INJECTION MOULDING TAKE-OUT ROBOT: INDUSTRIAL PROJECT

A PROJECT REPORT

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BONAFIDE CERTIFICATE

Certified that this project report titled "***Injection Moulding Take-Out Robot: Industrial Project***" is the bonafide work of "**Animesh Ghoshal (RA1611018010025), Satyapalsinh Gohil (RA1611018010042), Atif Akhtar (RA1611018010099), and Satyam Dudhagara (RA1611018010102)** who carried out the project work under my supervision. Certified further, that to the best of my knowledge the work reported here in does not form any other project report or dissertation on the basis of which a degree or award was conferred on an earlier occasion on this or any other candidate.

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ABSTRACT

The requirement of assistance in workplaces such as fabrication lab, workshops and small-scale industries is in, nowadays, a growing demand as can be seen with development of human assistive robots. Therefore, we aid to such requirement by designing and fabricating robots that will be used on plastic injection moulding machines for many years. Plastic injection molding automation involves use of pick-and-place robots to unload plastic parts from molding machine, as well as place the finished products onto a conveyor belt. This is moderate-speed servo traverse robot with adequate cycle speeds and stroke lengths to match all common press sizes and job specifications. Commonly available robots are driven by rack and pinion mechanism and have 3 DOF (P-P-P), this robot also employs 3 DOF (P-P-P) configuration. This take-out robot includes powerful servo motors on all three axes; all driven by a chassis mounted PLC control box to reduce floor space requirements and minimize cable runs. It includes two ball screw driven axes and one rack and pinion driven axis. The robot will have two end effectors for unloading the final product as well as to remove the runner of the part produced. Also, this robot is lighter and cheaper than other commercially available robots for this application with a suitable working life. This project is manufactured for NR Tech Poly Plast LLP. They encouraged us to complete this Industrial Project in stipulated time.

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The success and final outcome of this project required a lot of guidance and assistance from many people and we are extremely fortunate that we have got this all along the completion of our project work. Whatever we have done is only due to such guidance and assistance and we would like to thank them for their kind support.

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LIST OF ABBREVIATIONS

ABV. NO.	ABBREVIATIONS TITLE	PAGE NO.
1.	MISUMI	15
2.	THK	15
3.	NSK	15
4.	IKO	15
5.	NB	15

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF THE PROJECT

1.1.1 Injection Moulding Machine

Injection Press or Injection Molding Machine is employed for manufacturing plastic products by an injection molding process. It consists of two main parts:

- Injection Unit consists of Screw Motor Drive, Reciprocating Screw and Barrel and Heaters, Thermocouple, Ring Plunger.
- Clamping Unit consists of Mold, Clamping Motor Drive and Tie Bars.

1.1.2 Operations of Injection Moulding Machine

Injection Moulding Machine moulds may be affixed in either a horizontal or vertical plane. Most of these are aligned in a horizontal direction. However, vertical directional machines are utilized in some speciality applications, as an example, embed shaping, that permits the machine to use gravity. In some vertical directional machines, the moulds are not fixed. There is a number which depicts of how to connect the devices to the platen. The foremost known commonly being manual clamps (the two parts are rushed to the platens); be that because it may, pressure-driven braces and magnetic clamps are likewise used. These are utilized where rapid tool changes are required. The individual structuring is intended in such how that the mould is chosen accordingly. Various mould utilizes a chilly system or a hot system of runner that add these plastics and fillers in the infusion chamber to the cavities. A chilly runner could be the basic channel that digs a mould. These plastics that gets filled in the chilly sprinter cools because the part cools and it is then shot out with a part as the sprue.

This hot system of runner is increasingly hard, regularly utilizing tube heating chambers to allow this plastic within these runners because the part cooled down. After this part were removed, the plastic within the hot sprinter is infused into the subsequent part.

1.1.3 Types of Injection Moulding Machines

The Machines are differentiated based on type of driving systems used:

- **Hydraulic:** It is the predominant type in most parts of the globe and isn't nearly as precise.
- **Mechanical:** It uses a system that's used for building weight carrying capacity on the clamp side of the machine. It's necessity on all machines to make sure that clamp side doesn't open thanks to the injection pressure.
- **Electric:** It's also referred to as Electric Machine Technology (EMT). It reduces costs of operation, consumes less electricity. Its quieter operation is quicker and have higher accuracy, but they're comparatively costlier than other machines.

