioning, timing can also be controlled on this conveyor belt robot. All control operations are handled by an electrical and programmable relay called a mini programmable logic controller (PLC), color sensor, gripper arm, and electronic switches. An electropneumatic system is used to control the robot for placing objects. The main goal of this study is to develop a novel 3D structural design which make the procedure unique for better efficiency and accuracy. The novelty of this work lies within the 3D design of two belts and assembly of all electropneumatic components which are helpful for manufacturing assembly lines. Also, TCS230 sensor and AVR microcontroller are used to identify the colors within the operation. The results show the accuracy of the developed system is reliable in terms of color and positioning detection. The system is able to work non-stop for more than 1 hour without any issues.

1. Introduction

Robotics, mechatronics, and artificial intelligence are words that have become very common these days, although the definitions of these words are controversial [1–3]. In mechatronic systems, the integration of components in the production phase can be done in two ways: hardware and software integration [4–6]. Conveyors are a subset of a much larger set of material handling equipment [7]. Usually, with the proper use of material handling equipment, the manual handling of materials is reduced or eliminated [8].

Expanding the range of applications and the use of new technologies has led to the development of different modes of operation and mechanisms for conveyors by engineers, but in general, most conveyors use an electromotor to move an axis that is mainly a drum, a cylinder that moves a belt by friction (attached to it) [9,10]. On the other hand, the vagrant drum, using a belt or chain, forms a loop that can be moved from one place to another by placing objects or materials [11]. Conveyors are divided into ground conveyors, air conveyors, bucket elevators, chain conveyors, conveyor rollers, gravity roller conveyors, and multi-strand chain conveyors [12].

Conveyors are used to handle various products but detecting the size and color of the parts is vital. Thus, color detection sensors and robot visions make the system able to verify color, sort color and inspect color in specific products [13]. As an example, this system is widely used at airports to transfer, classify, and sort passengers' luggage. Also, this system can be used in other applications such as mining, automotive, agricultural, food and beverage, bottling, manufacturing, warehouse and logistics, and packaging industries.

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However, the main goal of using these systems is to transfer products in harsh and toxic environments. Meanwhile, optimizing the system can be done by proposing various algorithms to achieve the highest accuracy and precision [14,15].

Over the past few decades, different pick and place, sorting, and color detection robots have been developed by researchers [16,17]. The steps in color vision are usually color inspection, color verification, and color identification. Due to their vital role in the automation system, sensors and microcontrollers are used to detect a physical condition. Abbood et al. [18] developed a conveyor belt robot and proposed an algorithm to detect various colors and shapes in real-time. Results indicated the accuracy of the system was 92% in shape sorting and 97% in color sorting by using a microcontroller. Also, Shaikat et al. [19] and Halepoto et al. [20] built a jointed-arm robot to sort products based on computer vision detection to find various colors in specific products.

The developed robot by Shaikat et al. [19] consisted of an Arduino nano, a DC motor, a camera, and a rechargeable nickel metal hydride (Ni-MH) battery to approach the rectangular object, while Jokesch et al. [21] used a KUKA LBR to grasp objects of different shapes and colors on a rotatory conveyor. The developed system was 99% efficient in terms of color identification and height sorting. Halepoto, et al [20]. designed an automated conveyor belt system by proposing a mathematical model to determine the dynamic parameters. This model could be used to save energy and cost simultaneously which led to a longer life cycle. Ata et al. [15] used a PLC and sensors in a jointed-arm robot to achieve pinpoint color detection and product sorting. The program was developed to recognize 62 different colors with 100% accuracy for painted objects in 2 ms response.

In other works, Chakole et al. [22] controlled and modified the ABB IRB 140 industrial robot using a web camera and an algorithm developed in MATLAB software based on the DSQC IO card and relay module. The algorithm was 100% accurate in terms of color detection and product sorting. However, implementing an external camera was one of the limitations of this work. These automated systems are highly efficient at handling processes without human interaction. However, obstacles remain during the color detection or sorting due to unpredictable errors [7]. Based on their capabilities, an optimized automated mechanism or robot leads to better detection. Increasing speed and fast response are vital parameters in different situations based on requirements. Also, Zhang et al. [23] developed an industrial pick and place robot known as Gilbert. The object and time recognition were enhanced through a 3D camera Kinect sensor and time decrease in robot sorting operation. A problem was developed by Bozma et al. [24] for pick and place robot coordination on a conveyor system. The focus and precision of robot increased by developed algorithm in terms of action in a meantime.

Also, Rahimi et al. [25] developed a path planning algorithm for pick and place robots, Godel, to increase precision and repeatability. Alternatively, a method to separate deterioration and non-deterioration waste was presented by Dhayalini et al. [26] for pick and place robots. A simple method that is used in Android mobile phones was implemented accordingly. The robot was able to identify waste through a Bluetooth module. Meanwhile, Kato et al. [27] developed a robot's manipulator for construction with low-cost components. It was used to carry out lightweight goods with the help of DC motors and stepping motors. Andhare et al. [28] succeed to coordinate and locate objects with the help of a vision sensor and 2D coordinates. High-speed operation helps pick and place robots to work and identify faster. Also, simulation and path planning algorithm remove issues and obstacles in robot's control. As an example, Seredkin et al. [29] proposed a method to identify and classify the waste on conveyor belt which the precision for the neural network model was 64%. Meanwhile, difficulties still exist in terms of controlling and stability of robots to increase efficiency when it comes to a combination of different systems [30,31].

Despite a wide range of studies on pick and place or color identification robots, a combination of pneumatic system and conveyor robot has not been investigated to find out its features and challenges. Interactive design is deciphered in two ways which are intuitive design plan and intuitive structure utilization in terms of socially interactive robots. The design of machine parts is the goal of this research, which helps researchers build their customized robot belt conveyor in different sizes. Meanwhile, errors in handling and sorting and poor identifications of different colors are found out in previous works. Drawbacks in conveyors can be roller resistance and non-fluidity, system misalignment, and inflexibility of the conveyor belt. Thus, in this study, an intelligent pneumatic conveyor belt robot was developed to detect 3 different colors in circular shape. The contributions of this conveyor robot are the novel development of two lines and electropneumatic combination in terms of material handling. The robot's design is based on two lines instead of one to show how integrated systems and mechanisms can work properly in manufacturing lines. In order to detect color, samples' size and position, a low-cost robot is developed which can be used in different sectors in manufacturing industries. Also, a novel 3D structural design is proposed to increase the efficiency and adaptability with minimum cost. The proposed robot is able to recognize based on sense of light condition, color segmentation, and sample characterization. The system is highly important in packaging stations, assembly lines, inspection systems, palletizers, and workstations. Besides, the robot is worked by electropneumatic system which is able to pick and identify in complex task accordingly. Compressor, sensors, PLC, leather belt, tank, and a vacuum gripper are the main components of this automated robot. In the following sections, this paper is organized as follows. In section 2, the design and development of each component are discussed to minimize the error. Details of electrical parts and sensors are provided in section 3. Section 4 describes the pneumatic components and system accordingly and section 5 introduces how the conveyor robot works in terms of color detection. Finally, section 6 presents the conclusions and recommendations.

