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ABSTRACT

Nowadays, with considering the competition between enterprises, it is so essential for any types of enterprise to satisfy their own customers about many issues. One of the most important of these issues is production of variety of products with less manufacturing system changes. On the other hand, the capability of the enterprise's manufacturing systems to overcome these difficulty (different products without changing the structure of manufacturing system) is a highlighted subject to win this competition. With the old fashion types of manufacturing systems, enterprises are not able to handle the mentioned issues. One of the possible solutions for such a case in enterprises is integration of the old-fashioned manufacturing system with different types of motors, sensors, microprocessors, microcontrollers and etc. This integration in the manufacturing system is increasing the automation ability. In addition, designing new types of manufacturing control system and control architecture can make the enterprise able to produce different types of customer order. One of the most famous types of such a system is Flexible Manufacturing System. In this project, it is tried to design and implement a flexible automation system which is combination of flexibility and automation in the system by utilizing different devices such as automated conveyor, CNC Machine and robots. The design of Flexible Automation System make the enterprises able to produce different types of orders with less manufacturing led time, more quality, less production cost and less human labor utilization. The main aim of this project is doing different plotting operations by identifying parts. There will be 3 different parts with different colors (Red, Blue, and Green). According to this colors, different procedures will work. The system will decide itself, if start to a work or take a finished part from a CNC and put it to final destination.

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CHAPTER 1

INTRODUCTION

Unlike the beginning of the industrial revolution, it is not enough alone to produce something nowadays. The whole world has become competitive in an open market so that it become necessary to make the production; efficient, standard, fast and safe became an obligation. Without a doubt, this obligation the industry equivalent of the automation.

Different kinds of control systems can be used for operating equipments such as actions in companies, machinery, heat conducted ovens, networks, management of aircrafts, ships and some other applications. Automation is the use of this systems with minimal human labor. [1] Also automation can be defined as the sharing of a job between a human and machine. Total job-sharing percentage establishes the level of automation. Automation systems with intensive human labor is called semi-automation and the systems with less intensive human labor is called full-automation.

Automation systems are acquired by varied ways like hydraulic, mechanical, electrical, pneumatic, electronic devices and computers usually in combination. Airplanes, ships and modern companies are examples that use these combined techniques.

1.1 Types of Automation

Automation systems can be separated in two based on its flexibility and integration level in manufacturing process operations. Classification of the automation systems is as follows in Figure 1: [2]

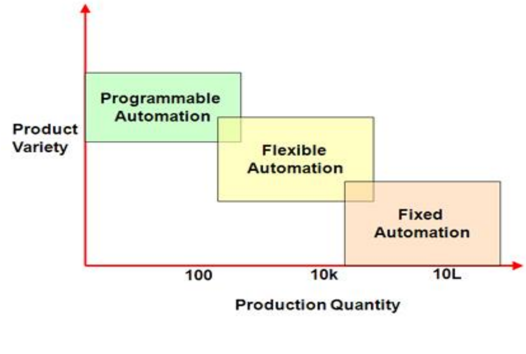

Figure: 1 Types of Automation

1.1.1 Fixed Automation: This type of system is used in high volume production with special equipment. Flow continually and Production Discrete Mass systems use this automation system. To produce high amounts of imitated parts this fixed automation process can be used.

1.1.2 Programmable Automation: Programmable Automation System used for operations that its series can be replaced and machine configurations while using electronical controls. To reprogram the machine, non-important programming effort may be required.

1.1.3 Integrated Automation: In this type of automation system, the whole system is computer controlled. Some technologies like CAD, CNC, Automated Storage and Retrieval System, Computer Integrated Manufacturing and flexible machining systems include this type of automation.

1.1.4 Flexible Automation: Flexible Manufacturing Systems (FMS) uses Flexible Automation Systems which is totally computer controlled. [3] Human operators send the high-level codes to the computers. Each machine in the production line receives settings (codes) which is sent from the computer. When a machine finishes its process, the workpiece will go to next machine automatically. Multi-functional CNC Devices use this type of automation system.

On the other hand, Flexible Automation can be used in the following cases.

- Major variability in product type.Combination of various parts is required in product mix and products that will be manufactured from the same production system.
- Life cycles of the products are short.Specific upgradation and modifications in design changes production requirements.
- Production volumes are moderated, and claim is not as predictable

1.2 Components of a Flexible Automation System

The components of the FAS project are manufactured and assembled together to form a complete system. They are designed specially. Some detailed information is given below for the system:

1.2.1 Structure

Most of the components in the system is made from metal, because it is very useful in manufacturing area. However, in this project chrome, aluminum, sheet metal, wood, Styrofoam and castermid will be used together. [4] The reason is, this is a simple prototype of the project so some cheap, strong and useful materials should be used.

The most of the structure of the CNC Devices are made of sheet metal.

The joint brackets of robot arm are made of aluminum.

Chrome is used to build the mills of the conveyor system.

A square wood part will lay under the project to make a support.

Styrofoam is used to cover the circuits and cables around the table.

The covers for the motors of the conveyor system will be made of castermid.

1.2.2 Control Systems

In FAS project, ARDUINO Uno and ARDUINO Mega, same as in Figure 2, is used. Because it is one of the cheapest microcontroller in marketing and its programming is easier than the others. [5]

ARDUINO Uno is used to control the CNC prototypes. Each CNC system will have its own microcontroller unit and this controllers will be programmed with 3 different computers. Also the conveyor system will be controlled with ARDUINO Uno, too. By this controller G Code Language can be converted to C Programming Language which is used by ARDUINO as well.

ARDUINO Mega is selected to control the robot arms and some other components. Furthermore, its connection area is larger than ARDUINO Uno so that whole connections and communication between all components are provided by Mega.

Also various sensors will be used and the ARDUINO controller system is able to control and read informations (input or output) from these sensors. [6]

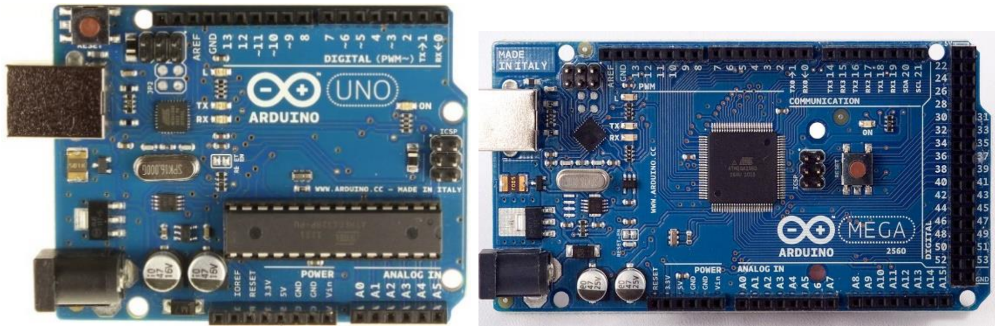

Figure: 2 ARDUINO Uno and ARDUINO Mega

1.2.3 System Objectives

In this project there is a robot arm and a robot pan, 3 CNC Devices and a Conveyor System.

- A **Robotic Arm** is a robotic manipulator, which can be programmable and has the same functions with a human arm. To rotate the joints, servo motors will be used.[7]
- This **CNC Devices** are actually CNC Plotters so they are able to draw any shapes and will be controlled by ARDUINO microcontroller.
- **Conveyor System** is used to carry the workpiece to the desired station so that the robot arm can reach and take that part on the conveyor.

1.3 Objectives of the Project

Nowadays, lots of automation systems produce only one type of material. To produce more than one, an operator should change the production line or the machines. However, the FAS project provides a fully automated system. The main objective is making different processes by identifying parts. Every part will have its own machine. The system will detect the part and put it to the desired machine. Number of human labor is decreased by this process. Furthermore, it is a flexible system. The places of the components can be changed according to the desired production lines.

1.4 Organization of the Report

- The first chapter gives brief information about automation systems and describes the components of the FAS project. In addition, objective of the project and the organization of the report can be found in this chapter.

- The second chapter includes a literature review and a background information about Flexible Manufacturing System. Advantages and disadvantages of the related works and some examples are mentioned as well.
- Some technical information about the components and equation analysis is explained in chapter 3.
- In chapter 4, manufacturing and assembling processes explained briefly.
- Chapter 5 describes the results and technical difficulties occured in the FAS project.
- Conclusion and the future work sections are mentioned in chapter 6.
- Logbooks of the team members, Gantt chart, drawings of the components and the project, engineering standarts and the website and the poster of the project are presented in Appendices section.

CHAPTER 2

LITERATURE REVIEW AND BACKGROUND INFORMATION

2.1 Literature Information of Flexible Automation System

Flexible automation has lots of definitions and meanings. A CNC machine can be given as an example to the flexible automation system. However, a completely automated flexible system consist of multiple CNC machines, possibly robot arms and vehicles guided automatically which transport parts between the machine inventories and a computer which has a connection with all the machines and send them orders.

The level of automation changes inversely the level of human intervention approved by the specific application. Flexible Automation System can be found in both assembling and fabricating and the various types of manufacturing in these categories.

Flexible automation might be found in both fabrication and assembly and the different types of manufacturing include in these categories. However, the main aim in this report is flexible automation in Flexible Manufacturing Systems. [8]

2.2 What Has Been Made on a Chosen Project?

There are lots of examples of Flexible Automation System which is used in various areas. Flexible Automation System is used to increase the productivity in manufacturing areas by using less cost per unit production and high mix of different parts.

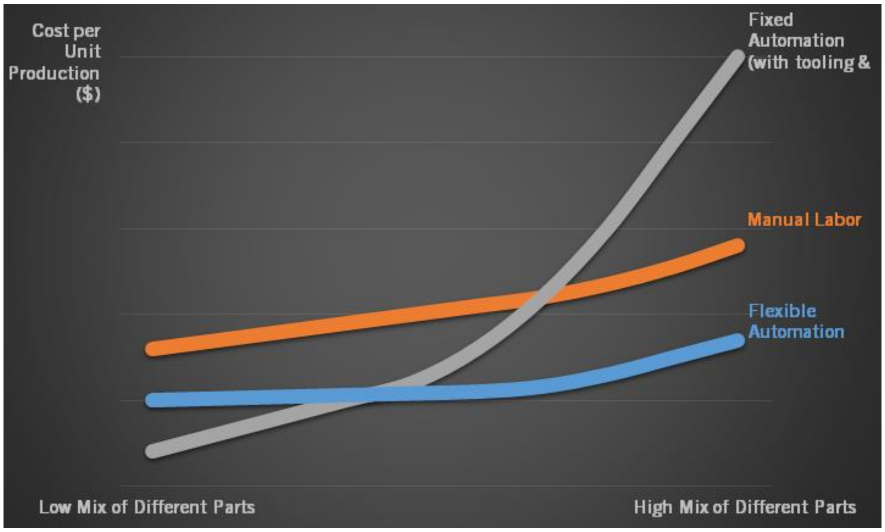

Figure: 3 Difference of Fixed Automation and Flexible Automation [26]

Flexible Automation System is generally used in Industrial Manufacturing areas. For example Flexible Automation System can be used to build automobiles. On the other hand, it can be used in medicine sector to take and identify the pills, make processes on them and put them in the specific bottles.

Moreover, by using sensors some properties can be added on automation system. For example, automation systems with wireless connection are produced, nowadays. In this kind of systems, wireless connection is used to provide the communication between the machines so that the design becomes more intelligent and easier to understand.

Another property is reached by using identification sensors such as RFID, colour sensor, etc.

For example, RFID sensor is a new technology and is used to get better and faster issue solutions. RFID sensor detects the part itself by reading the label. It is not human controlled, it is fully automated. Also colour sensor can detect and identify the part by reading its colour. It is fully automated, too. It does not need any human control.

2.3 Examples to the Flexible Automation System in Different Areas

As it mentioned before Flexible Automation System is used in different areas.

Some of them are listed below:

2.3.1 Automotive Sector

Nowadays in automotive sector robots are the most usable devices in the production line as shown in Figure 4. In this production line there is a direction of material follow, which is called sequence that all the devices must follow. This sequence is created by a user on the computer. The robots and all the devices will do their job in this sequence and the parts will be produced, taken from the conveyor and be assembled.

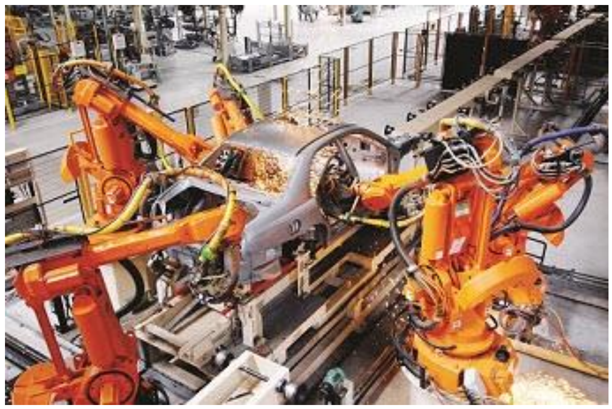

Figure: 4 Flexible Automation System in Automotive Sector [27]

2.3.2 Medicine Sector

The usage of the Flexible Automation System in medicine sector come up with an idea which will increase the productivity of medicine products. For example; The Inventek Engineering Automated Bottling System is a highly flexible fully automated bottle processing line as shown in Figure 5. This bottling system can identify various sizes and types of bottles with no mechanical setup. Loading, capping, filling and labeling operations can be done with this bottling system. The collection of data and process controls are designed in this systems and according to the desired product and it is fully automated. The Inventek Engineering Automated Bottling System allows you to change between the different bottle types by just touching a photo of the bottle in advanced user interface like in Figure 6. [9]

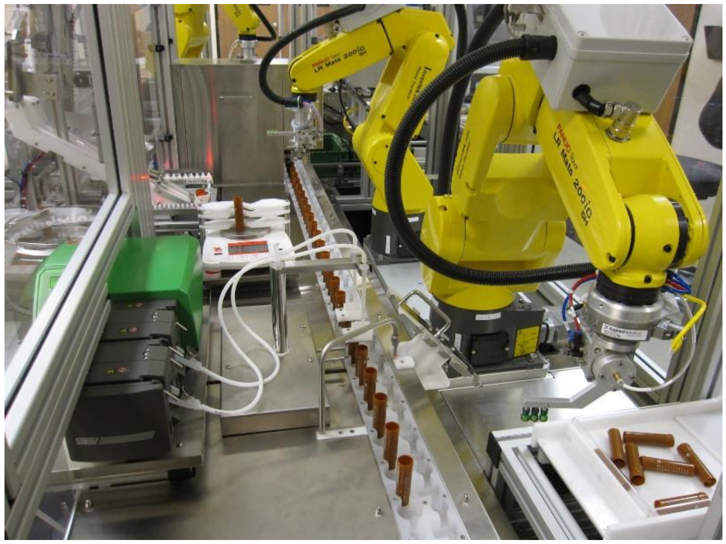

Figure: 5 the Inventek Engineering Automated Bottling System [28]