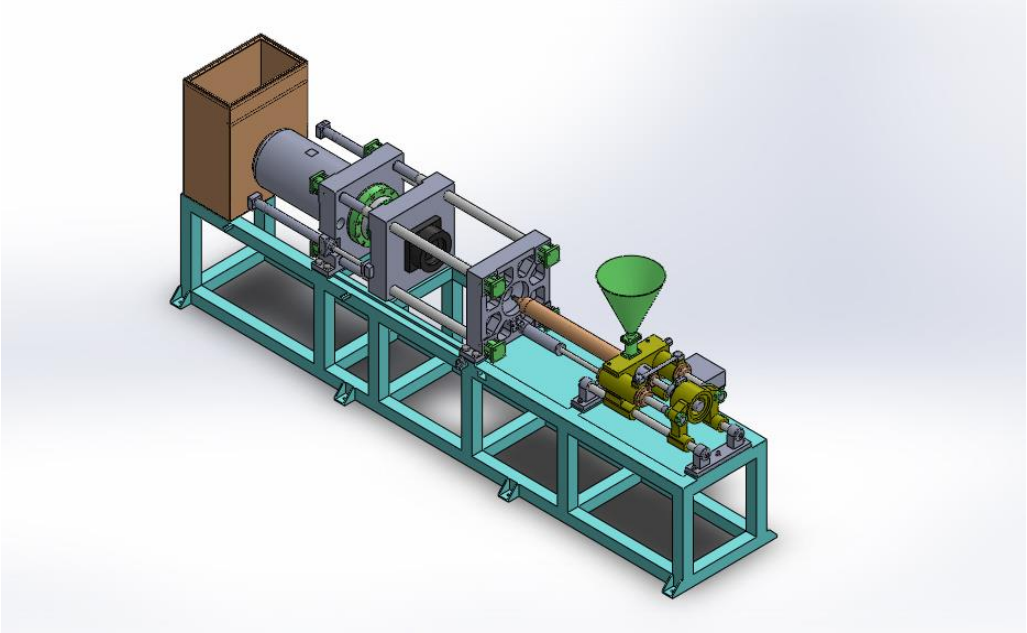


Figure 1.1: Injection Moulding Machine.