2. System design

Conveyors, like all material handling equipment, have no added value for moving parts, products, and objects. They do not alter the product in any way, either. Possible costs, in addition to the system's cost and electrical controls, have existed for conveyors. However, if the conveyor simply contains a pair of simple 3-meter wheeled conveyors, this cost can be omitted. Each type of conveyor and each manufacturer have their propulsion system based on the application. These systems typically include electric motors and mechanical gearboxes. Three main methods are used to position the components of the drive unit in conveyors, which are the gearbox

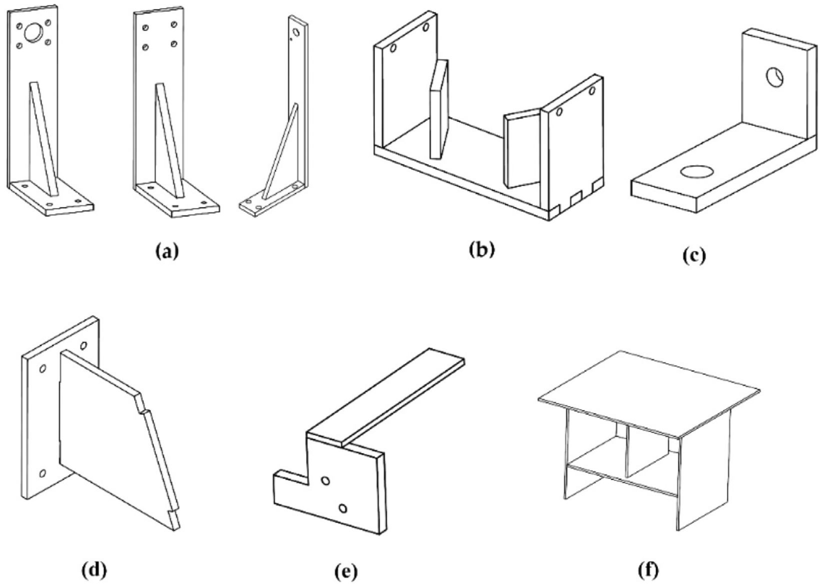


Fig. 1. 3D schematic of support structure of (a) conveyor machine, (b) sensor detector (c) vacuum arm, (d) collectors, (e) force arm and (f) desk.

motor, mounted motor next to the gearbox, and the separate motor and reducer (e.g., belts and chains). In general, most conveyors use an electric motor to drive an axle, which is attached to a cylinder that drives a belt by friction.

As stated, the key goal of this study is a novel design and assembly of various components and structures to achieve highest accuracy with minimum cost in conveyor robot. Also, a scaled-down design with two belts has not investigated yet properly. Thus, the assembly and the arrangement of each part to maximize precision is the key factor in this research. The mechanical design of this robot is based on pneumatic equipment. The initial costs and cost-effective maintenance are the main concerns in this project. It should be noted that this device is used in most factories as a separation and packaging route. More than 400 components were used in this automated mechanism. The parts were designed and assembled in SolidWorks© software. The movement path and the equipment used in this automated machine are discussed as follows. Each component is discussed in detail to investigate the robot's behavior and show how the system works.

2.1. Structure design

As mentioned, there were more than 400 components in this machine, while the first components that were considered to be designed and assembled were the basic structure to hold and support the whole system. A simple wood shape was used to hold the whole system. Different designs were accomplished to assemble each component accordingly for better stability and performance. The schematic of the basic support structures is shown in Fig. 1. The main material for this structure was polymethyl methacrylate (PMMA) or plexiglass due to its high strength and stiffness [32]. Various parts were combined and assembled by glue, bolts, and nuts to achieve the final support structure.

2.2. Parts tank

Moreover, other main parts were designed to be assembled on support structures. The tank to keep circular samples in an array was designed as shown in Fig. 2(a). The capacity of this tank was approximately 10 to 12 pieces, which were removed from the tank by a pneumatic cylinder and placed on the first belt. There is a connection between the tank cylinder and the arm in such a way that each time the arm moves a piece from the first belt to the second one, one sample comes out of the tank through the corresponding cylinder.

2.3. Conveyor first belt

The conveyor was made of PMMA, which is a light and endurable material [32]. Both belts were made of leather due to their good material properties. Leather belts were designed, cut and attached to the part which are shown in Figs. 2(b) and 3. The first belt moved forward and caused the sample to move accordingly. These cylinders have the following specifications: 10 mm diameter, 4 mm shaft diameter, and 40 mm cylinder course. It should be noted that all pneumatic parts were selected based on 6 bar pressures at room temperature. Cylinders must be brought forward and returned to their first position after arranging the part.

The movement of each cylinder is provided by a 3-5 pneumatic solenoid valve. The 3-5 valve can activate the first valve at one moment and the second at another moment, and when neither of them is active, air does not come out or enter through these valves