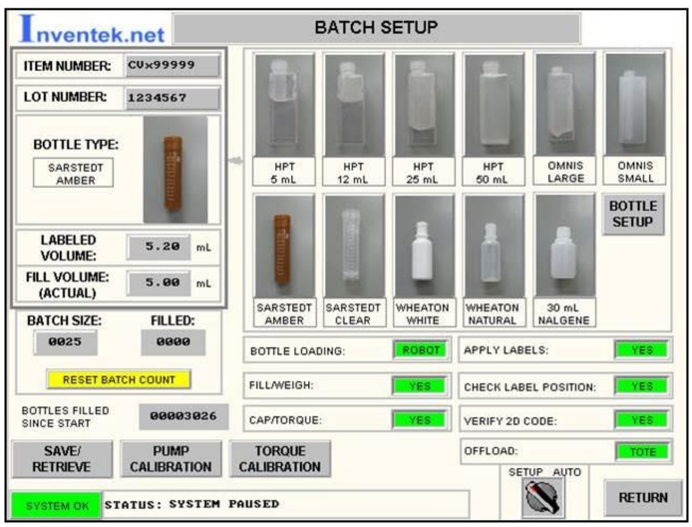

Figure: 6 Software for the Bottling System [28]

2.3.3 Flexible Automation System in Food Sector for Packaging

The food industry has traditionally lagged behind other industries in assimilate new technology. However, quick development in computer technology and rapidly increased expectations from the users for improved food quality and safety have enforced food industry to regard automation of most manufacturing processes.[10] For example; The PicknPack packaging system serves the benefits of automation to the food industry. The cost can be reduced, a greater hygienic environment can be satisfied by this system. In this system there are several cells as shown in Figure 7. One cell assesses the quality of the products just before or after packaging process. Second cell includes a robotic handle module which picks up and separates the products from a dustbin or transferring system and puts it in the desired positon in a package. Finally, the last cell has an adaptable packaging module that can do various types of packaging with different package shape, size, sealing and printing. [11]

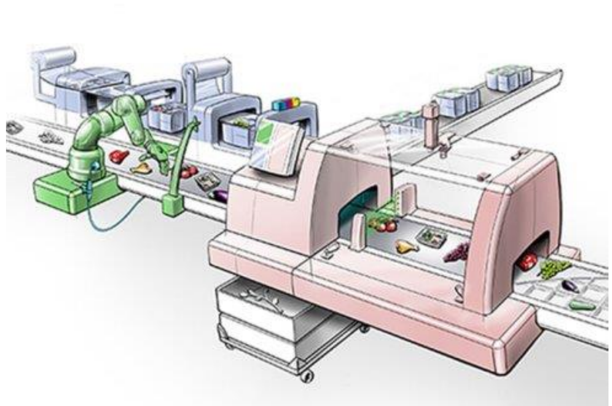

Figure: 7 PicknPack Packaging System [29]

Figure: 8 Flexible Automation System in Food Sector

2.4 Advantages and Disadvantages of the Flexible Automation System

The capability of producing different products without major retooling is really high. Human labor is less and the total salary that is given to the workers will decrease. Furthermore, the system is flexible in itself. All of the components can change places according to the desired workpiece production. Also, more components can be added. In addition, the control mechanism of the project can be centralized or distributed to several computers. It produces more products under one roof, more quickly. Moreover, it improves efficiency, the product quality and routing. The time is reduced for product completion as well.

On the other hand, installation cost of the project is a bit expensive. Moreover, too much work is required to connect the wires. Also, there is difficulty to find errors on the system. It requires a skillful work force. The biggest problem is exact component positioning and precise timing necessary to process a component.

CHAPTER 3

DESIGN OF THE PROJECT COMPONENTS

3.1 Conveyor System (Sliding Type)

A conveyor system is a part of mechanical handling equipment. It is used to move materials from one place to another. Conveyors are useful in applications including the transportation of heavy materials in general. There are lots of conveyor systems according to the needs of different industries. In this project, the materials will be transported by a single bed on a conveyor system. This bed will be on 2 steel shafts and will be pulled by a small belt. This belt will be rotated by a 12 Volt DC Motor with gearbox. Switches will be used to stop the bed in desired position. Also a robot pan is replaced at the end of the conveyor and the color sensor is attached on to this pan. This conveyor system is shown in the Figure 9 below:

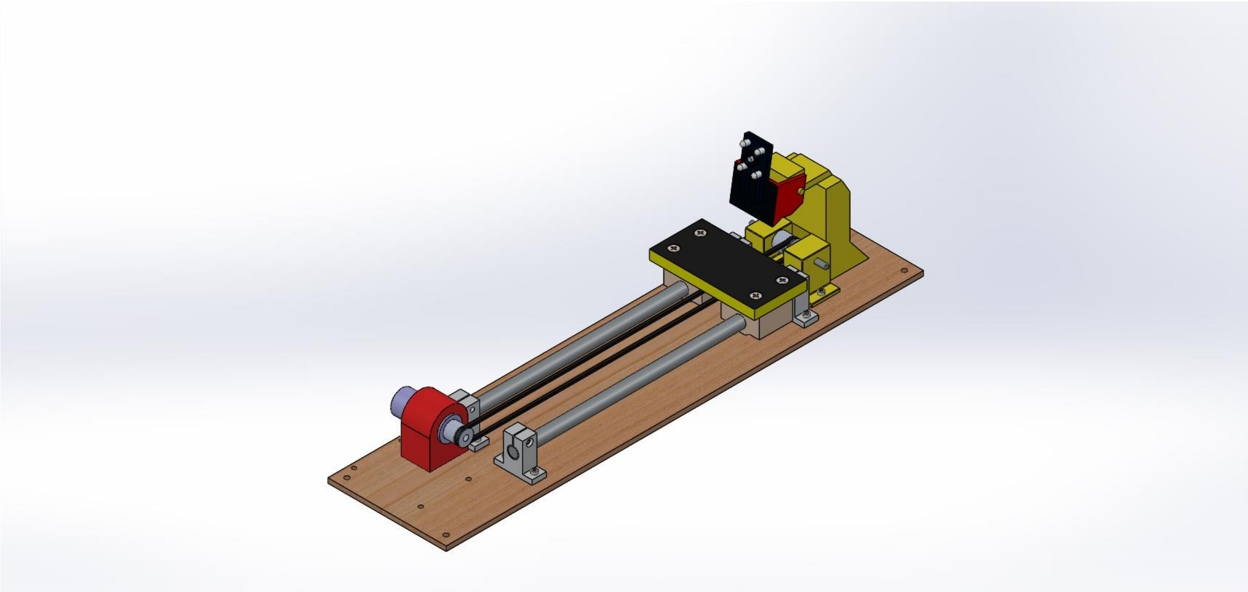

Figure: 9 Conveyor System in Flexible Automation System Project

3.1.1 Equations Related to Conveyor System [12]

3.1.1.1 Torque Calculation

Torque is the force that produces rotation. It causes an object to rotate. Torque consist of a force acting on distance. Torque, like work, is measured is Newton-cm.

$$T = F\ x\ D \qquad (1)$$

Where T is the torque (N.cm)

F is the force (N)

D is the distance in cm

For example, in this project the torque calculation of the DC motor is as follows:

The motor provides 30 N loads and the diameter of the pulley that is attached on DC motor is 1 cm. So, $Torque\ (T) = 30N\ x\ 1cm = 30N.cm$

3.1.1.2 Modulus of Elasticity

The number that measures an object or substance's resistance to being deformed elastically when a force is applied to it is called Young's modulus or modulus of elasticity. [13]

By dividing the axial or normal stress (σ) by axial strain (ε), the modulus of elasticity can be calculated in the Equation (2) below:

$$E = \frac{\sigma}{\varepsilon_{elast}} \qquad (2)$$

Where E is the modulus of elasticity (N/m^2 (Pa))

σ is the axial or normal stress (N)

ε_{elast} is the elastic elongation at the end of the described number of cycles (m$^{2)}$

The modulus of elasticity of castermid is 4000 MPa.

3.1.2 Robot Pan in Conveyor System

Robot pan will help a part which is montaged on to it to rotate 180 degrees by servo motor. In this project it will carry the color detector sensor module will put it to the desired position. It will stand at the end of the conveyor system as shown in Figure 10:

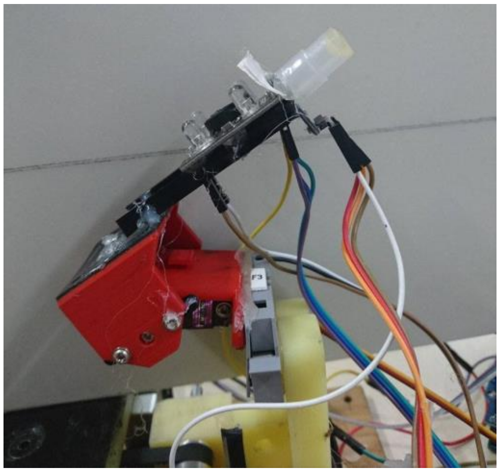

Figure: 10 Robot Pan and Color Sensor

3.1.3 DC Motor in Conveyor System

A 12 Volt motor will rotate the belt and this belt will carry the bed until switches. When the bed touches a switch, it will stop.

These are the properties of the DC Motor which is shown in Figure 11:

- Operating voltage of the motor is 12 V DC. The working speed is 60 RPM.
- Power of the motor is 14 W.
- No-load current of the motor is 70 mA.
- Motor’s load current is 1.2 A.

Figure: 11 12V DC Motor for Conveyor System

3.1.4 DC Motor Driver (L298N Driver)

This driver in Figure 14 will be used to control the 12 V DC Motor which will run the conveyor system.

L298N Motor Driver is used to drive the motors that works with up to 35V DC. It has two channels that each channel supports 2A connection. It has a L298N microchip which is usable for driving motors. This driver also can be used to drive stepper motors as well. [14]

3.1.4.1 Pins of the driver:

GND: Ground connection

5V: 5V output

EnA: Enables PWM signal for Motor 1

In1: Enable Motor 1

In2: Enable Motor 1

In3: Enable Motor 2

In4: Enable Motor 2

EnB: Enables PWM signal for Motor 2

3.1.4.2 Specifications:

Microchip: L298N

Logical voltage: 5V

Drive voltage: 5V-35V

Logical current: 0-36mA

Drive current: 2A

Max power: 25W

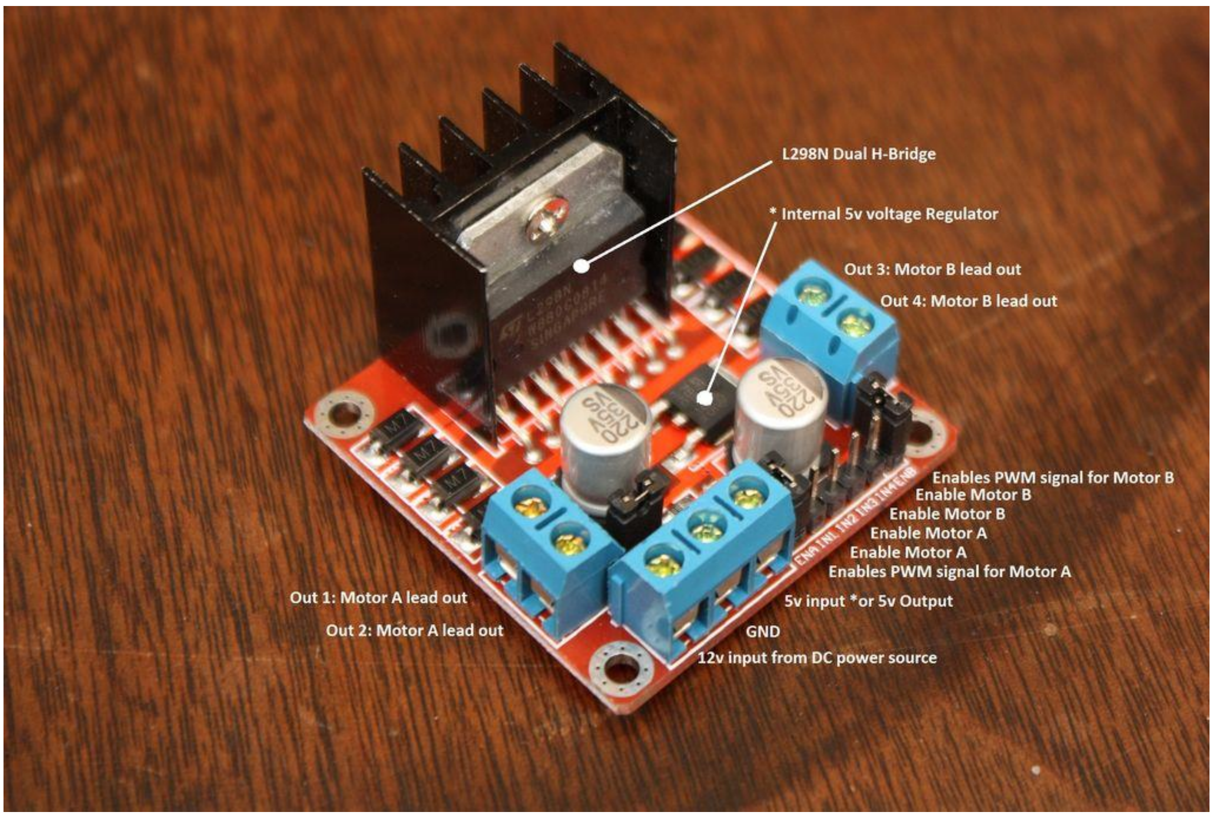

Figure: 12 Pins of the L298N Motor Driver

3.1.5 Sensors in Conveyor System

In this conveyor system several sensors will be used in different places to help the system to continue to run. These are as follows:

3.1.5.1 Mechanical Switches

At the beginning of the conveyor, there is a mechanical switch as shown in Figure 13. This switch will send signal to the microcontroller whether it is pressed or not. When the conveyor bed touches the switch, the switch will be activated. After the activation, it will send a signal to the control system and the control system will do several actions according to the program.

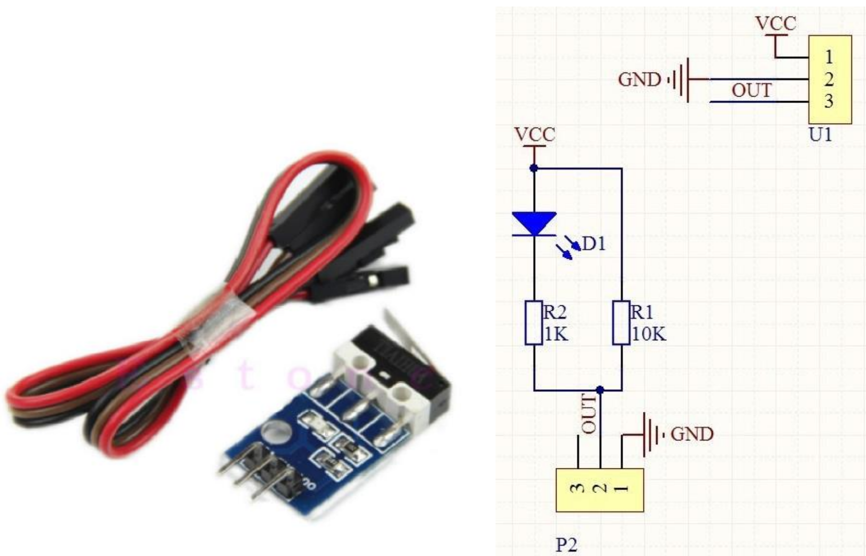

Figure: 13 Switch Sensor

3.1.5.2 Infrared Obstacle Avoidance Proximity Sensor Module

Infrared Obstacle Avoidance Proximity Sensors Module (Figure 14) has built in IR transmitter and IR receiver that sends out IR energy and looks for reflected IR energy to detect presence of any obstacle in front of the sensor module. The module has on board potentiometer that lets user adjust detection range. The sensor has stable response even in ambient light or in complete darkness.