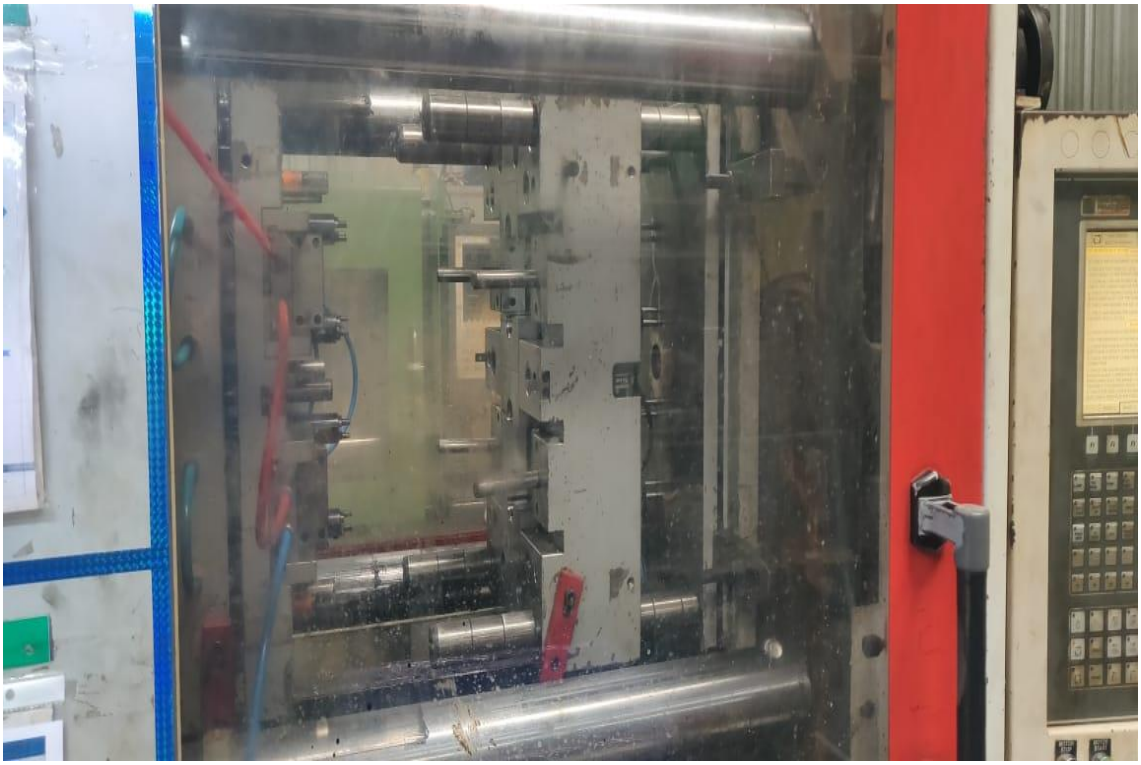


Figure 1.2: Injection Moulding Machine in NR Tech Poly Plast LLP.

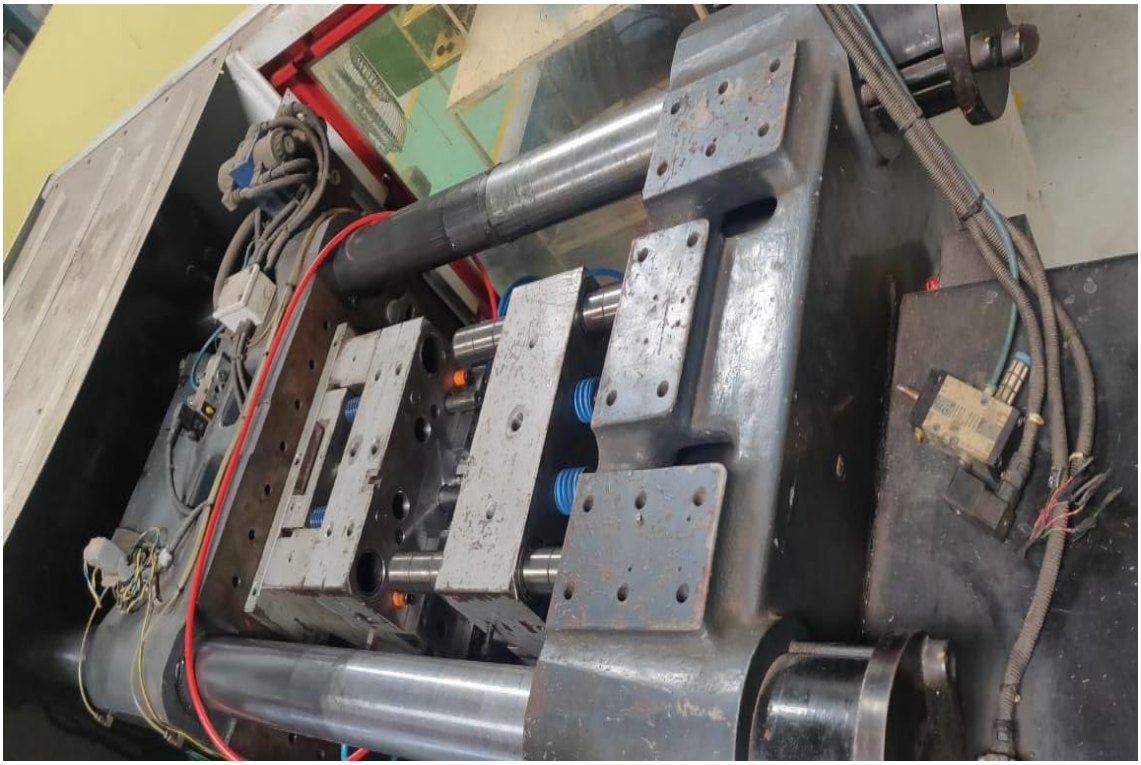


Figure 1.3: Injection Moulding Machine on which Robot will be Mounted.