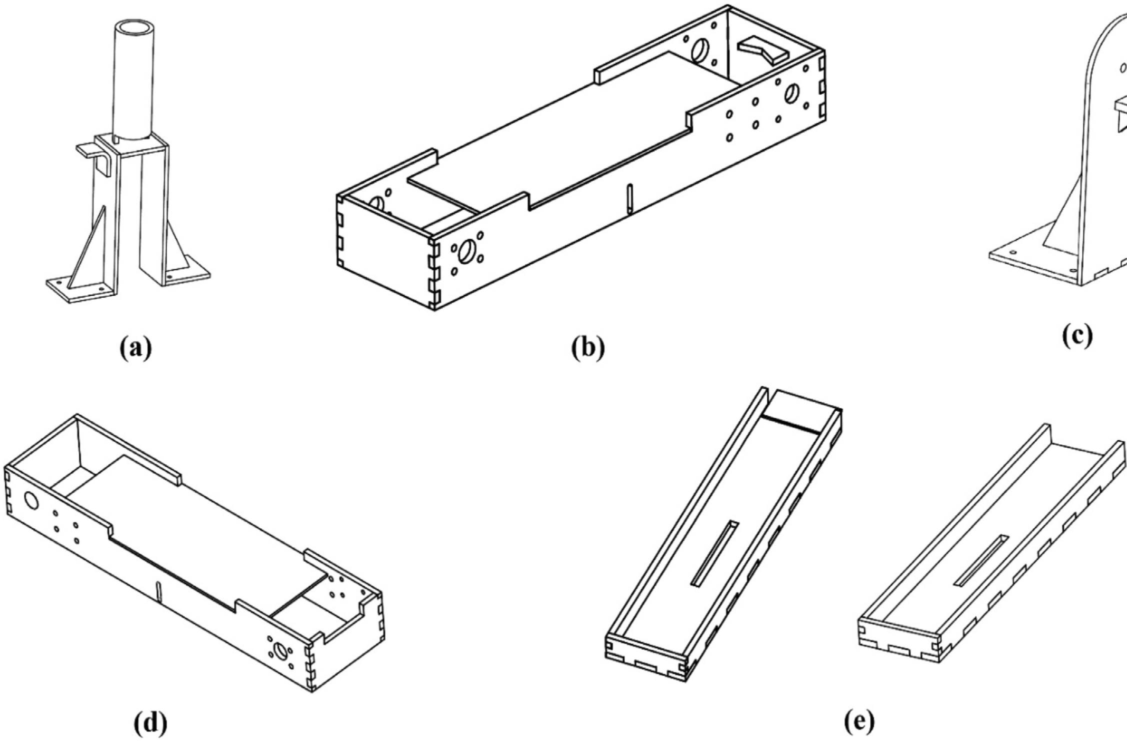


Fig. 2. 3D design of (a) sample collectors, (b) parts tank, (c) vacuum arm, (d) second belt and (e) first belt.

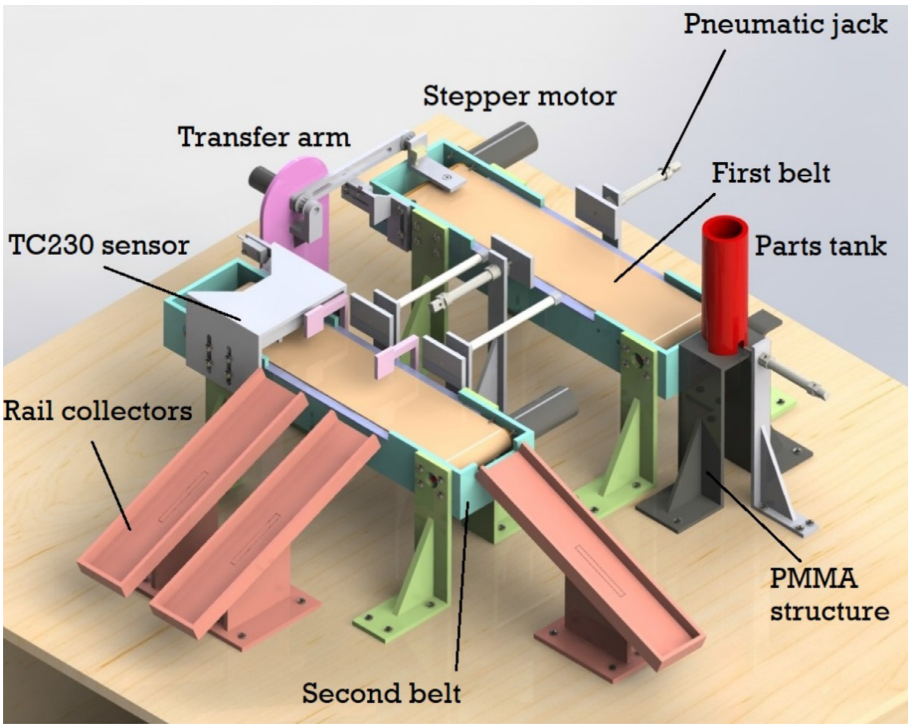


Fig. 3. 3D schematic of conveyor belt robot.

[33]. Meanwhile, the movement of the first belt is provided by a DC motor, which is connected to the shaft at the end of the strip, and by moving the shaft connected to the motor and the (leather) belt, the end shaft is rotated, and a series of movements are performed. The Zheng DC motors which were used in this system had 7 kgcm torque, 120 rpm, and the shaft size was 6 mm.

2.4. Parts transfer arm

This arm consisted of a motor that is connected to the base and to the arm simultaneously. The movement of the arm was provided by two pulleys, timing belts and bearings. The system of this arm was also pneumatic, and the part was vacuumed and transferred from the first line to the second one by the pack frame attached to the arm (which worked based on rapid discharge and creating a hole at the same time). The structure of this part is shown in Fig. 2(c). The gripper was a piece of plastic that lifts the sample when it was attached to it, along with a vacuum valve to quickly evacuate the air under the gripper and create a hole, respectively.

2.5. Second belt

This part belt is somehow similar to the first one, but there is a small difference in their design, as shown in Fig. 2(d). Similarly, the walls are made of PMMA, and the belt is made of leather. In this belt, sensors and sample collectors were attached to separate parts based on their colors. After reading the command, the part is inserted into the specific rail and this separation of the parts is done in the specific collector (see Fig. 2(e)). All these components were assembled somehow to minimize errors and issues. The 3D schematic and the main parts of this machine are shown in Fig. 3.

3. Electrical system

Each project, including electronic circuits and moving parts, requires an electrical power supply. If the project is a mobile robot, ideally the power supply is embedded inside the robot [34]. Battery cells can be used for this purpose. If the device in question is fixed such as electronic circuits and electromechanical devices used in this project, typically a DC power is used. Microprocessors, microcontrollers, and intelligence software are implemented inside the robot. The basic stamp chip provides a simple way to add a degree of intelligence to a machine. The chip can be programmed to make decisions based on inputs received from external control circuit sensors. To run the robot and detect color, PLC, sensor, automatic voltage regulation (AVR), and a DC motor are used.