The sensor module can be interfaced with ARDUINO, having IO voltage level of 3.3V to 5V. In this project, it is used for part detection and is replaced on the conveyor bed. [20]

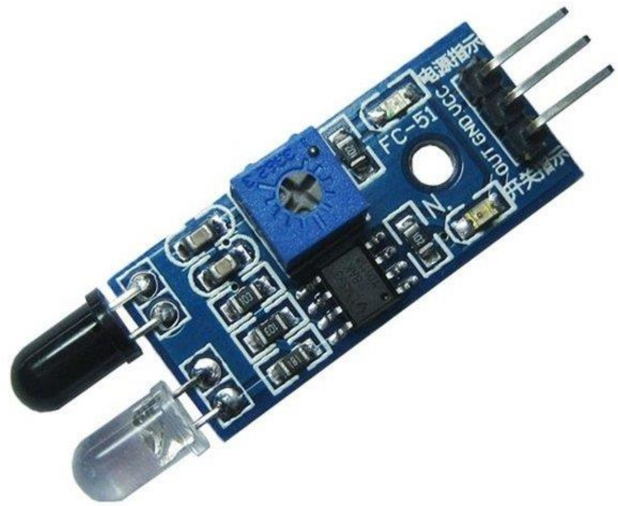

Figure: 14 Infrared Obstacle Avoidance Proximity Sensor Module

3.1.5.3 Color Sensor Detector Module (TCS230)

The color detector module (Figure 15) can measure and detect a nearly limitless range of visible colors. The TCS2300 has an array of photodetectors, and it can clearly detect red, green and blue. In this project it is used for color detection of the parts on the conveyor bed. [21] [22]

Figure: 15 Color Sensor Detector Module

3.2 Robot Arm

A Robotic Arm is a robotic manipulator, which can be programmable and has the same functions with a human arm. To rotate the joints, servo motors will be used. The number of the degree of freedom is nearly same as the human arm. While taking something from somewhere, humans do not need to think about the steps. They just take it. However, if a robot arm wants to take something, a user should send it some codes in a specific order. Opening or closing of the gripper or rotation of the joints should be told to the robot arm. All the joints are controllable with the computers. Furthermore, the control system will get various data from sensors and the robot arm will do its job according to the data's from the sensor. [15]

In this project a 4-DOF (Degree of Freedom) robot will be used. Also a pneumatic vacuum suction will be replaced on the top of the robot arm. The joint rotation will be provided with servo motors. This servo motors will be integrated to the robot arm with brackets (Figure 17) which already exists according to various sizes of servo motors. These are some properties of this robot shown in Figure 16:

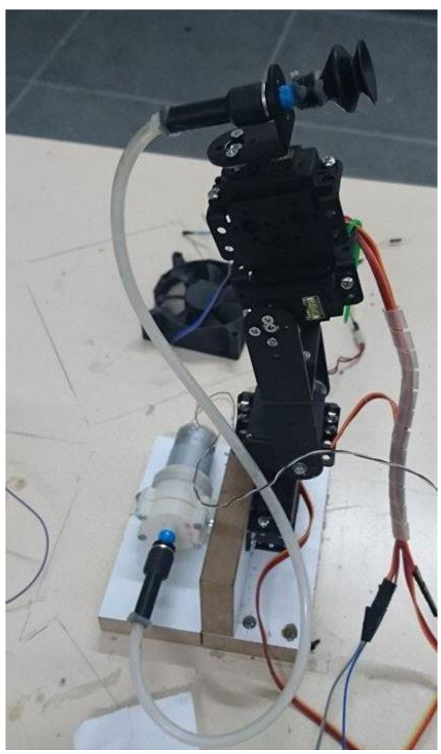

Figure: 16 4-DOF Robotic Arm with Pneumatic System

Figure: 17 U-Bracket

- **Material:** The material which is selected for this robot arm's brackets is Aluminium. Because it is strong enough and soft and lighter metal than the steel. The modulus of elasticity of aluminum is 69 GPa. So that the total weight of the robot is reduced. The advantage of reducing the weight is less load on servo motors. Also the robot arm will stand on a wooden base.
- A small pneumatic system is integrated on the robot arm. This system consists of a vacuum suction and a pneumatic pump.

3.2.1 Servo Motors of Robot Arm

The joints of the robot arm is controlled by various servo motors.

To correct the performance of the system, an error detecting feedback control system is used. Servo applies to this feedback control system. A servo mechanism is implemented to Servo Motors to control the angular position. The servo motors do not rotate continuously. Their rotation is fixed. They can only return in a specific range of angles. [16]

For sensitive and definite positioning, the servo motors can be used. Generally, robotic arms use servo motors that is shown in Figure 18.

Figure: 18 Servo Motor

The Servo Motors includes three wires or leads in them. The positive supply and ground is provided by first two cables. The third wire is for the control signal. The wires of a servo motor are colour coded. Ground wire is coloured by black colour. The DC supply is coloured by red and it has to be connected to a DC voltage supply in the range of 4.8 V to 6V.For the third cable, all servo motors can have a different colour. Generally it is in yellow colour, same with the motors which will be used in this project.

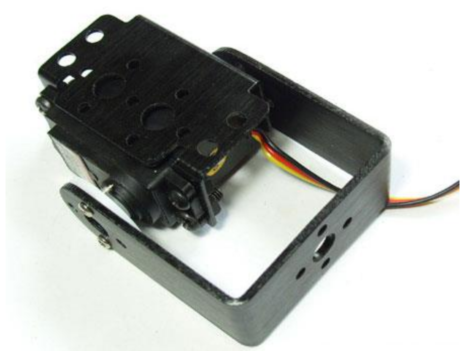

Figure: 19 Servo Motor with a U-Bracket

Here are the properties of the desired servo motors which are shown in Figure 18 and 19:

- The gears are made from metal.
- The operating speed at 4.8 V is 0.17sec / 60 degrees.
- The operating speed at 6.0 V is 0.13sec / 60 degrees.
- The stall torque is 13kg/cm at 6V.
- This servo motor can run between 4.8 and 7V.

- Power can be provided through external adapter.
- The length of the motor is 54mm.The width is 20mm and the height is 38 mm.

3.2.2 Pneumatic Pump and Vacuum Suction

This system will help to pick the part from conveyor system by sucking the air with the suction part. It contains two parts: vacuum suction and pneumatic pump.

The pump can be used for both air and water. Here are the properties of the pump and suction as shown in the Figure 20:

- Size of the pump: 90 mm * 40 mm * 35 mm
- Inner diameter is 6 mm and outer diameter is 9 mm
- Operating voltage is 6-12V DC
- Current is 0.5-0.7A
- Flow: 1.5-2L / Min (left)
- The maximum suction lift: 2 m
- When the voltage is 6V the power is 6W / H
- Overall diameter of suction is 23.5mm and fitting diameter is 4mm.
- Static height is 23mm but when compressed height compressed 11m
- It provides a 0.68 Kg load capacity

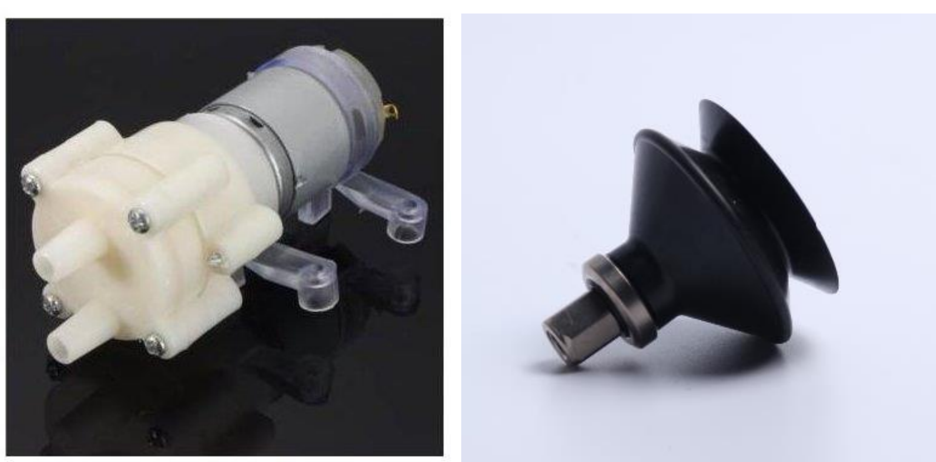

Figure: 20 Pneumatic Pump and Vacuum Suction

3.2.2.1 Equations for Pneumatic System

Several equations are used to calculate the pumping speed and compression ratio. These are as follows:

3.2.2.1.1 Compression Ratio

The compression ratio **K_0** of a Roots pump is generally between 5 and 70. To determine this ratio, the volume of gas pumped and the backflow by means of conductivity C_r is considered first, as well as the return flow of gas from the discharge chamber at pumping speed S_r:

$$\frac{Pa}{Pv} = Ko = \frac{So+Cr}{Cr+Sr} \qquad (3)$$

S_0 = Theoretical pumping speed on the intake side

S_r = Pumping speed of return gas flow

C_r = Conductivity

Pa = Inlet pressure

Pv = Backing vacuum pressure

3.2.3 Pneumatic Pump Control with Relay

In pneumatic pump, there is a 12V DC motor. To control this motor a relay module is used. It helps to open and close the DC motor as shown in the Figure 21:

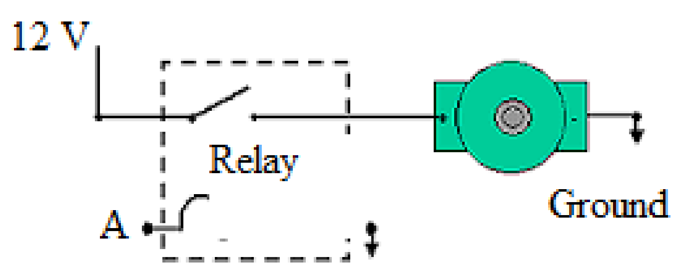

Figure: 21 Controlling a DC Motor with Relay

3.3 CNC (Computer Numerical Control)

3.3.1 CNC Devices in Flexible Automation System Project

In manufacturing sector, the computers are used to control the machines. This process is called CNC Machining. The turning machines, milling machines and grinding machines can be given as an example. The meaning of the CNC in CNC Machining is Computer Numerical Control. People can see that it is just a normal computer controlled process. However, there is a specific software and a console to control the system and machines.

In order to give a shape to a part a special computer program should be customized and the machines will be programmed with a special code language which is called G-Code Language. This program can control the feed rate, location and the speeds. The computer can control the exact velocity and position of the tool with CNC Machining. Both plastic and metal workpieces can be machined with CNC Machining.

In this project there will be three 3-axised CNC machines as shown in Figure 26. They will be used to make several drawing processes so they are actually called CNC Plotters. To control this devices, the user should use a software which generates G Codes for CNC machining. This software will send G codes to ARDUINO. Then ARDUINO will convert this codes and send them to CNC devices.

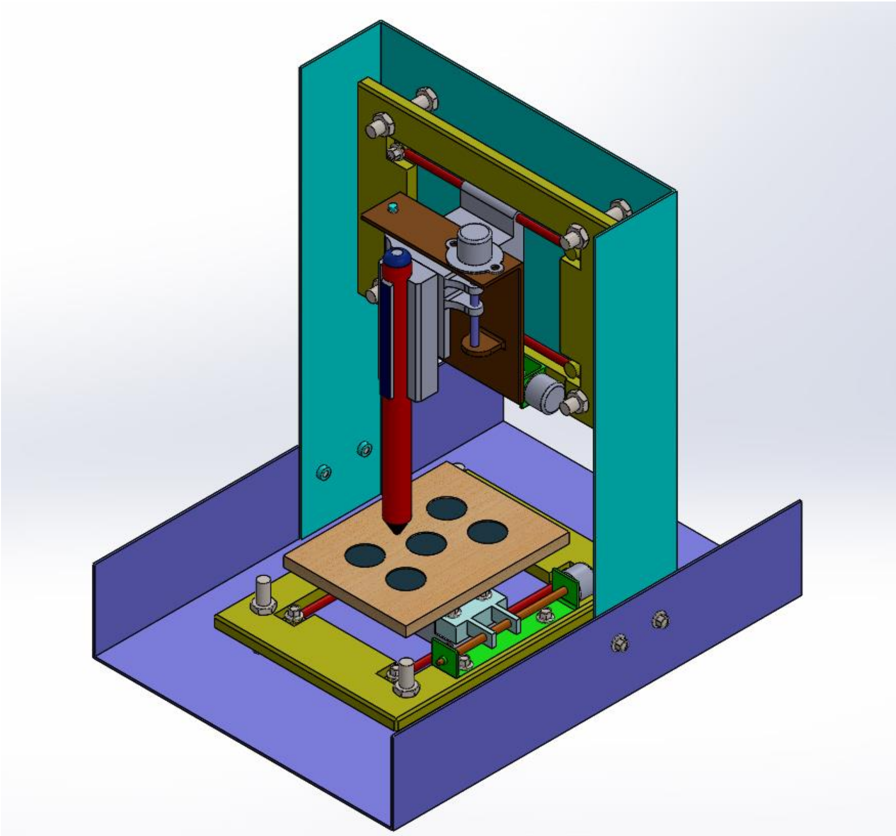

Figure: 22 CNC CAD Design

3.3.1.1 Stepper Motor Properties

This stepper motor is called B-04F3 and is 2-phased 4-wired with screw stages and slider screw nut and it is shown in Figure 23.

The properties are as it follows:

- A 4-12 V voltage should be given to the motor to drive it.
- The diameter of the screw is 3mm.
- Slider Width: 12mm (to reduce shaking improve accuracy, the original 10mm now increased to 12mm)
- Slide stroke: 61mm
- The step angle is 18°.