1.2 ROBOTS IN INJECTION MOULDING MACHINES

Robots have been an integral part of industries and have been at the forefront of Industry 4.0, where Internet of Things and Smart Manufacturing have been used in production line to meet the ever-growing demand of products. Plastic Injection Moulding uses Pick and Place Robots to unload parts and components onto a conveyor belt. In traditional Injection Moulding Machines, labours are used for part handling. Due to heat sensitive material being used in these machines, a robot can be deployed to reduce repetitive work done by the workers and lower down the injuries. It allows to build the product consistently and increase the production capacity. These are employed with vacuum and pneumatic grippers that allows careful procurement of new injection moulded parts.

Some of the Operations performed by Robots in this industry are:

- **Insert Moulding:** The process involves encapsulating during a moulded part. The inserts like pin, blade, etc are placed in the plastic moulded part before or after moulding process. The robot employed, puts them in the machine.

- **Overmoulding:** This process usually employs combining two or more than two individually moulded parts to make one single part. A robot picks this part and places it on another injection moulding machine to complete this process. This helps in lowering manual labour and assembly expenditure. Increases quality, reliability and integrity of the product.

- **In-Mould Labelling or Decorating:** This procedure is generally deployed for naming and decorating the moulded parts to increase their aesthetics. This can be done during the moulding cycle itself and is a common area for automation using robots. It generally deploys robots to put the pre-printed labels and films and paste it on the open plastic mould. They are then placed to make them a important part of the product. These robots are equipped with an end effector that allows them to place the label with high precision.

- **Recycling:** Materials like thermoplastic are often used in these industries. Sprue and Runner are picked with efficient robots that are Pick and Place in nature and put them on the conveyor for recycle. It allows reduction in action time if in and out of the mould that helps in pre-staging and upside part of the mould.

1.3 ROBOTS USED IN POST PROCESSING

The upgradation in automation has increased robotic applications and this can also be seen in injection moulding post-processing industry. These operations are repetitive and easily copied, therefore robots provide better flexibility in doing various tasks, as compared to a worker. These can also help in improving cycle time and lowering waste by accurately and consistently dispensing equal amount of sealant, which follows a high repetitive pattern. It may or may not use vision for these robots. These are pick and place robots for moulded parts and can also perform other operations like inspection, testing and stamping. They can also help in performing difficult welding processes with the help of laser, ultrasonic and infrared. This helps in improving precision and reducing cycle times. They also meet the criteria for automation in finishing, ranging from PAD printing and polishing.

We can also automate the nozzle of the plastic system that helps in increasing production rates and reduces cost.

These can also help in reduction of repetitive and complex tasks that are generally done by manual labour. Common operations that are automated are wrapping, labelling, palletising, etc which helps in flexibility in packing, storing and logistics of the product.

	INJECTION MOULDING RELATED PROCESS	ROBOT TASK	Options
Primary tasks	Machine Tending	Load & Unload	Cartesian robot 6-axis robot 6-axis collaborative robot SCARA robot
	Extraction	Pick & Place	Manipulator 6-axis robot 6-axis collaborative robot SCARA robot
	Insert moulding	Load & Unload	Cartesian robot 6-axis robot 6-axis collaborative robot SCARA robot
	Over moulding	Part picking & handling	6-axis robot 6-axis collaborative robot
	In-mould Labelling/decorating	Labelling work	Cartesian robot 6-axis robot 6-axis collaborative robot Side entry robot
	Recycling	Pick & Place	Sprue Picker
Post processing outside of the mould machine	Material Handling, Trimming/Deburring, Cutting, PAD Printing, Polishing, Dispensing, Welding		Cartesian robot 6-axis robot 6-axis collaborative robot Due arm Robot
	Assembly		6-axis robot SCARA robot
End of Line Operations	Wrapping, Labelling, Sorting and Stacking, Palletising, Packaging		Cartesian robot 6-axis robot 6-axis collaborative robot SCARA robot

Figure 1.4: Tasks performed by Robots in Injection Moulding Processes.