3.1. Programmable logic controller (PLC) and Sensors

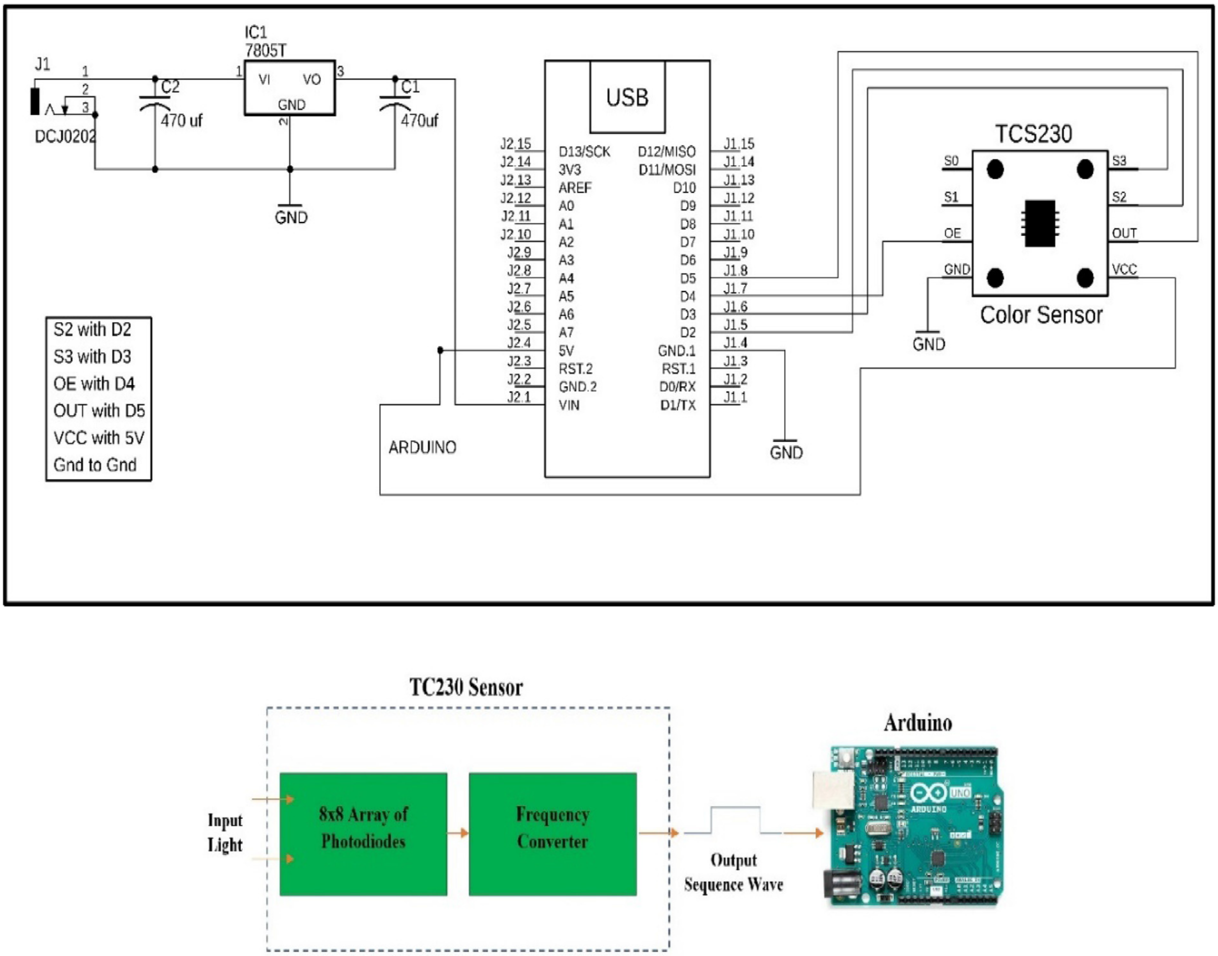
In small PLCs (Siemens SIPLUS 230RC) which have been used in this research, the processor, semiconductor memory, I/O modules, and a power supply are housed in one unit. The programming tool is connected to the main unit separately. Components of a mechatronic system include sensors, actuators, microcontrollers, and real-time control software to detect objects or path [35,36]. The automatic performance of a machine can be graded by the number of sensors in it. It should be noted replacing electronic sensors instead of mechanical sensors makes the weight of packages carried out proportionate and better controlled.

In this research, to detect the color of the parts, an 8 by 8 array of photodiodes TCS230 sensor is used, which frequency is the output and this frequency output is read by the AVR system [37]. This sensor could detect three different colors. A converter changes the photodiodes into square waves. TCS230 sensor has 16 photodiodes with red, green, and blue filters that converts light into current. The intensity of various colors can be read by choosing the photodiode filter's readings. The procedure of chosen color is based on sensor function. The light intensity of the color is corresponding by converting photodiodes' readings into a square wave with a frequency. Subsequently, Arduino reads the given frequency. Arduino is used to read data to achieve the highest accuracy for detecting colors.

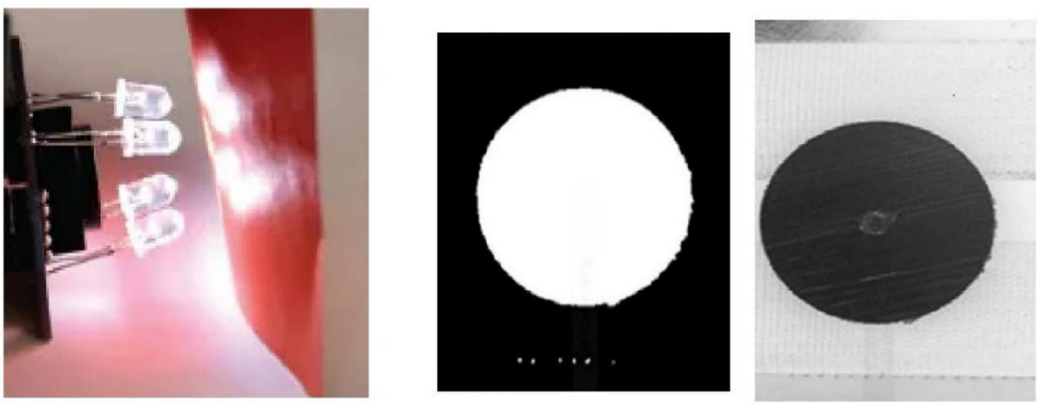
S2 and S3 control pins are used to select the color in photodiode as shown in Fig. 4a. Low and high settings in parallel connection allow the user to different photodiodes. The 5-volt regulated power supply based on 7805T voltage regulator is used to power up the Arduino. The printed circuit board (PCB) board was designed and developed to attach Arduino, sensor, and voltage regulator. The diagram of connections between sensor and the Arduino with color and is shown in Fig. 4a and 4b. The sensor detects the object by changing the frequency from 330Hz to 7 to 14 kHz.

Moreover, after passing the component and color recognition, the board is connected to PLC and programmed accordingly. The commands send to the AVR, and the AVR activates a series of relay outputs. After activating the relay, the command reaches the PLC, and the PLC activates the relevant jacks according to the diagnostic color. The Arduino is connected to the PLC by RS232 converter. A 12-volt transformer is used for AVR, and a 24-volt transformer is used for PLC. Two jacks are connected to PLC and programmed to put the sample into the rail. Meanwhile, the whole conveyor is also powered by a DC motor to handle the procedures.