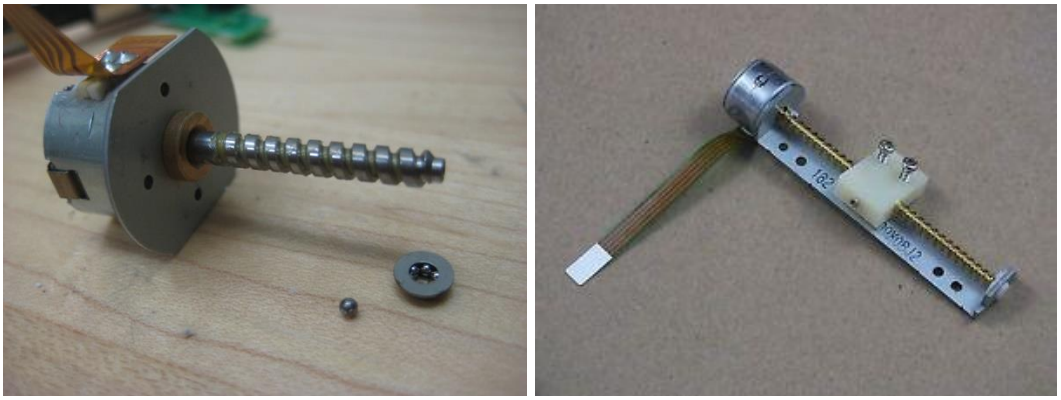

Figure: 23 Stepper Motors

3.3.1.2 Stepper Motor Drivers

To control the stepper motors, motor driver which is called EasyDriver is used which is shown in Figure 24. It has simple step and direction control interface. Also it is usable for each stepper motor in 3 axis of CNC devices. The board of the driver is powered by 7V to 30V supply to power stepper motors with any voltage. It has an on board voltage regulator for the digital interface that can be set to 5V or 3.3V. Also EasyDriver drives bipolar motors, and motors wired as bipolar. I.e. 4, 6, or 8 wire stepper motors. [24]

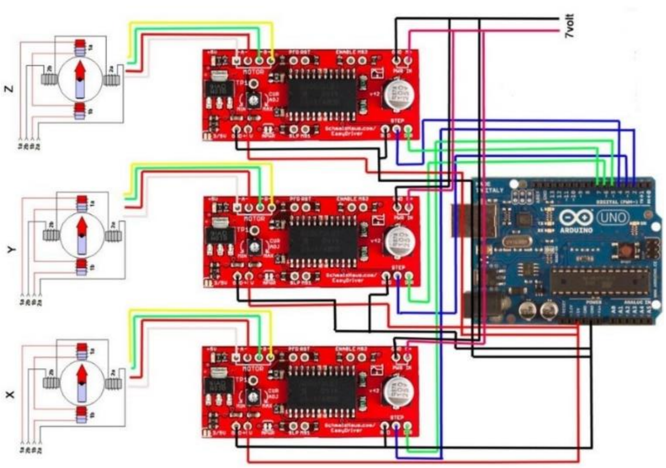

Figure: 24 EasyDriver Stepper Motor Driver

The EasyDriver has an adjustable current control from 150 mA/phase to 750 mA/phase and it is compatible with ARDUINO GRBL G-Code interpreter for driving 3-axis CNC machines.

3.3.2 G-CODE

G-codes are codes that is used in CNC Machining. Generally the machine tool knows to perform what type of work according to this code. [18] For example;

- It provides rapid movement. (It transports the tool as fast as possible through space to the location where it will cut.)
- It sets tool information such as offset.
- It is used to switch coordinate systems.

3.3.2.1 Software (G-CODE SENDER)

G-Code Sender will take a G-code program and send it line-by-line to the ARDUINO. In this project user can also execute individual commands to test your setup.

G-Code Sender's screen vision is shown in Figure 25 below;

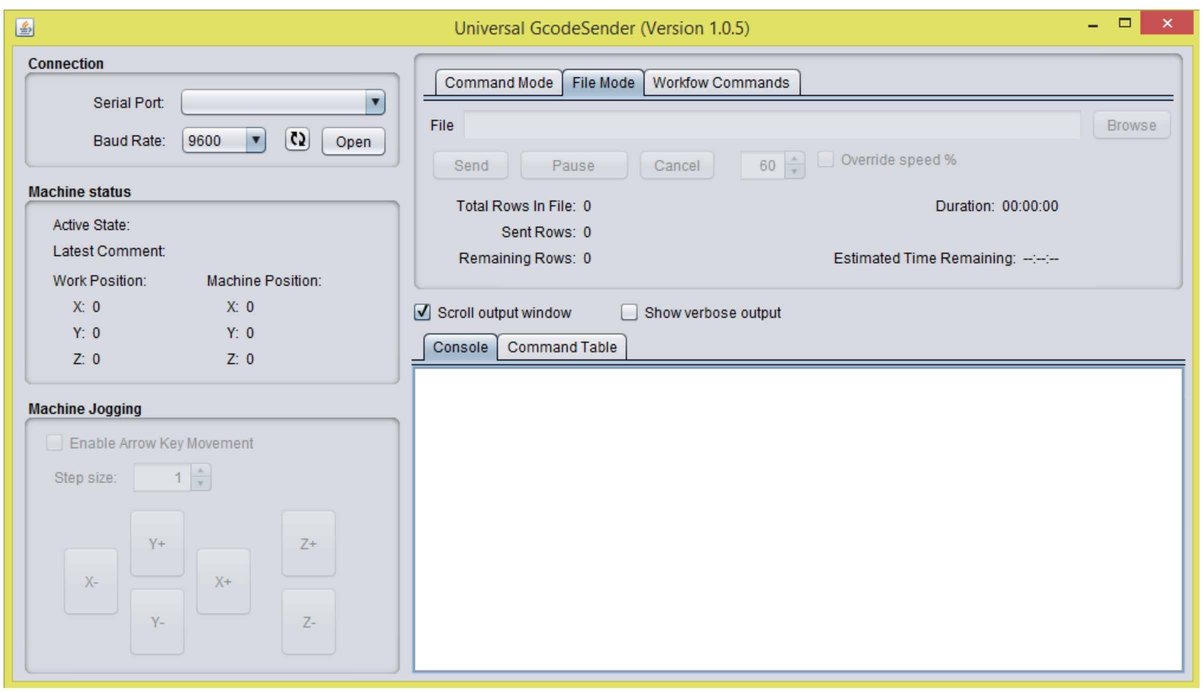

Figure: 25 G-Code Sender Software

3.3.3 CNC Equations [19]

3.3.3.1 Speed Formula

To calculate the cutting speed for the milling machine, the following formula, Equation 4, can be used:

$$Speed = \frac{SFM}{Circumference} \qquad (4)$$

Speed is selected as the speed of the spindle in revolutions per minute (RPM).

The speed at which the material moves past the outside diameter of the tool in feet per minute is called Surface Feet per Minute (SFM).This value is related with the tool type, tool material, and material being machined.

Circumference is the perimeter of the cutting tool in feet.

For example, if the speed is 500 rpm for a 10 mm drilling tool the SFM value is 5000.

3.3.3.2 Feed Formula

The following Equation 5 is used to calculate cutting feeds in inch per minute:

$$Feed = Speed\ x\ CL\ x\ NumFlutes \qquad (5)$$

The linear feed of the tool through the material is called Feed. It is in inch per minute.

Speed is calculated from the speed formula and will be put in this formula.

The tool removes some materials from each cutting edge and this is called CL (Chip Load).

NumFlutes is the number of cutting flutes. (For a twist drill, this value is one.)

3.4 Other Usable Equipments

- **Breadboards** will be used because, this makes it easy to use for creating prototypes and experimenting with circuit design. It is reusable.
- **Jumpers** will provide connection between components and it is necessary to build circuits on the breadboard.
- **Buttons** may be used on devices for decisions. (Resetting operations, on or off operations, etc.)
- **LCD Screen** will provide a display to the user. For example it will display if the motors are working or not.
- **LED** and **Buzzer** will provide visible content to the user. Such as alarm or remind the user a process.
- **Power Supply** is used to give external power for the system. In some cases different voltage limits are needed so ARDUINO cannot provide more than 5V and the current is so low. Therefore, this part supplies the required voltage and the current.
- **Fans** are used to cool down the microprocessors and motor drivers.
- There are two **Sensor Shields** which are used for easy plugging for ARDUINO Uno and MEGA. Also they have their own circuit designs according to the sensor's pins.

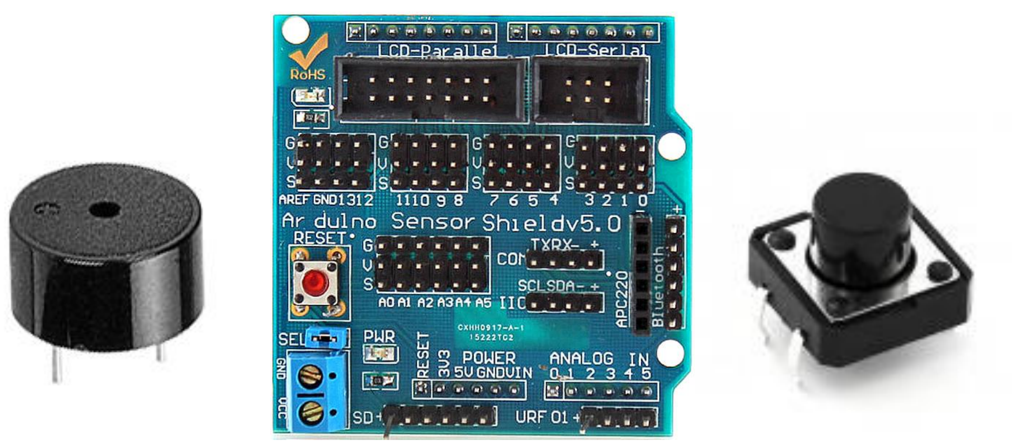

Figure: 26 Sensor Shield, Buzzer and Button

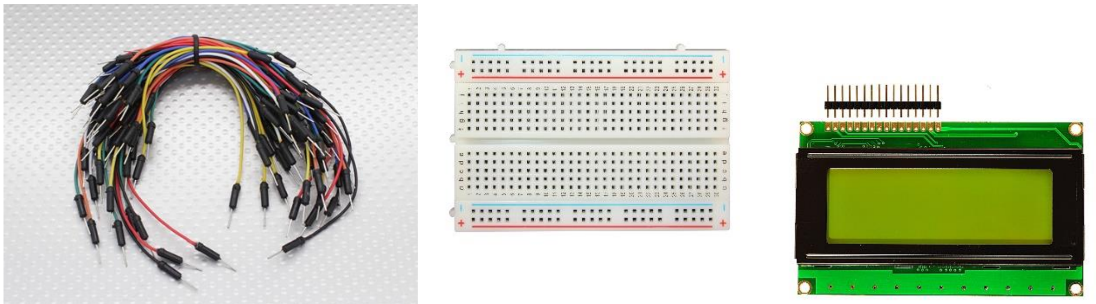

Figure: 27 Jumper Cables, Breadboard and LED Screen

3.5 Workpiece Prototype

The parts that will be used for drawing process is made of Styrofoam and covered with red, green and blue colored papers as shown in Figure 28. According to this colors, several drawing processes will be done to the workpieces. This pieces are actually a prototype of a metal workpiece so a small metal piece has been attached under the Styrofoam piece. This will help the magnets on the CNC bed to hold them still.

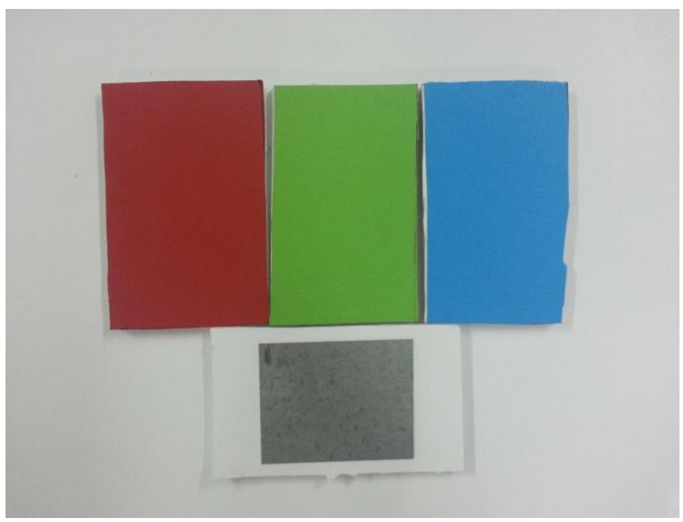

Figure: 28 Workpiece Prototype

3.6 Nuts and Bolts

The bolts are used to tighten the components of the project. According to the bolt measurements, the nuts will be chosen, too. The flanged nuts will be used in this project because, it cannot be untightened easily.

Figure: 29 Bolt and Nut

3.6.1 Where will Nuts and Bolts be used?

The nuts and bolts will be used to fix the CNC body parts together. Also it will be used to fix the robot arm on to a smooth surface. Furthermore, the conveyor system will be fixed to a table with bolts.

3.7 Final Cost Analysis

The expected cost for all the components used in FAS Project is as follows in Table: 1

Table: 1 Cost Analysis of FAS Project

MATERIALS	AMOUNT	COST
CONVEYOR SYSTEM		
Chrome Shaft	x2	100 TL
Timing Pulley and Belt	x1	40 TL
60 RPM DC Motor with Gear Box	x1	50 TL
Robot Pan with Servo Motor	x1	50 TL
Wooden Base of Conveyor	x1	10 TL
Shaft Holder	x4	60 TL
Linear Bearing	x2	50 TL
Castermid	-	30 TL
Color Detection Sensor Module	x1	50 TL
Mechanical Switch Module	x3	15 TL
Infrared Sensor Module	x1	15 TL
ARDUINO Uno Sensor Shield	x1	30 TL
ARDUINO Uno R3 Kit	x1	50 TL
Power Supply 12V/10A	x1	50 TL
Robotic Arm		
Aluminium Bracket Set	x1	165 TL
MG995 Servo Motor	x4	160 TL
Pneumatic Pump	x1	50 TL
Vacuum Suction with Plastic Pipe	x1	45TL
Wooden Base of Robotic Arm	x1	10 TL
ARDUINO Mega Sensor Shield	x1	50 TL

Arduino Mega 2560 Kit	x1	140 TL
Power Supply 5V/16A	x1	80 TL
CNC Plotters		
CD-ROM	x9	-
Laser Cut Wooden Part	x3	30 TL
Magnet Kit	x1	5 TL
Styrofoam	x1	30 TL
Stepper Motor Driver (EasyDriver)	x9	180 TL
Marker	x3	30 TL
ARDUINO Uno R3 Kit	x3	150 TL
Other Components		
Breadboard	x3	60 TL
Jumper wire	x240	100 TL
Button, Buzzer, LED	-	20 TL
LCD Screen	x1	50 TL
Fan	x3	45 TL
Nuts (M5)	x72	10 TL
Bolt (M5)	x24	20 TL
Screws (M3)	x20	10 TL
Screws (M5)	x10	10 TL
Wooden Base of the FAS Project	x1	30 TL
Total Cost		**2080 TL**

CHAPTER 4

MANUFACTURING, ASSEMBLY AND TESTING

4.1 Conveyer System

4.1.1 Manufacturing Process of Conveyor System

The conveyor system which is used in FAS project is a linear sliding bed type conveyor. The reasons are the vibration is reduced to minimum by using this type and it provides accurate motion to desired positions. Also it is not needed to carry several parts together, it will only carry only one part and there is no need of a long range. A short one is enough. In addition, it can carry heavier objects with compared to belt type conveyors. This system is supported by two 12x300mm shafts which is made of steel and chrome plated. Chrome is selected because it has resistance to corrosion and scratching and it provides a smooth movement when used with linear bearings (Figure 30). Instead of using short shafts, long ones preferred because it provides a stronger base.