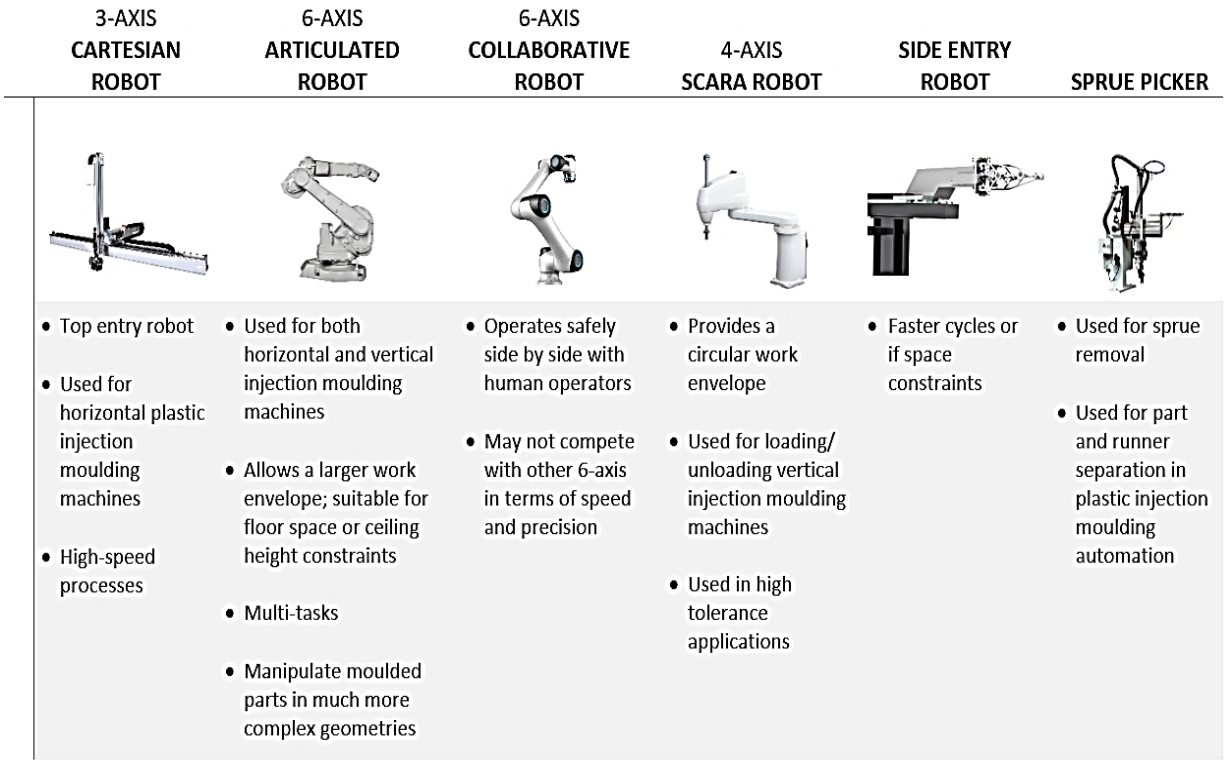


Figure 1.5: Configurations of Robots used in Injection Moulding Industries.

These robots can be of different configurations but the most commonly used configuration robot is 3 DOF (P-P-P), where all the three joints are linear in motion. This project uses 2DOF (P-P) configuration for its operation.

Figure 1.6: Existing System for Pick and Place Applications.

1.4 WHAT IS POSITIONING CONTROL?

Positioning Controller together with Programmable Logic Controller, Computer and Operator Interface are primary components of Factory Automation. Positioning Controller is considered the centre of the mechatronics field.

Positioning directly involves motion which regularly results in speed and precision. Hence speed is directly associated with productivity, therefore positioning is a neighbourhood of wide interest for researchers. When the speed of the machine increase, the matter with stop precision arises. to unravel this, diversified grades of positioning controllers are required and developed.

Often there are few problems associated with positioning aspect of a machine, this means that the machine isn't running as efficiently because it should be. Therefore, the science of developing and retrofitting an optimum positioning system is vital.

1.5 AC SERVO SYSTEM

The current system uses AC Servo System which has following features.