Due to the small number of outputs of the PLC device, AVR technology is used to move the arm. When the part is in front of the color recognition sensor, the sensor commands the AVR, and the AVR rotates the left arm motor. When the arm is rotated and reaches the part, the AVR is commanded by the corresponding microswitch, and the clockwise motor is stopped. After the motor is stopped, the vacuum valve connects and sucks the part, and after suction, the microswitch commands the AVR to run the motor in a straight circle in the opposite direction, and the arm reaches the corresponding microswitch on the left side. It is the microswitch that commands the AVR and the vacuum valve to shut off. After performing the above steps, the piece is placed on the second belt and starts moving.



(a)



(b)

Fig. 4. (a) TCS230 sensor and Arduino diagram with (b) position detection in black and white color detection test.

4. Pneumatic system

4.1. Compressor, air filter, and regulator

To produce compressed air, a compressor is needed that can compress the air according to the required pressure [38]. In order to operate the pneumatic devices, it is not necessary to provide a separate compressor for each part, but there should be a compressed air production center in each system. Then, the produced air should be delivered to all components of the machine through the piping network. In this research, a piston compressor is used to accomplish the process accordingly. This type of compressor is more commonly used than any other type of compressors because it can produce a broad range of compressed air. Pneumatic controllers are designed to operate in the pressure range of 7 to 10 bar. To produce this pressure range, two-stage reciprocating compressors with a cooling unit between the two stages are used. In the cooling unit, the compressed air in the first stage, which is heated during compression, is cooled as much as possible in the second stage.

Small rust particles that travel with the compressed air in the pipeline network can interfere with operation and need to be treated. Also, the air pressure should be adjusted to the working pressure required by the machine, and if necessary, oil should be added to the compressed air for lubrication of the equipment. The preparation unit usually includes a compressed air filter, a pressure regulating valve, and a compressed air lubricating device.

The compressed air filter is responsible for separating all pollutants from the compressed air passing through, as well as the produced water during this process. Compressed air enters the filter bowl through the guide grooves. Liquid particles and coarse particles are separated by the centrifugal phenomenon and collected at the bottom of the filter bowl. The separated water and particles must be drained before their amount exceeds the maximum allowed, otherwise they re-enter the compressed flow.

The purpose of the lubricant is to deliver a small amount of oil dust to a part of the compressed air distribution system, and it is used if lubricating compressed air is necessary for the operation of the pneumatic system. The compressed air lubricator mixes the lubricant with the air. The operation of this device is based on the characteristics of a cone-shaped bullet (venturi) in which the velocity of the fluid flow increases as the cross-sectional area of the path decreases. As a result, the pressure decreases to below atmospheric pressure. Moreover, a regulator is used to keep the system pressure (secondary pressure) and the primary pressure (the amount of air consumption) constant and uniform. The place of the regulator in the system and different parts of a regulator is shown in Fig. 5.

4.2. Air tank

The tank is used to store compressed air and to ensure a constant working pressure required by the network. As a result of cooling, the saturated compressed air in the steam tank, its water is distilled and cooled in the bottom of the tank, which must be emptied from the tank subsequently. The size of the tank depends on the amount and type of air consumption. The volume of the tank must be at least 10% of the amount of compressor aeration per minute. Compressed air is transferred from the tank to the consumer through a network of pipelines which are made of polyvinyl chloride (PVC) plastic tubes. The pressure drop in pipelines, bends, and equipment for normal working pressure of 8 bar should not exceed 0.1 bar.

4.3. Pneumatic cylinder

The production of linear motion by mechanical devices or electric actuators is very expensive, and the most efficient way to produce these movements is with pneumatic cylinders. Pneumatic cylinders convert pneumatic energy into mechanical energy. Inflatable cylinders are divided into two groups: single-function and double-function cylinders. In this research, single-function piston cylinders are used to operate the system in the first belt to arrange the sample as well as the second belt to divide circular samples. A single-cylinder actuator is affected by compressed air in only one direction and can only work in one direction of production. Therefore, air is needed only in one direction of motion. The movement in the opposite direction is done by the spring force that is installed in the cylinder or is done by an external force. The length of the pneumatic cylinder stroke should not exceed 200 cm. Cylinders with large piston diameters and long stroke lengths consume a lot of air and are cost-effective to use. The force from the piston depends on the air pressure, the diameter of the cylinder, and the friction of the sealing parts inside the cylinder. The theoretical force of the piston is calculated based on the following formula:

$$F_{th} = A * P \tag{1}$$

where F_{th} is piston theory force (N), A is usable surface of the piston (cm^2) and P is pressure (bar). This force for single-function piston cylinders is conducted as follows:

$$F_n = A * P - \left(F_R + F_F\right) \tag{2}$$

where F_R is friction force (N) and F_F is spring force (N). The speed of the piston depends on the air pressure, the forward force, the length of the air ducts, the cross-section between the control valve and the working part, as well as the amount of current flowing through the control valve. End position shock absorbers are also effective in speed. When the piston rod exits the end position and its air is discharged from the speed control valve, in such a case, the piston rod speed also decreases. In this case, the average speed of standard cylinders is in the range of 0.1 to 1.5 m/s. Also, the amount of air consumption in the calculations is given in liters per