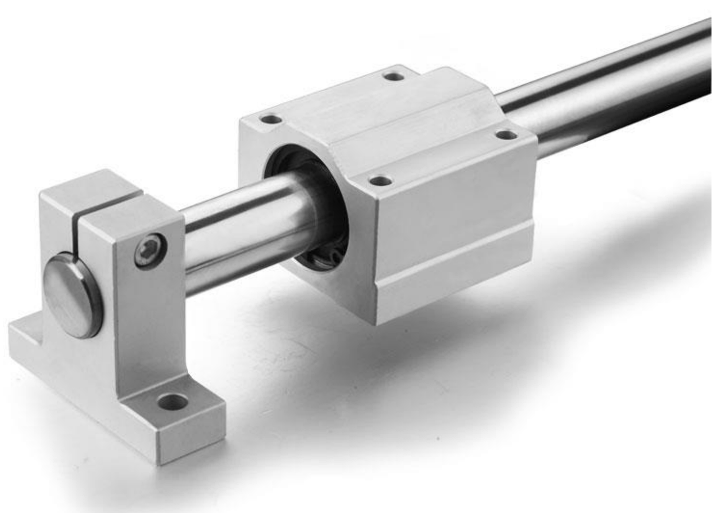

Figure: 30 Chrome Shaft, Shaft Holder and Linear Bearing

Linear bearings carry the conveyor's bed. Also there is a GT2 type timing pulley and belt as shown in Figure 31. The timing pulley has 20 teeth on it. In addition, there is a 6x700mm belt that is made of rubber reinforced with fiberglass and the pitch distance is 2mm which is attached to the bed, that provides a linear motion and it is connected to the DC motor. The reason that timing pulley used is it gives better smoothness and accuracy of positioning, resulting a better linear movement and positioning.

Figure: 31 GT2 Timing Pulley and Belt

The holder of the timing pulley and the conveyer's bed are made of castermid. Castermid has been preferred in places that needs endurance because it has low rubbing index, it is economic and easily cultivable. [25] At the top of the holder there is a robot pan which is made of plastic and it is produced by 3D-Printer.

4.1.2 Assembly of the Conveyor System

The shafts, bearings and the bed are assembled together and the shafts are fixed to a wooden base with shaft holders by using M5 screws. The distance between shaft holders should be 300mm and this will provide a 300mm range of movement of the conveyer's bed. DC motor is attached to the beginning of the conveyor system and is connected with the belt. After that IR sensor is montaged to the conveyer bed and moves together with it. Also the robot pan is attached to the pulley holder.

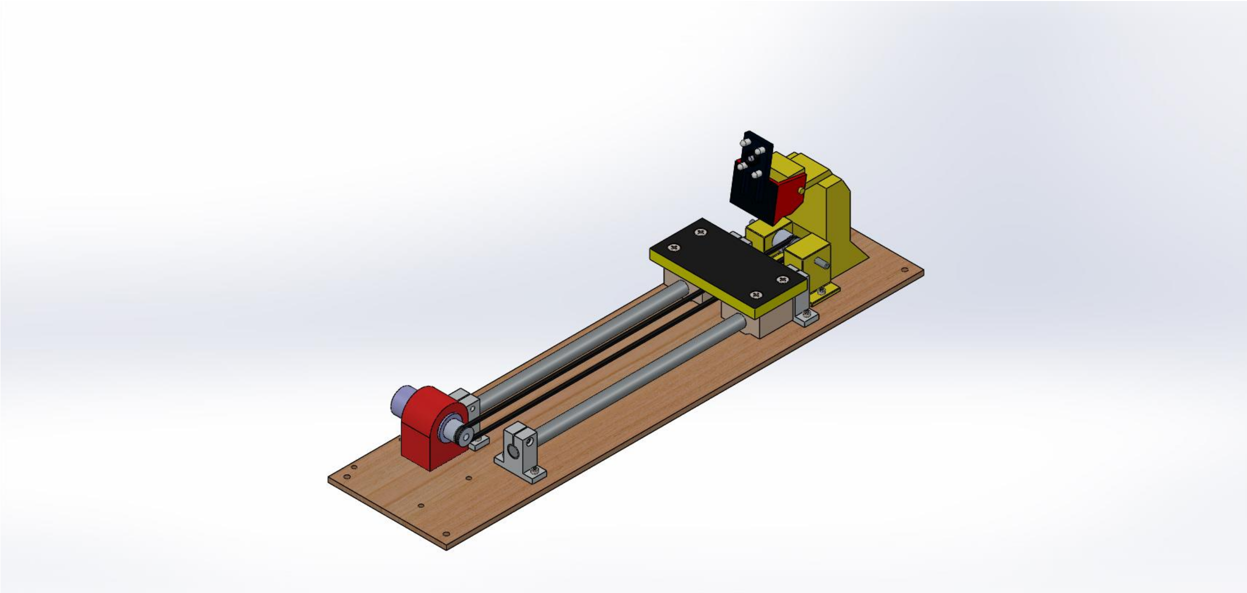

Figure: 32 Final Assembly of the Conveyer System

4.2 Robotic Arm

4.2.1 Manufacturing of Robotic Arm

The material of the U-Brackets is anodized aluminum. It is called anodized because an electrochemical process is applied to aluminum surface to make it decorative, durable and corrosion-resistant. Also, it is called hard aluminum

The shape of the brackets are in U-shape. The reason is, it can grab a servo motor well and suitable for assembling processes.

At the top of the robotic arm there is a vacuum suction as shown in Figure 33. The vacuum suction is specially designed and it is made of a type of rubber which is called nitrile. The flared overall diameter is 23.5mm and the fitting diameter is 4mm. Static height is 23mm but when it is compressed, the height becomes 11mm and this provides 0.68 Kg load capacity.

Figure: 33 Vacuum Suction

For the base of the robotic arm, a wooden block has been chosen because it is lighter than a steel base and it is easy to obtain.

4.2.2 Assembly of the Robotic Arm

Firstly, three 135x60x18mm wooden blocks are prepared in workshop. Two of them are attached in perpendicular to form the base of the robotic arm and it is fixed to the first joint of the robotic arm and the main base of the project with M5 screws. The third block will lay down under the pneumatic pump and it is fixed to the other blocks and the main base with the screws as shown in the figure 34.

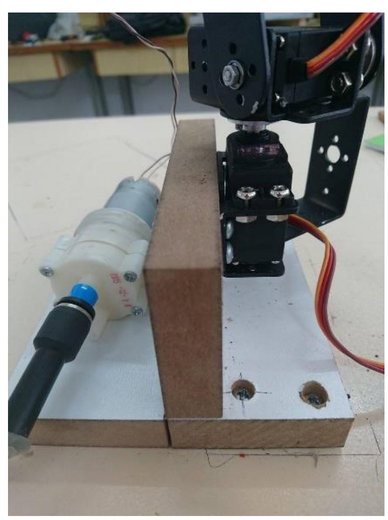

Figure: 34 Assembling of Wooden Base

After that the servo motors are attached to each other by using U-brackets with M3 screws to form the robotic arm (Figure 35). The servo motors are the joints of the robotic arm and U-brackets form the links of the robotic arm.

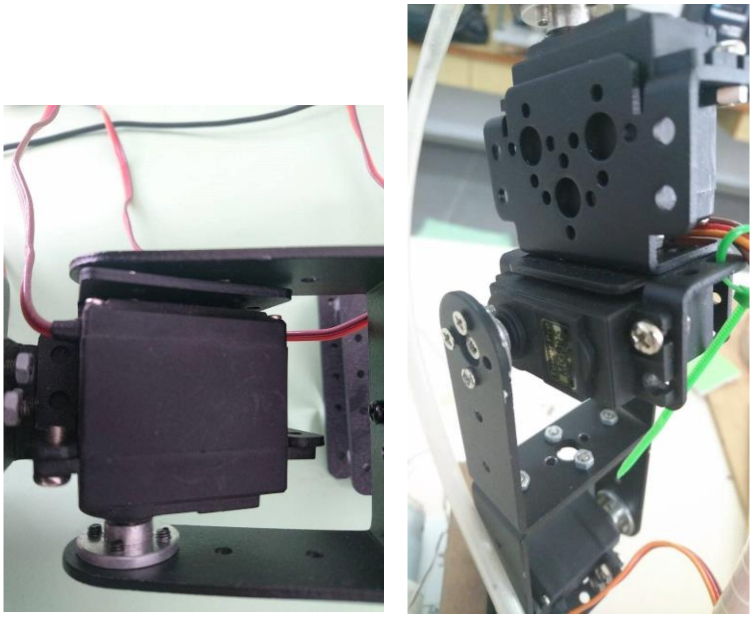

Figure: 35 Joint and Link Assembly

Finally, the vacuum suction is assembled to the top of the robotic arm. The pneumatic pump is placed at the back of the robotic arm and a 300mm plastic pipe will make the connection between the pump and the suction (Figure 36).

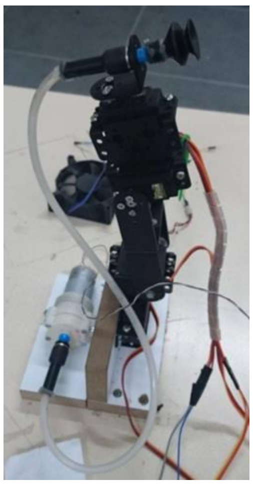

Figure: 36 Final Assembly of the Robotic Arm

4.3 CNC Plotters

4.3.1 Manufacturing of CNC Plotters

There are 3 CNC Plotters in FAS project. This plotters is produced from unused and old CD-ROMs. CD-ROMs are used because it is low cost and they have their own rail system which is usable for building a CNC axis. When 3 axises are assembled together perpendicularly a CNC device can be constructed. In addition a CD-ROM can only provide a single axis so that for each CNC Plotter, 3 different (total of 9) CD-ROMs are needed.

The building process is begun with demounting the CD-ROMs. The material of the cover is sheet metal. However, it has high endurance against bending. These covers shown in Figure 37 will be used carry the X and Y-axis rails.

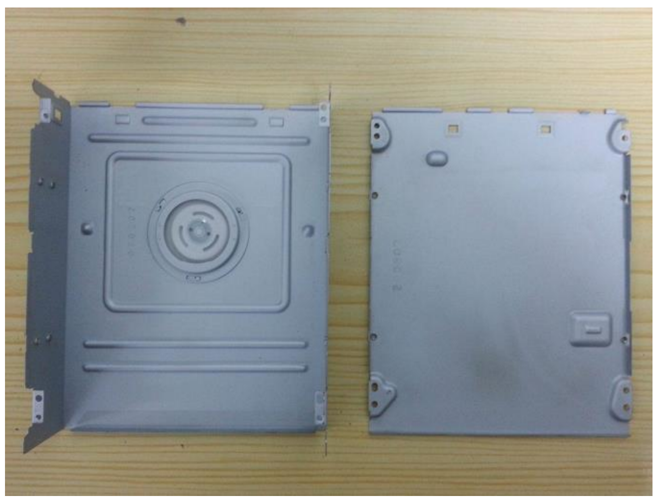

Figure: 37 CNC Covers Made from CD-ROM Covers

The stepper motor section of the CD-ROMs is used to make the axes of the CNC Plotters (Figure 38). The range of these axes will be 40mm. Several jumper wires are attached to the stepper motors by soldering to connect them easier and by using a multimeter, correct combinations of the phases of the motor is found to drive them.

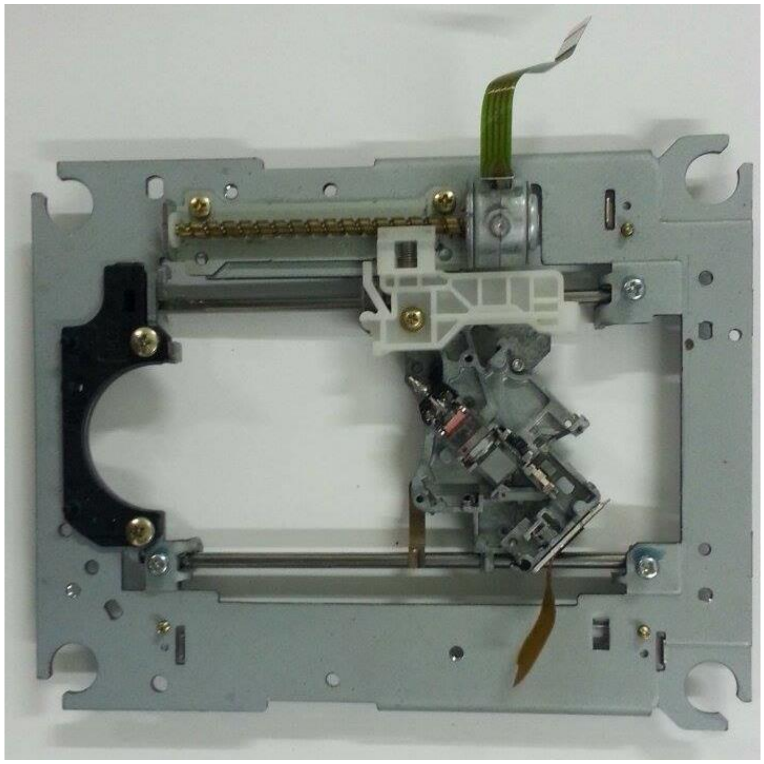

Figure: 38 Rail System for Axes

4.3.2 Assembly of the CNC Plotters

Firstly, rail systems are placed on to the covers to mark the places of the screw holes. Then marked holes are drilled in workshop. After that, rail systems are mounted on the cover in parallel with nut bolts. This procedure is made for only X and Y-axis. After mounting X- axis, a smooth straight plate attached on to X-axis rail and Z-axis is mounted on this plate.

Then, two covers which have rails on them are attached together perpendicularly with welding method (Figure 39).

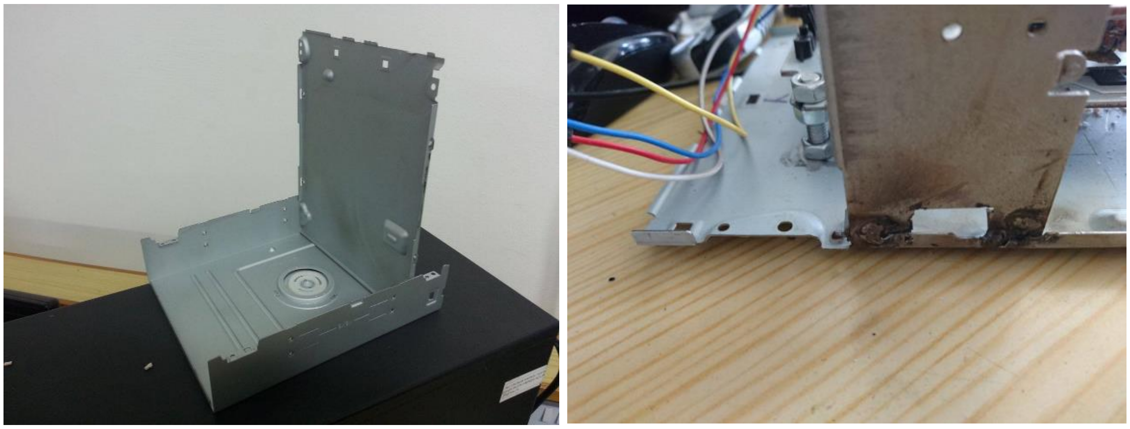

Figure: 39 CNC Covers

A wooden plate is designed and cut with laser CNC as shown in Figure 40. This plate will carry the manufactured parts on it. Then, the wooden plate is mounted on to Y-axis rail. There are several magnets on the plate as well. Magnets will be used to hold the material which will be processed.