- Compact and Light: In Factory Automation Workplace, less spaced Servo System is beneficial.
- Robust: It can withstand severe operation conditions.
- Easy Usage: These are easy to use and are flexible, as compared to hydraulic systems.
- Cost: It has good cost performance which reduces overall engineering costs.

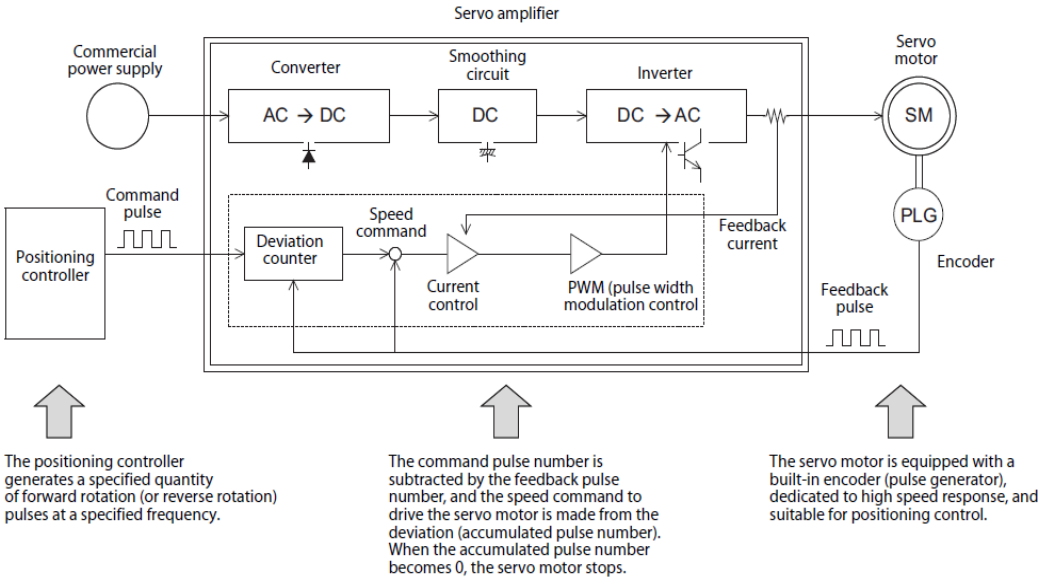


Figure 1.7: Block Diagram of AC Servo System.

1.6 INJECTION MOULDING TAKE OUT ROBOT FOR NR TECH POLY PLAST LLP.

This project is been developed for NR Tech Poly Plast LLP, a company manufacturing component for automobile companies through injection moulding process. Their client list includes Mindarika, Stellar Plastic India Pvt. Ltd., Roki Minda Co. Pvt. Ltd., etc. The company was founded by Mr. Nallarasu in February 2014. It has 14 machines in total with around 3 operators on each machine operating at 8-hour shift per day. The company decided to use robots for its post-processing operation in injection moulding machines.

The robot consists of servo motors on two axes. These are driven by a chassis mounted control box to minimize floor space requirements. It is driven by two ball screw at two of its axes.

This robot is lighter and can be available at a lower cost than other commercially available robots for this application with a suitable working life.