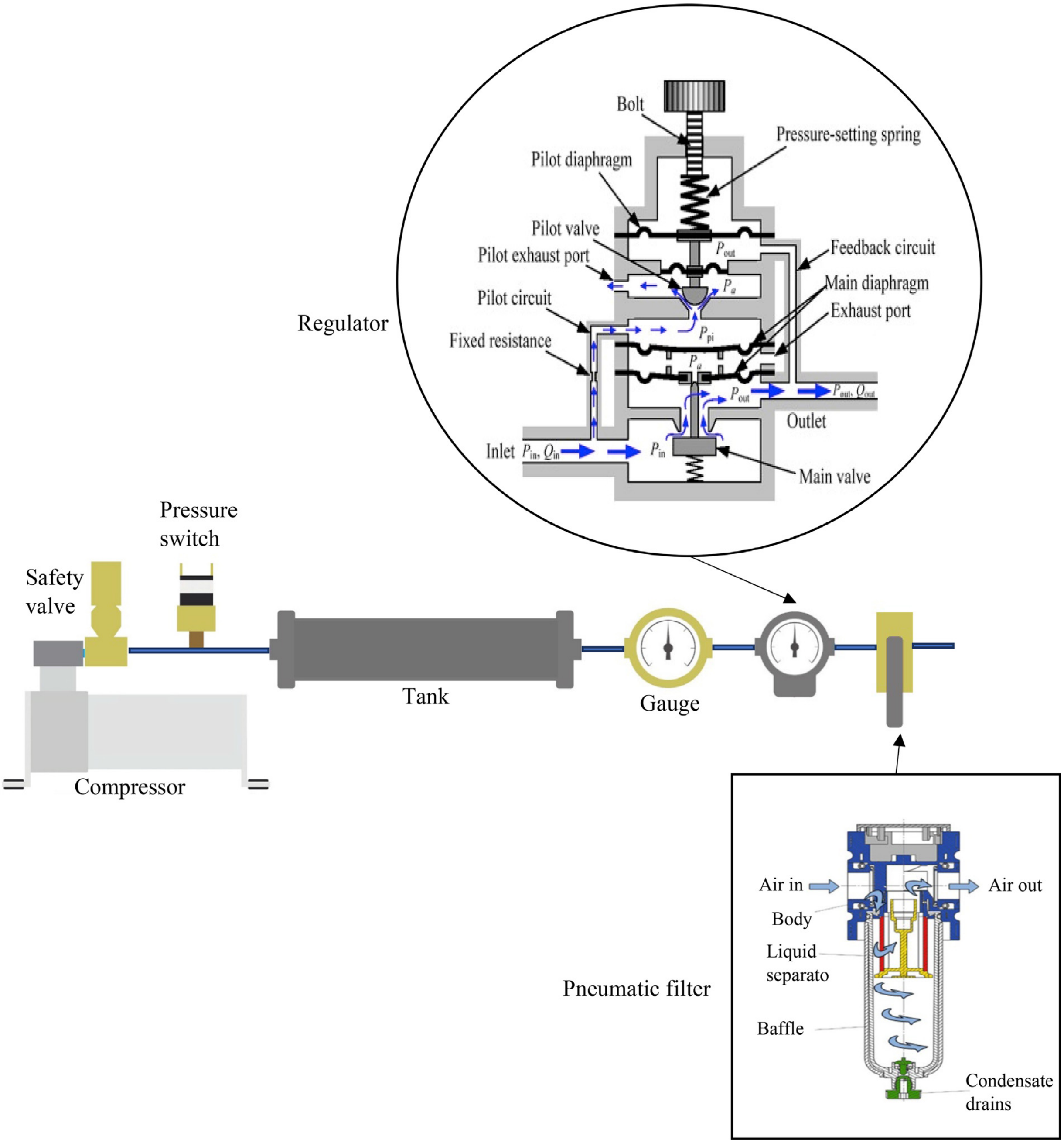


Fig. 5. A pneumatic system with details of a pressure regulator and pneumatic filter.

minute. The following formula is used for single-function piston cylinders:

$$V = s * n * q \tag{3}$$

where V is the amount of air (liters/minute), s is the course length (cm), n is the number of courses per minute, and q is air consumption in terms of one centimeter of course length. Based on provided formulas and information, the cylinders are designed in SolidWorks© (see Fig. 6). The diameters of the cylinder and shaft are 10 mm and 4 mm, respectively. Subsequently, the course length is 40 mm to achieve the highest accuracy. These cylinders must be brought forward and retracted after rearranging the part. The movement of each cylinder is done by an electric pneumatic 3-5 valve.

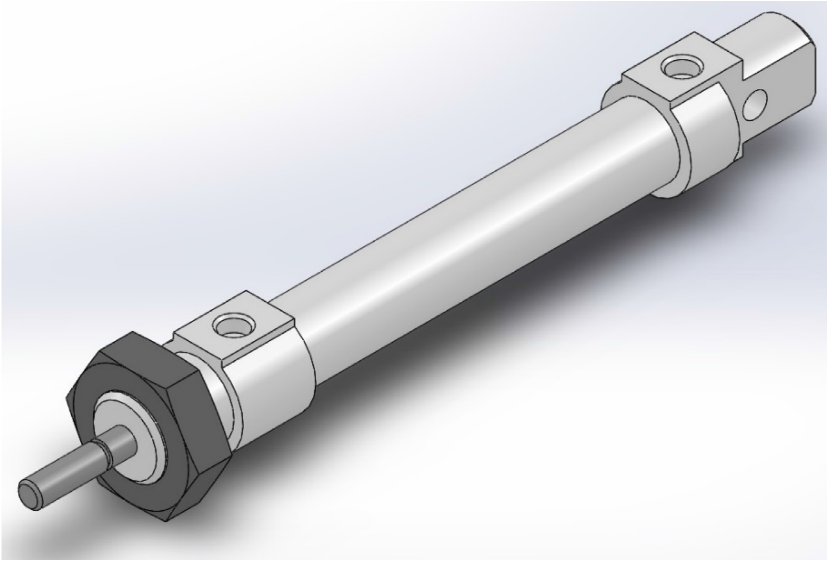


Fig. 6. 3D design of the cylinder jack in a conveyor machine.

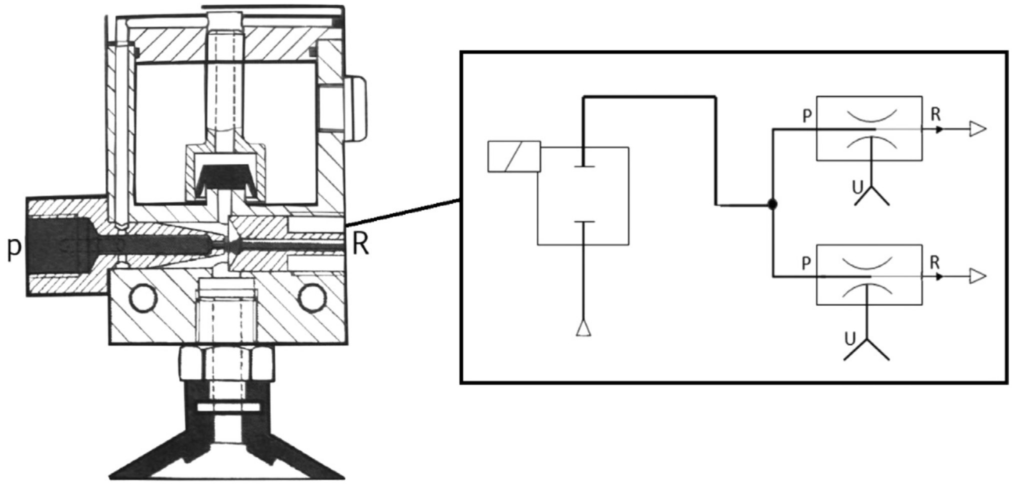


Fig. 7. The pneumatic circuit used in the suction system (vacuum gripper).