Figure: 40 Laser Cut of the Wooden Plate

Finally, a drawing pen will be attached on to the Z-axis rail and it will make the desired drawing processes.

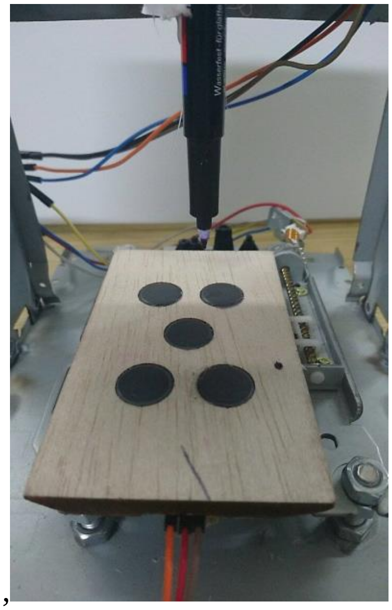

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Figure: 41 Wooden Plate of the Y-axis Rail

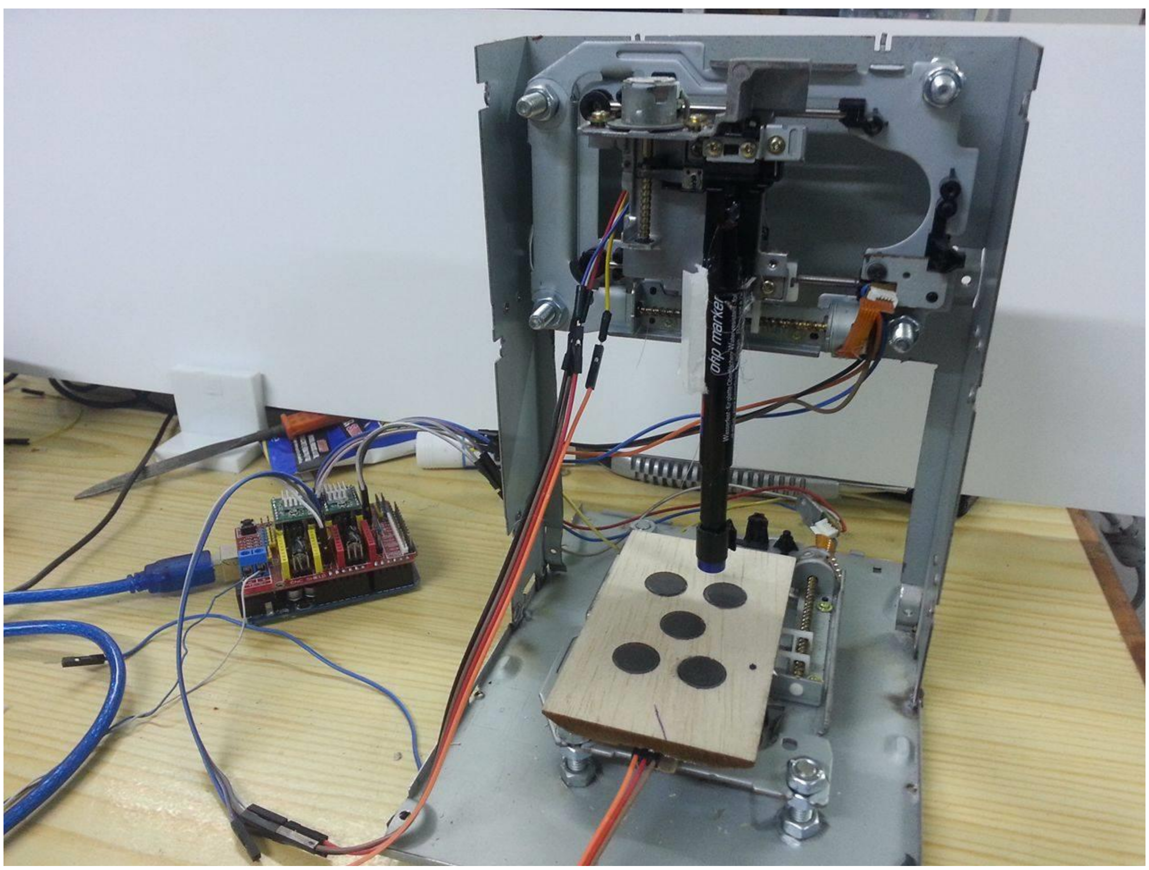

Figure: 42 CNC Plotter

4.4 Working Principle of Flexible Automation System

The principal objective of the Flexible Automation System is to make an automation system by identifying parts with different properties. In this project, the identification criteria is color of the workpiece.

Firstly, the power supplies are opened to provide power to the system. One of them is connected to the robotic arm and the second one gives power to the conveyor system. Since they are opened, the robotic arm and the conveyer system goes to their home positions.

A human operator puts a part on the conveyer’s bed. IR sensor detects the part and the bed starts going at the end of the conveyor. There are two mechanical switches at this point. One of them deactivates the DC motor until robot arm takes the part and the other switch activates the motor of the robot pan. When the bed reaches the end, the switches activated. Robot pan moves the color sensor to the top of the bed and sensor activates to detect the color of the workpiece.

After detecting the color, robot pan goes to a safe position and robotic arm comes toward to the workpiece. When the arm is at the top of the workpiece, the pneumatic pump starts and vacuum suction grabs the workpiece. When there is no part on the conveyer bed, it returns to the home position and waits the next workpiece. When the robotic arm is in home position, it always checks the working status of the CNC Plotters if they are busy or not. Also each plotter will work for only one type of part (Red Plotter, Green Plotter, and Blue Plotter). If the detected workpiece’s plotter is empty, the robotic arm takes it from the bed and places it on to the plotter’s bed. If the detected workpiece’s plotter is not empty, this means there is a finished part on this plotter. The robotic arm takes that finished part from plotter and puts it to the finishing box. After that it comes back again to the conveyer system, takes the workpiece and put it to its plotter.

Finally, the robot arm returns to its home position. It checks all the plotters if they are busy or there is a finished workpiece. When they are empty, it waits for a signal to take the new workpiece from the conveyor system.

Figure: 43 CAD Design of Final Assembly

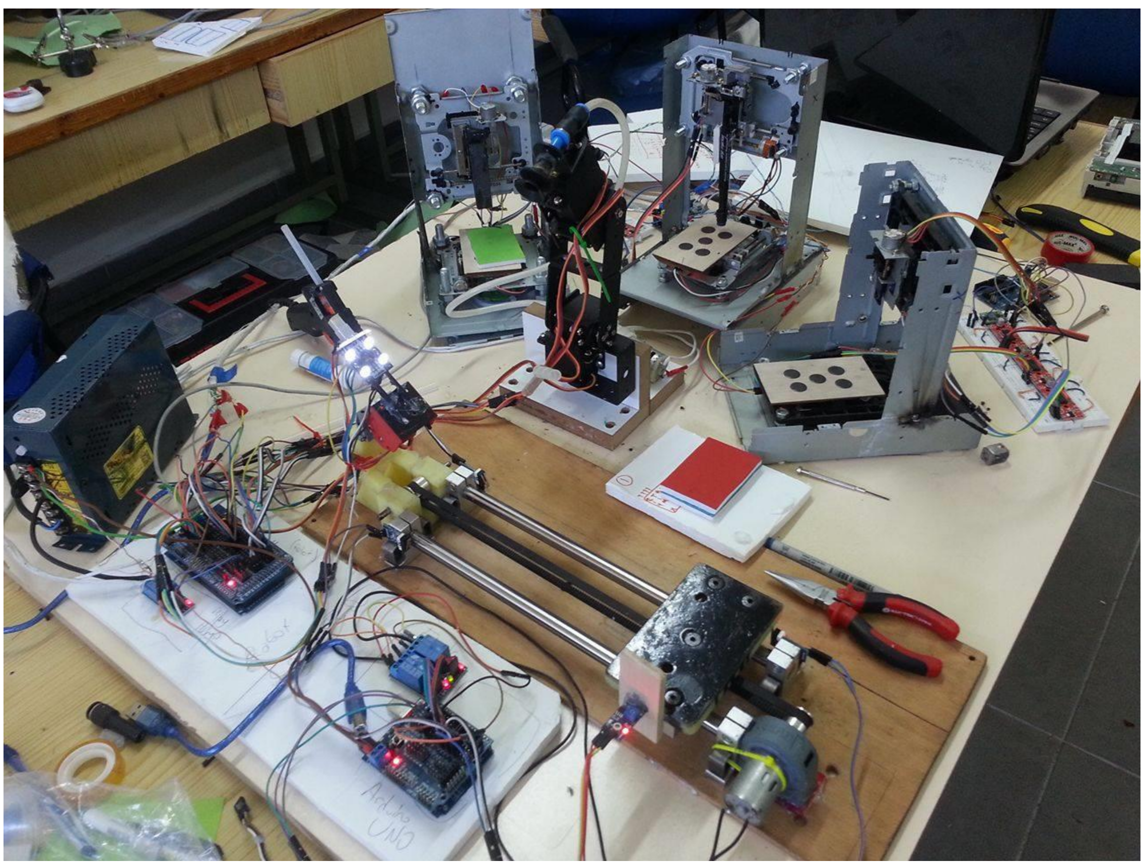

Figure: 44 Final Assembly of FAS Project

CHAPTER 5

RESULTS AND DISCUSSION

In early beginning of the study, the motor of the conveyor system was DC motor with a plastic gear. This motor isn’t purchased. The team were using it in somewhere else so it is chosen to control the conveyor system. However, it was really weak and there was positioning errors. Instead of this DC motor, a metal geared DC motor is purchased and replaced (Figure 45). In addition, more torque power is acquired and the positioning error is solved. The old motor was providing 3 N.cm. However, the new motor provides up to 30 N.cm torque power.

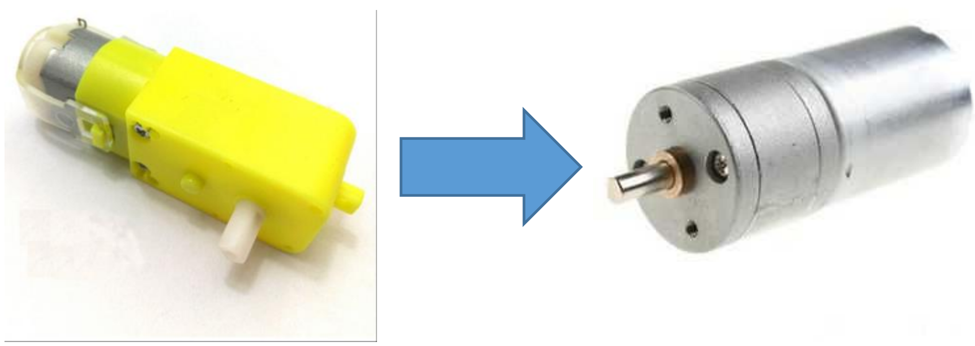

Figure: 45 Changing the Motor of the Conveyor System

The color sensor was leaning stably over the conveyor system. This part was blocking the robot arm to take the part from the conveyer’s bed. To solve this problem, the color sensor is attached to a robot pan. Before the robotic arm takes part, robot pan goes up and gives space to robotic arm.

The biggest problem occurred in FAS project was gripper of the robotic arm. It was really heavy and it caused vibration to the system. The servo motors were slogging and their efficiency was decreasing. Also the opening range was so low. To replace it, a small pneumatic vacuum system has been created (Figure 46). By using a pneumatic pump and a vacuum suction, the robotic arm can grab a part easily by sucking the air.

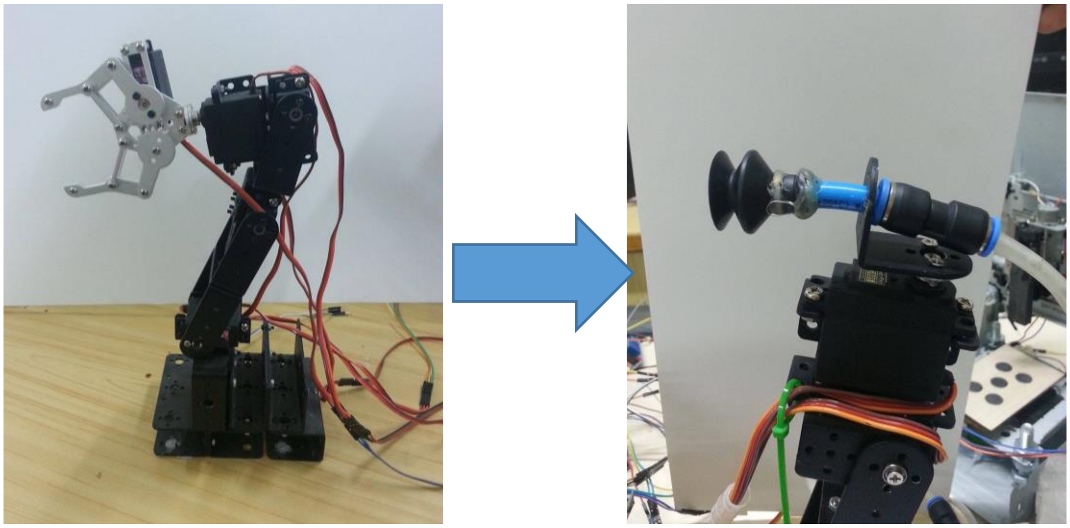

Figure: 46 Replacing Gripper with Pneumatic System

Also the base of the robotic arm is replaced with a wooden part instead of a hard aluminum long U-bracket. This provided a stable base and less total weight.

The covers of CD-ROM were attached with a glue previously. To decrease the possibility to break easily, they are mounted with welding method (Figure 47).