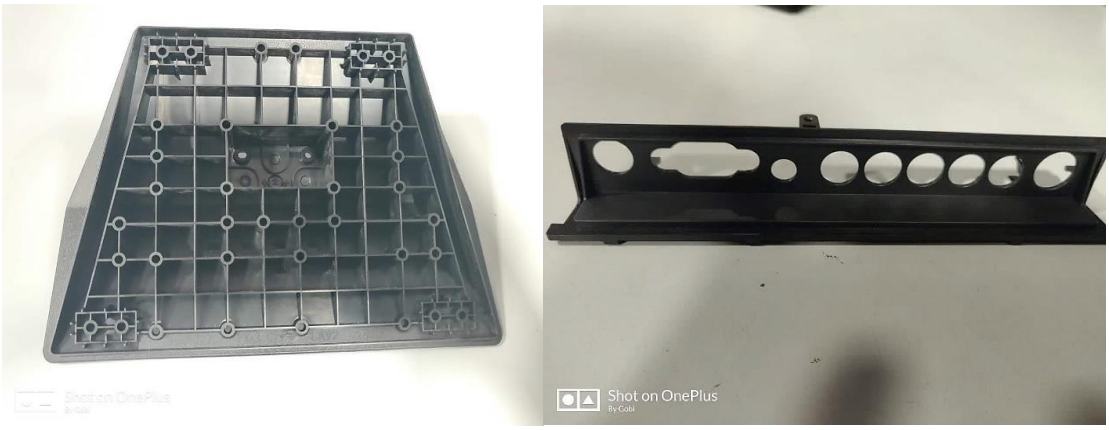


Figure 1.8: Components Manufactured by NR Tech Poly Plast LLP.

1.7 CHALLENGES IN EXISTING SYSTEM

The existing system deploys belt-drive mechanism for movement of its axes along the length of the robot. The belt drive system causes slippage and the service life of this mechanism is very low. To remove this disadvantage, we have used Ball and Screw Mechanism on two of its axes. This increases the product life span and increases the robustness of the system.

The existing system also employs Relay based control of the robot which does not provide flexibility and programmability, but this can be removed by using Programmable Logic Controllers (PLC). These provide robustness and efficient operation of the robot.

1.8 APPLICATION

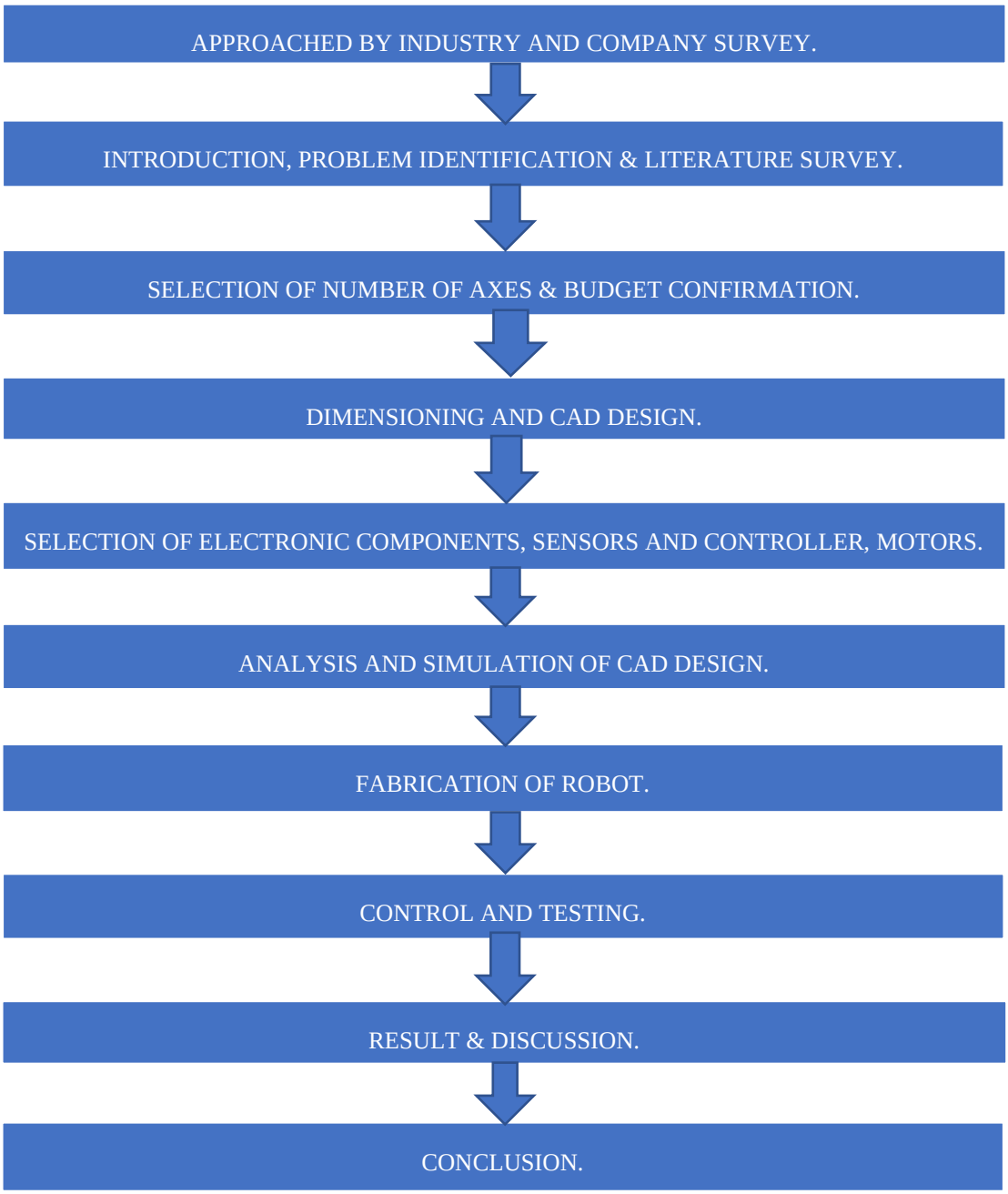
The robot will have 2 DOF (P-P) configuration, traversing along the length with the help of Ball Screw mechanism. These systems are actuated by powerful servo motors. The robot is a simple Pick and Place where there will be pneumatic grippers to remove parts from the mould and place it on a conveyor belt and a gripper to remove runner.