4.4. Vacuum gripper system

This part of the machine is used to pick and place the part. This part also follows a pneumatic system that works based on rapid evacuation and creates a vacuum at the same time. The pack frame system consists of several plastic parts that adhere to the piece when creating a vacuum and cause it to lift, along with a vacuum valve, to quickly evacuate the air under the pack frames and create a vacuum area. Drain valves are also commanded by a 2.2 valve. The same operation of valve 2.2 can be performed in the circuit with a valve 2.2 by closing one of its valves, which means the valves 2.5 and 1.5 mentioned by the solenoid, can be controlled. Meanwhile, its pneumatic diagram can be seen in Fig. 7. The suction system in the arm is used to connect with the suction cup as a transport mechanism in this device. The operation of this device is based on the principles of venturi (vacuum pressure). The supply pressure is applied at the inlet P due to the tightness of the section. The flow velocity is increased towards R. It transports samples by suction. It is necessary to have a good suction operation to achieve the highest accuracy.

There is an extra tank in this process. This tank is filled during the suction operation to cut-off the inlet pressure. The air in the tank is released through a quick drain valve. The release of this air is from the path of the suction cup. Thus, it creates a shock pressure on the sucked part and the part separates from the cup. It should be noted that the valves are stimulated by a pneumatic system.

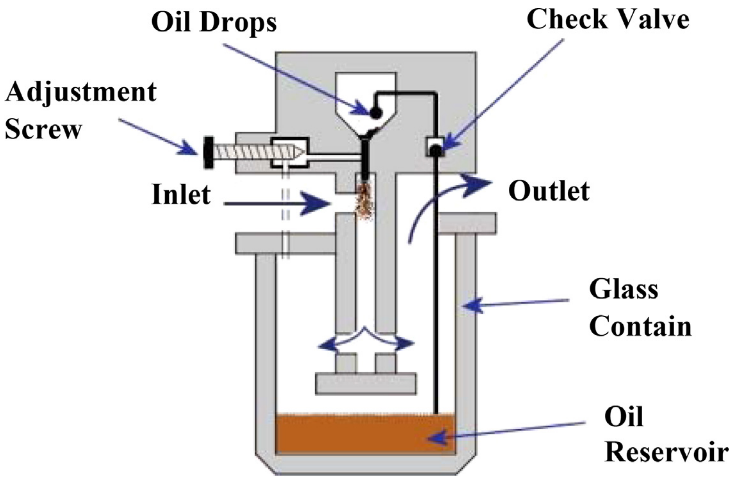


Fig. 8. Different components of lubricating unit.

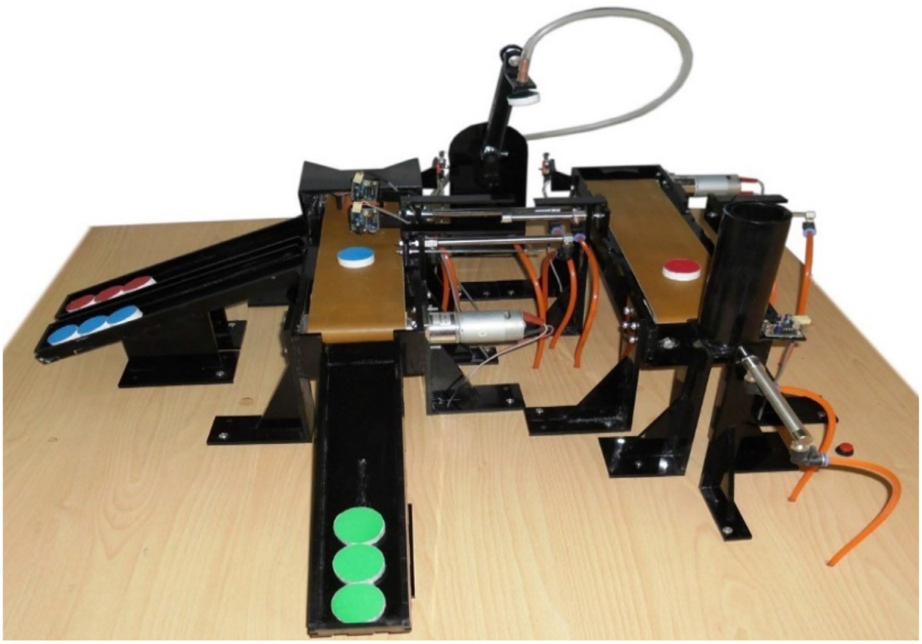


Fig. 9. Assembled conveyor system.

4.5. Lubrication unit

The purpose of lubricating oil is to deliver a small amount of oil dust to a part of the compressed air distribution system. It is used if compressed air lubricating oil is necessary for the operation of the pneumatic system. The compressed air lubricator mixes the lubricant with the air. The operation of this device is based on the characteristics of a cone-shaped bullet (venturi) in which the velocity of the fluid flow increases as the cross-sectional area of the path decreases, and as a result, the pressure drops to below atmospheric pressure. Also, its evaporation is used by using an adjustable screw. The number of oil droplets that enter the air stream and eventually evaporate can be adjusted accordingly. In this part of the care unit, the incoming air, while leaving, carries the oil particles for lubrication of other parts, which depends on the intensity of the lubrication of the air as well as the adjusting screw located on the top of the lubrication unit (see Fig. 8). A system that has all the components of a care unit is technically called a filter, regulator, and lubricator (FRL) or trios.