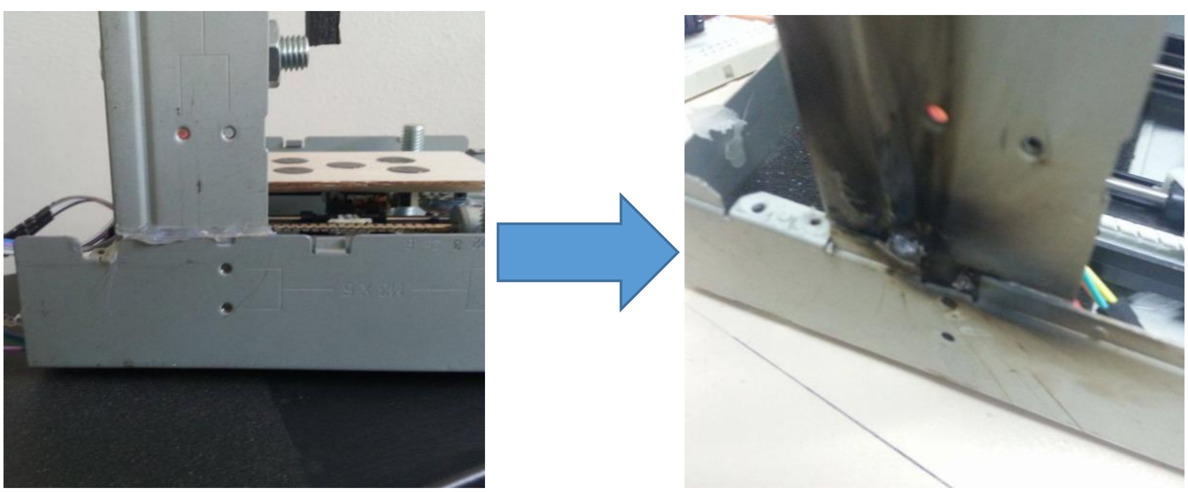

Figure: 47 Welding of CNC Covers

The CNC beds are made of wood. In previous design they were made of steel. However, the weight on the motor was increasing and efficiency was decreasing so it is replaced with wood. Also, several magnets were mounted to CNC bed to hold the parts easier.

Lastly, the drilling and milling processes have been removed. To be able to this processes, additional motors should have been replaced to the Z-axis rail systems but this will lead to strain in motors at the Z-axis because additional weights was going to be on them. Also the programming was going to be hard and complicated. Therefore, the project team decided to build CNC Plotters and drilling and milling processes have been replaced with pen (Figure 48). By using pen, motors' efficiency is satisfied and the required speed is reached.

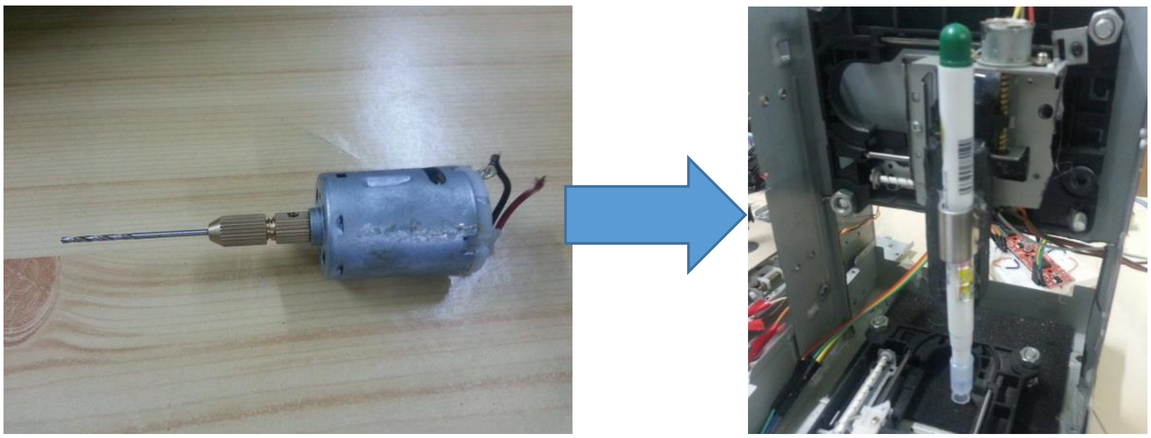

Figure: 48 Replacing Motor with Pen

CHAPTER 6

CONCLUSIONS AND FUTURE WORK

At the beginning of the semester, the Capstone Project has been discussed between the members of the project team and with the supervisor teacher. After some meetings, the project name decided to be Flexible Automation System. As the result of many discussions and researches, the team decided to integrate a CNC Machining System into this Flexible Automation System. However, it is changed to a CNC plotting system later on. A conveyor system will used in transportation of parts. Also the robot arm will take the parts from one device to another. Colour and IR sensors will be used to identify the parts. All of the system will be integrated and programmed by a manager computer and it will be fully automated. Each CNC will have its own operator who uploads the G-Codes to CNC. The main aim of the project is part identification. There will be 3 different coloured parts (Red, Blue, and Green). According to this colors, different procedures will work. The system will decide itself, if start to a work or take a finished part from a CNC and put it to final destination.

The Flexible Automation System is a developed multipurpose project, which can be used in advanced industry with cost effectiveness. The production runs at an increasing phase especially medium size companies in the worldwide. The project also involves development of computer and ARDUINO Programming, which control the fully automated integrated system. It has been observed that the implementation of the components of the project improves the effectiveness and productivity of production line operations in Flexible Manufacturing Systems.

FUTURE WORK

Flexible Automation System project is a compound of a mechanical structure and an interface between the ARDUINO control system and a computer. This is a flexible system so in future the places of the components can be changed according to a new process. Also this automation system can be used in any manufacturing area that has the same working principle with this system. In this prototype, the user puts the part on to the conveyor bed. To decrease the human labor, a second robotic arm can be replaced. This arm will take the workpiece and put it on to the conveyer's bed. Also, instead of a finishing box, a new conveyer system can be mounted. This system will carry the workpiece to another section of the production line.

The numbers of the current components can be increased too. For example, the number of the CNCs can increase. In addition, the types of CNCs can also be changed. Instead of a drawing process, a drilling or milling process can occur. In addition, the robotic arm design should change as well. A vacuum suction cannot grab a drilled part so that the gripper system should be used. Also the servo motors of the robotic should be changed. The system will get heavier and motors should provide more power.

In current FAS project, the CNC plotters have their own operators to upload the codes in them. However, in the future they can be fully automated and be used without any human labor.

Moreover, a visual reality system can be uploaded, too. Before starting any process, the user or customer will be able to see whole production process and this will prevent the costly installations. If some errors occur, the operator will be able to see and correct it before installation. Also, this visual system can decrease the positioning and timing errors of the components.

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APPENDIX A

Ayhan Özgür's Logbook

18.10.2015	We decided our project that is automation system.
19.10.2015	This week we went to advisor and we explained the project ,after that Cafer Kızılörs accepted it.
23.10.2015	I find the some information about automation system ,then we figure it out that there are many kind automation systems.
30.10.2015	We choosed flexible automation which is more relative with our ideas.
06.11.2015	

	We visit the our advisor and we gave the some information what we are doing fort he project.
13.11.2015	I searched about CNC machining and find out how it can be programmed.
20.11.2015	I search the about G-CODE and find out software and installed it.
27.11.2015	I learn a lot of information about CNC machining of principles and we decide what we should order necessary staff for our project.
04.12.2015	I prepared cost analysis about all equipments
11.12.2015	I bought the desired equipments of flexible automation systems and we went to advisor we demostrated our cost analysis.

18.12.2015	I have started prototypes and I started to collectecting all staff from Turkey to TRNC.
23.12.2015	I used workshop for build CNC prototypes ,at the same time we discussed with our advisor.
24.12.2015	We started our report writing and searching on internet and other sources.
25.12.2015	We started the design of the conveyer system,and ı calculated by formulas.
26.12.2015	I prepared cost analysis ,and my logbooks for the final report.
27.12.2015	I printed out our final report .

09.02.2016	The team has started to collect the components of the FAS project.
15.02.2016	I design CNC plotters in SolidWorks.
21.02.2016	I assamblied CNC axes-rails And made it in balance between them.
03.03.2016	The team has learned how to write programs with G-Codes.
08.03.2016	I try to find suitable G-Codes for our CNCs.
20.03.2016	I did assembly of the conveyor System.
02.04.2016	I found out how to control the robotic arm with arduino.

08.04.2016	The team has started to learn how to control a robotic arm.
15.04.2016	The team gathered necessary information about how to control a robotic arm.
04.05.2016	The team started to do the ARDUINO connections.
16.05.2016	I started to entagrate the components.
23.05.2016	I started to write codes for robotic arm and communicate between all devices.
24.05.2016	The coding process is continued.
25.05.2016	I have done coding of robotic arm's code.

28.05.2016	The team has started to write the code for all system process according to the working principle.Also,i started to prepare chapter 3 and 4 for final report.
31.05.2016	The team has tested the project,corrected the errors and finished the final report.

Mustafa İnanıroğlu's Logbook

18.10.2015	We discussed different projects with our teammates.
19.10.2015	The project is selected to be Automation System with the group members and supervisor Cafer Kızılörs.
23.10.2015	The Gantt chart has been prepared.
30.10.2015	Research has been done about Automation System and some general information has been collected.
06.11.2015	We started to learn Flexible Automation System.
	The advisor is visited to get some information about the Flexible Automation

13.11.2015	project.Also we distribute the duty between our teammates.
20.11.2015	We search the information about the components that will used in the project such as sensors,conveyor,robot etc.
27.11.2015	Some design analysis and calculations has been made.
04.12.2015	I started to prepare appendix, ganttchart and my logbook for the final report.Some calculations has been made aswell.
11.12.2015	Some research has been done on the internet.
18.12.2015	We collect some information about the final report.

23.12.2015	We prapared the proposal with my teammates and continued to collect some information aswell.
24.12.2015	We continued to write the chapters and finished the proposal.
25.12.2015	I wrote the Chapter 1 and 2 and also we finished the writing formulas and calculations.
26.12.2015	The appendix, Gantt chart and logbooks has been prepared for the final report.
27.12.2015	The report is finished and it is ready to submit.

09.02.2016	The team has started to collect the components of the FAS project.
15.02.2016	I collected the CD-ROMs for CNC Plotters.
21.02.2016	I started to collect information about G-Codes.
03.03.2016	The team has learned how to write programs with G-Codes.
08.03.2016	I continued to learn and write programs with G-Codes.
20.03.2016	The G-Codes for the CNC Plotters has finished.
02.04.2016	I did the assembly of the robotic arm.

08.04.2016	The team has started to learn how to control a robotic arm.
15.04.2016	The team gathered necessary information about how to control a robotic arm.
04.05.2016	The team started to do the ARDUINO connections.
16.05.2016	All connections are completed.
23.05.2016	I started to write codes for CNC Plotters.
24.05.2016	The coding process is continued.
25.05.2016	The coding of the CNC Plotters have finished.

28.05.2016	The team has started to write the code for all system process according to the working principle. Also, i started to prepare chapter 5 and 6 for the final report.
31.05.2016	The team has tested the project, corrected the errors and finished the final report.

Cener Meder's Logbook

18.10.2015	First of all , we decided our project.
19.10.2015	We talked with Cafer Kızılörs about our topic of the project.
23.10.2015	I started to prepare the gantt chart.
30.10.2015	I Research about Automation System.
06.11.2015	I continue the collect the information about the Automation system and I try to learn Automation system.
13.11.2015	We visited our advisor to discussed about Automation system and working procedure of it.

20.11.2015	We search the information about the Project what we are going to use in this Project like sensors,design,robot etc.
27.11.2015	I found lots of sources about Automation system and Flexible Automation system.
04.12.2015	I prepared desire part list of the project.
11.12.2015	I draw the design of automation system of components with my Project member from AutoCAD.
18.12.2015	I did some calculation abaut the Project.I discuss with my friend How we can fix the part.Also I collect the information fort he final report.

23.12.2015	I continue the collect the information and I prepare the proposal with my friends.Moreover I started to writing Chapter 1.
24.12.2015	I finished the proposal with my friends and I continue the write the Chapter 1.
25.12.2015	I finished the Chapter 1 and also we passed to calculation and formulas
26.12.2015	I prepared my logbooks for the final report.
27.12.2015	We made the report ready for the submission day.

09.02.2016	The team has started to collect the components of the FAS project.
15.02.2016	I started to manufacturing of the CNC plotters.
21.02.2016	I assembled the CNC plotters.
03.03.2016	The team has learned how to write programs with G-Codes.
08.03.2016	I started to manufacturing of conveyor components.
20.03.2016	I designed the robot pan.
02.04.2016	I completed the robot’s manufacturing.

08.04.2016	The team has started to learn how to control a robotic arm.
15.04.2016	The team gathered necassary information about how to control a robotic arm.
04.05.2016	The team has started to do the ARDUINO connections.
16.05.2016	I searched some information about the codes.
23.05.2016	I started to write codes for Conveyor System
24.05.2016	The coding process continued.
25.05.2016	The coding of the Conveyor System has finished.

28.05.2016	The team has started to write the code for all system process according to the working principle. Also, i started to prepare chapter 1 and 2 for the final report.
31.05.2016	The team has tested the project , corrected the errors and finished the final report.

APPENDIX B

GANTT CHART

	18.10.2015	19.10.2015	23.10.2015	30.10.2015	06.11.2015	13.11.2015	20.11.2015	27.11.2015	04.12.2015	11.12.2015	18.12.2015	23.12.2015	24.12.2015	25.12.2015	26.12.2015	27.12.2015
Selecting project	■	■														
Preparation of Gantt Chart			■													
Searching information about the project				■	■	■	■									
Learning the Flexible Automation System					■	■	■	■								
Distribution of duty						■										
Design and calculation processes								■	■	■	■					
Collecting information										■	■	■				
Preparation of proposal												■	■			
Preparation of report writing												■				
Writing chapter 1, 2 and 3											■	■	■	■		
Writing the formulas and calculations											■	■	■	■		
Resulting the final report															■	■

	09.02.2016	15.02.2016	21.02.2016	03.03.2016	08.03.2016	20.03.2016	02.04.2016	08.04.2016	15.04.2016	04.05.2016	16.05.2016	23.15.2016	24.5.2016	25.5.2016	28.5.2016	31.5.2016
Collecting the project components																
Manufacturing process of the CNC Plotters																
Assembly process of the CNC Plotters																
Searching information and learning about G-Codes																
Manufacturing process of the Conveyor System																
Assembly process of the Conveyor System																
Manufacturing and assembly process of the Robotic Arm																

Learning about how to control the Robotic Arm																
Connecting drivers and motors																
Making the ARDUINO connections																
Integrating all the components to the system																
Writing the codes of the components and whole project																
Preparing the final report																
Testing the project																
Correcting the final errors and making the final touch																

Distribution of Tasks	Ayhan	Mustafa	Cener
CNC Plotter selection		X	
Robotic Arm selection	X		
Conveyor System selection			X
Material selection	X	X	X
Shaft selection for conveyor	X		
Motor selection for conveyor	X		
Conveyor manufacturing			X
Conveyor System assembly	X		
Robot Pan design			X
Robot Arm manufacturing			X
Robot Arm assembly	X	X	
Robot Arm controlling	X	X	X
G-Code selection and learning	X	X	X
CNC Plotter manufacturing	X		X
CNC Plotter assembly		X	X
System integration	X	X	X
ARDUINO	X	X	X

Electronics and Cable Connections	**X**	**X**	
Solving Problems	**X**		**X**
Coding of the project	**X**	**X**	
Report Writing	**X**	**X**	**X**
Website design		**X**	
Poster design		**X**	
Testing the system	**X**	**X**	**X**

APPENDIX C

DRAWINGS

APPENDIX D

ENGINEERING STANDARTS PROPERLY USED

Standard Sheet Thickness Tolerances:

The tolerances for different size of thicknesses of sheet metals are mentioned below:

Standard sheet thickness tolerances (for precision cast sheets)

Nominal thickness (mm)		Tolerances on the nominal thickness (mm)							
		Class A		Class B		Class C		Class D	
from	below	lower	upper	lower	upper	lower	upper	lower	upper
		limit deviations							
3	5	- 0,4	+ 0,8	- 0,3	+ 0,9	0	+ 1,2	- 0,6	+ 0,6
5	8	- 0,4	+ 1,1	- 0,3	+ 1,2	0	+ 1,5	- 0,75	+ 0,75
8	15	- 0,5	+ 1,2	- 0,3	+ 1,4	0	+ 1,7	- 0,85	+ 0,85
15	25	- 0,6	+ 1,3	- 0,3	+ 1,6	0	+ 1,9	- 0,95	+ 0,95
25	40	- 0,8	+ 1,4	- 0,3	+ 1,9	0	+ 2,2	- 1,1	+ 1,1
40	80	- 1,0	+ 1,8	- 0,3	+ 2,5	0	+ 2,8	- 1,4	+ 1,4
80	150	- 1,0	+ 2,2	- 0,3	+ 2,9	0	+ 3,2	- 1,6	+ 1,6
150	250	- 1,2	+ 2,4	- 0,3	+ 3,3	0	+ 3,6	- 1,8	+ 1,8

Figure: 49 Sheet Metal Tolerances

Bending Tolerances of Sheet Metals:

Sheet metals must be bended according to special bending degrees.