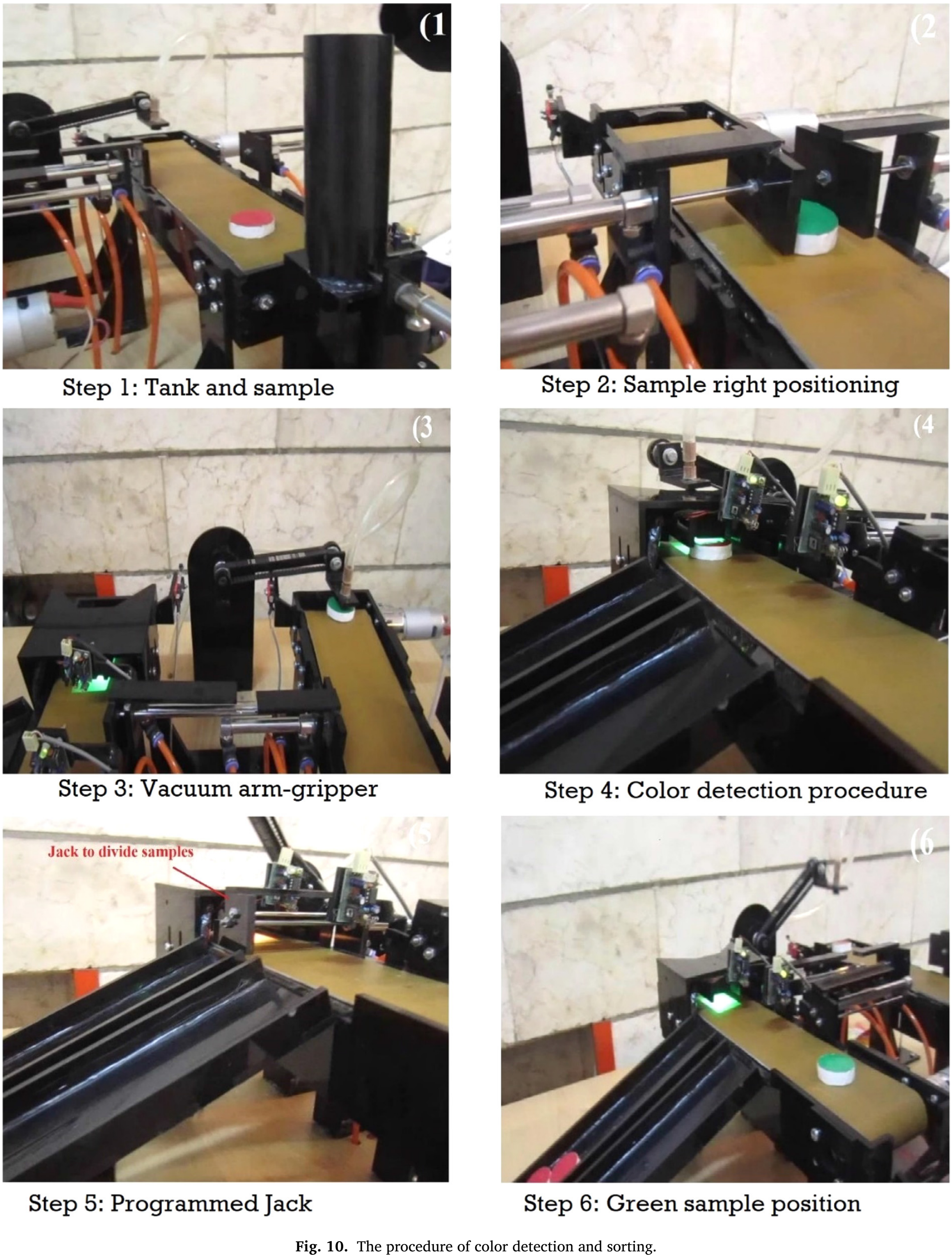


Fig. 10. The procedure of color detection and sorting.

5. Color detection and sorting procedure

According to the brief description given about the general mechanics of the robot, this device consists of four dynamic parts, which are the parts tank, the first conveyor belt, parts transfer arm, second conveyor belt, and separating rails. However, there is a wide range of components such as sensors, compressors, air tanks, PLCs and jacks. All parts are assembled and the system is shown in Fig. 9. Three different colors (red, blue, and green) are used in this robot. The procedure of color detection and sorting is shown in Fig. 10. For a better understanding of the procedure, a video of the process is added as a supplementary file. The samples are collected in the tank to start the process. The part is first taken out of the tank by a pneumatic jack and placed on the first conveyor belt. Then, the sample is passed through the belt, and two jacks arrange the correct place on the first belt. Subsequently, the sample takes the desired coordinates and continues on its way. At the end of the strips, there is an arm that moves the part by means of a vacuum (pneumatic structure) from the first belt conveyor to the second one. The sample continues its way after being placed on the second bar. Then, the color recognition sensor detects the color of the parts and commands the jacks to throw the part on the desired rail and separate them in this way. For green samples, there is no command to divide them, and they follow the second belt to the end to be separated from the blue and red ones. The accuracy of the robot was reliable in color detection, and no delay was found in this section. However, the speed of belts is constant, and the machine is programmed for circular shapes. Meanwhile, the suction system in the transferable arm works with high accuracy and takes samples without errors. Based on recorded time, the machine is able to make decision in less than a second to detect the color and command related jack to separate samples accordingly. The speed of belts was modified, and the conveyor robot was capable to detect samples in high speed as well. The robot worked properly in dark condition without delay and error while the lightening condition was changed accordingly.

6. Conclusion

In this article, the design and assembly of different components followed by electropneumatic systems are proposed. The proposed conveyor robot is suitable for color detection and sorting in manufacturing companies. More than 400 components are used to assemble the machine and the real test station and experiments have been described. A wide range of products, from color detection sensors to compressor, regulators, PLC, structure design, is discussed accordingly. The machine can detect a specific color in a second with the shape of circle. Also, the developed robot used two lines instead of one which is highly reliable in manufacturing lines. Meanwhile, the programmed PLC and Arduino are suitable for three colors in this case. Controlling of the robot is done by adjusting of roller speed without any extra loads. This interactive design helps to decrease the material waste which make the best results in terms of stability and dynamic control. In addition, this stability and efficiency help to increase the life cycle while the power consumption is low. Implementing of a small robot arm is not needed since this system can grasp samples without issue. Also, placing the object can be done throughout the system without any external interaction. However, by programming the machine, it would be possible to increase the number of colors and shapes.

The developed machine is promising and worthwhile to be discussed by developing other sections in this system to be tailored in different applications. The proposed robot shows the sample grasping is easy without changing the robot design. Also, due to the existence of pneumatic system, this method is useful for soft robot grippers as well. Thus, the integration of soft and hard robots can be done accordingly. Also, increasing the performance can be accomplished through self-built dataset for proposed robots. To improve the accuracy in sensitive products, complementary information should be fused into the image, and the thermal infrared to identify various objects in the future. Meanwhile, developing an algorithm for image processing and sensor integration for color detection can be implemented to increase efficiency and accuracy.

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Authors' contribution

Conceptualization: M.L.D.; Methodology: M.L.D.; Formal analysis: M.L.D., S.H., A.Z., M.B.; Investigation: M.L.D., S.H., A.Z., M.B.; Supervision, M.B.; Visualization, M.L.D.; Writing – original draft: M.L.D.; Writing – review & editing: M.L.D., S.H., A.Z., M.B.

Consent to publish

All authors have agreed to publish this article.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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