Type:	Stainless Steel Gauge Table				
Process	Stainless Steel Air Bending				
K-Factor	.400				
Gauge No.	Gauge(Thickness)	Available Bend Radius	DIE WIDTH	SHRINK	BEND DEDUCTION
3 Gauge	.239	0.2240	1.575	0.046	-0.430
4 Gauge	.224	0.1880	1.260	0.050	-0.396
5 Gauge	.209	0.1733	1.260	0.051	-0.365
6 Gauge	.194	0.1095	1.260	0.018	-0.356
7 Gauge	.179	0.1175	0.984	0.052	-0.304
8 Gauge	.164	0.1236	0.984	0.040	-0.286
9 Gauge	.150	0.1380	0.984	0.029	-0.269
10 Gauge	.135	0.1348	0.709	0.025	-0.243
11 Gauge	.120	0.0942	0.709	0.016	-0.224
12 Gauge	.105	0.0675	0.551	0.020	-0.188
13 Gauge	.090	0.0782	0.472	0.021	-0.157
14 Gauge	.075	0.0655	0.394	0.017	-0.131
15 Gauge	.067	0.0630	0.394	0.015	-0.117
16 Gauge	.060	0.0553	0.394	0.007	-0.113
17 Gauge	.054	0.0675	0.394	0.005	-0.101
18 Gauge	.048	0.0352	0.236	0.013	-0.081
19 Gauge	.042	0.0360	0.236	0.011	-0.071
20 Gauge	.036	0.0435	0.236	0.004	-0.068
22 Gauge	.030	0.0205	0.236	-0.002	-0.058
24 Gauge	.024	0.0165	0.157	0.008	-0.040
25 Gauge	.021	0.0050	0.157	0.005	-0.031

Figure: 50 Bending Tolerances of Sheet Metals

Castermid Properties:

The castermid material is a type of casting polyamide. It can be easily shaped and they are strong enough to carry the heavy objects. This is cheaper than metal, lighter, more durable and longer lasting. The application areas are various machine parts, gears, wheels, bearings, shafts and rolls, heavy machinery parts etc.

	Test Method	Unit	CASTING POLYAMIDE
General Features			
Color			Yellow / Natural
Specific Weight	1183	gr/cm³	1.15
Water Absorption(saturated)	62	%	7
Mechanical Features			
Tensile strength	527	kg/cm²	850
Elastic modulus:	527	Mpa	4000
Elongation:	527	%	>20
Compressive strength:	604	kg/cm²	950
Pressing module:	604	MPa	2700
Impact strength (Charpy unnotched)	179	kj/m²	Unbroken
Impact strenght (izod notched)	180	kj/m²	5.6
Coefficient of friction (dynamic)			0.39
Stiffness	868	Shore D	84
Wear rate		mg/km	0.44
K factor		mm³/Nm	$5.0x10^{-6}$
Thermal Characteristic			
Melting temperature		ºC	220
The maximum continuous operating temperature		ºC	110
Short term maximum operating temperature		ºC	170
Coefficient of thermal expansion:	11359	$ºC^{-1}$	$8x10^{-5}$
Electrical Characteristic			
Dielectric Constant	60250		3.7
Dielectric Strength	60243	kV/mm	25
Volumetric Resistance	60093	Ωcm	$>10^{-14}$
Surface Resistance	60093	Ω	$>10^{-13}$

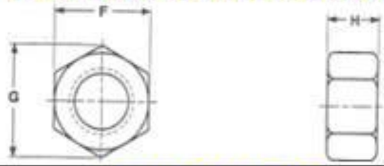
Figure: 51 Polyamide Properties

Base Polymer	Poly-ethylene-tereph-thalate	Poly-ethylene-naph-thalate	Poly-carbonate	Polyether-sulfone	Poly-arylate	Poly-nornornene (Polycyclic olefin)	Poly-imide
CTE (-55-+85 °C) ppm/°C	15[a]	13[a]	60-70	54	53	74	30-60
%Transmission (400-700 nm)	>85 ·	85	>90	90	90	91.6	Yellow
Water absorption (%)	0.14	0.14	0.4	1.4	0.4	0.03	1.8
Young's Modulus/GPa	5.3	6.1	1.7	2.2	2.9	1.9	2.5
Tensile Strength/MPa	225	275	NA	83	100	50	231
Glass Transition	~80	~120	150	225	345	335	360

Figure: 52 Polyamide Properties

Table: 2 Dimensions of Metric Hex Nuts

Dimensions of Metric Hex Nuts



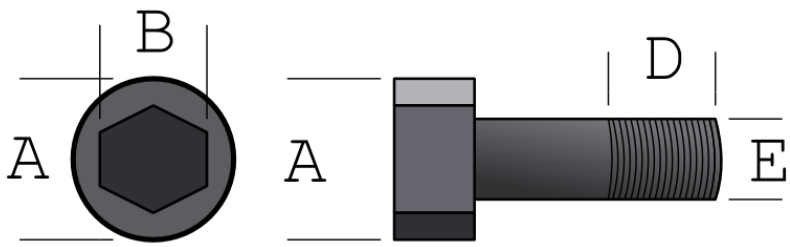
Metric Hex Nuts
ISO 4032

Nominal Size	Thread Pitch	F: Width Across Flats (Wrench Size)		G: Width Across Corners	H: Thickness	
		Max	Min	Min	Max	Min
M1.6	0.35	3.2	3.02	3.41	1.3	1.05
M2	0.4	4	3.82	4.32	1.6	1.35
M2.5	0.45	5	4.82	5.45	2	1.75
M3	0.5	5.5	5.32	6.01	2.4	2.15
M4	0.7	7	6.78	7.66	3.2	2.9
M5	0.8	8	7.78	8.79	4.7	4.4
M6	1	10	9.78	11.05	5.2	4.9
M8	1.25	13	12.73	14.38	6.8	6.44
M10	1.5	16	15.73	17.77	8.4	8.04
M12	1.75	18	17.73	20.03	10.8	10.37
M14	2	21	20.67	23.35	12.8	12.1
M16	2	24	23.67	26.75	14.8	14.1
M20	2.5	30	29.16	32.95	18	16.9
M24	3	36	35	39.55	21.5	20.2
M30	3.5	46	45	50.85	25.6	24.3
M36	4	55	53.8	60.78	31	29.4
M42	4.5	65	63.1	71.3	34	32.4
M48	5	75	73.1	82.6	38	36.4
M56	5.5	85	82.8	93.56	45	43.4
M64	6	95	92.8	104.86	51	49.1

Table: 3 Metric Bolt Dimensions

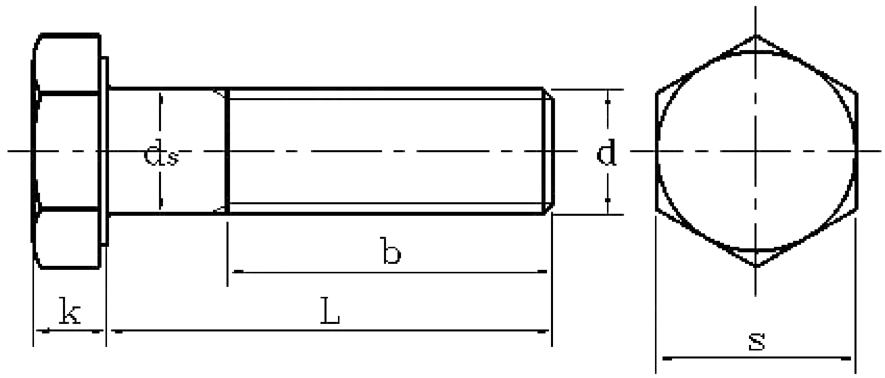
METRIC BOLT CORE DIMENSIONS

VALVERS



Metric Size	Pitch	Drill	E	A	B
M3	0.50mm	2.50mm	3mm	5.5mm	2.5mm
M4	0.70mm	3.30mm	4mm	7.0mm	3.0mm
M5	0.80mm	4.20mm	5mm	8.0mm	4.0mm
M6	1.00mm	5.00mm	6mm	10.0mm	5.0mm
M8	1.25mm	6.80mm	8mm	13.0mm	6.0mm
Fine	1.00mm	7.00mm			
M10	1.50mm	8.50mm	10mm	17.0mm	8.0mm
Fine	1.25mm	8.80mm			
S.Fine	1.00mm	9.00mm			
M12	1.75mm	10.20mm	12mm	19.0mm	10.0mm
Fine	1.50mm	10.50mm			
S.Fine	1.25mm	10.80mm			

Table: 4 Metric Bolt Dimensions-2



Unit: mm

d	P	b			ds		k		s	
		L≤125	125<L≤200	200<L	max	min	max	min	max	min
M5	0.8	16	22	35	5.48	4.52	3.875	3.125	8	7.64
M6	1	18	24	37	6.48	5.52	4.375	3.625	10	9.64
M8	1.25	22	28	41	8.58	7.42	5.675	4.925	13	12.57
M10	1.5	26	32	45	10.58	9.42	6.85	5.95	16	15.57
M12	1.75	30	36	49	12.70	11.30	7.95	7.05	18	17.57
M14	2	34	40	53	14.70	13.30	9.25	8.35	21	20.16
M16	2	38	44	57	16.70	15.30	10.75	9.25	24	23.16
M18	2.5	42	48	61	18.70	17.30	12.40	10.60	27	26.16
M20	2.5	46	52	65	20.84	19.16	13.40	11.60	30	29.16
M22	2.5	50	56	69	22.84	21.16	14.90	13.10	34	33
M24	3	54	60	73	24.84	23.16	15.90	14.10	36	35
M27	3	60	66	79	27.84	26.16	17.90	16.10	41	40
M30	3.5	66	72	85	30.84	29.16	19.75	17.65	46	45
M33	3.5	/	78	91	34.00	32.00	22.05	19.95	50	49
M36	4	/	84	97	37.00	35.00	23.55	21.45	55	53.8
M39	4	/	90	103	40	38	26.05	23.95	60	58.8
M42	4.5	/	96	109	43.00	41.00	27.05	24.95	65	63.1
M45	4.5	/	102	115	46	44	29.05	26.95	70	68.1
M48	5	/	108	121	49.00	47.00	31.05	28.95	75	73.1
M52	5	/	116	129	53.2	50.8	34.25	31.75	80	78.1
M56	5.5	/	/	137	57.20	54.80	36.25	33.75	85	82.8
M60	5.5	/	/	145	61.2	58.8	39.25	36.75	90	87.8
M64	6	/	/	153	65.20	62.80	41.25	38.75	95	92.8

Physical Properties

- Density: 2.7 g/cm^3
- melting point : approx 580^{0}C

Mechanical properties

- Young's modulus - 68-72 GPa
- Poisson's ratio - 0.33
- Tensile Strength - 70-360 MPa
- Hardness- Vickers - 30-100 Hv
- Yield Strength - 30- 286 MPa
- compressive strength – 30- 286 MPa
- Elongation - 2-41 %

Figure: 53 Properties of Aluminium

APPENDIX E

Website of the Project: http://students.emu.edu.tr/123424/

Poster of the Project:

EASTERN MEDITERRANEAN UNIVERSITY
DEPARTMENT OF MECHANICAL ENGINEERING
FLEXIBLE AUTOMATION SYSTEM (FAS)

SPRING 2015-2016

GROUP NAME: AMC

PROJECT SUPERVISOR: Lec. Cafer Kızılörs

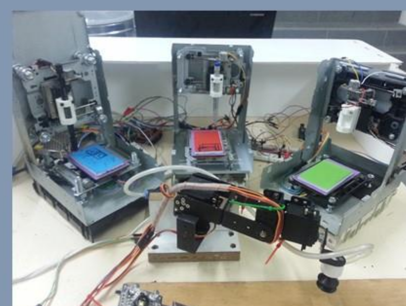
AYHAN ÖZGÜR
110747

MUSTAFA İNANIROĞLU
123424

CENER MEDER
123419

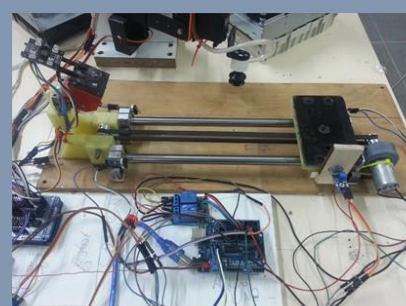
AIM OF THE PROJECT

The main aim is making different processes by identifying parts. Every part will have its own machine. The system will detect the part and put it to the desired machine. Number of human labor is decreased by this process. Furthermore, it is a flexible system. The places of the components can be changed according to the desired production lines.



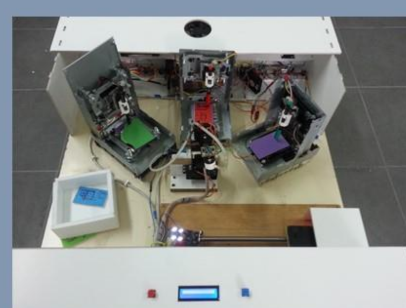
INTRODUCTION

Automation is the use of control systems with minimal human labor. Also automation can be defined as the sharing of a job between a human and machine. Total job-sharing percentage establishes the level of automation. Flexible Automation Systems are totally computer controlled. Human operators send the high-level codes to the computers. Each machine in the production line receives settings (codes) which is sent from the computer. When a machine finishes its process, the workpiece will go to next machine automatically. Multi-functional CNC Devices use this type of automation system.



CONCLUSION

The Flexible Automation System is a developed multipurpose project, which can be used in advanced industry with cost effectiveness. The production runs at an increasing phase especially medium size companies in the worldwide. The project also involves development of computer and ARDUINO Programming, which control the fully automated integrated system. It has been observed that the implementation of the components of the project improves the effectiveness and productivity of production line operations in Flexible Manufacturing Systems.



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