1.9 NEED OF THE PROJECT

Industrial Automation greatly affects the productivity and profitability of the industries. Therefore, to help in the increase of production capacity of an industrial plant this project can help in achieving this goal. It will also help in reducing direct human labor costs and expenses of the company, this will help in increasing the profitability of the company. Automation in industries will allow reduction in cycle

time of the operations being performed which will allow further increase in production capacity. It will also ensure manufacturing of different types of components. Industrial Automation also relieves humans from monotonous and hazardous labor in all forms, therefore manual labor can be deployed in less complicated and precarious environments. Industrial Automation also costs less in the long run to a company than manual labour and provide more work life and support.

1.10 METHODOLOGY



1.11 ORGANIZATION OF THE REPORT

The results of the project have been compiled in an elaborative manner into a report as mentioned below:

Chapter 1 explains the background information of the injection moulding take-out robot, it's types and the various types of robots deployed in injection moulding machine industry, use of positioning control and it's need and usage in this project, components manufactured NR Tech Poly Plast LLP, challenges of present systems, their applications, the need of this project, methodology implemented and the organization of report.

Chapter 2 explains the literature review in the area of the injection moulding take-out robots.

Chapter 3 elaborates the design and calculation that are used to decide the components that will be used in the robot in detail description with individual component description and selection criteria.

Chapter 4 explains the fabrication and assembly and the manufacturing processes used to make them.

Chapter 5 provides the electronics and control of the project with PLC Code and Pneumatics Simulation that was conducted in Festos Software and the various components used in Pneumatics.

Chapter 6 mentions the various conclusions drawn from this project and the future scope and improvement to be carried out for this project.

CHAPTER 2

LITERATURE SURVEY

Naveen Kumar E, T.V.Snehprabha and Senthil Kumar (*IJMRA Conference, Bangalore*) *PLC & HMI Interfacing for AC Servo Drive, October,2014. Volume 1)* in the paper titled "PLC & HMI Interfacing for AC Servo Drive" has developed PLC and Human- Machine Interface for AC Servo drive. The position mode control is achieved through Programmable Logic Controller (PLC) ladder logic programming to oscillate the motor shaft forward/reverse direction for required speed and position. Position mode parameters are realized by configuring the application software (R-advanced Setup) for Sanmotion servo-drive. PLC ladder logic program developed is capable of reading serial encoder data in incremental mode by establishing RS485 communication with Sanmotion AC Servo drive. An attempt was made to establish RS232 and Ethernet communication protocols to interface Redlion's Human Machine Interface (HMI) and Galil's DMC 21x3 (Digital Motion Controller) to monitor the servo motor parameters. The real time data related to DMC 21x3 controller and servomotor parameters was read/write with the help of HMI for supervisory monitoring of servo motor.

Gurjeet Singh and Ajay Verma *(5th International Conference of Materials Processing and Characterization (ICMPC), A Brief Review on injection moulding manufacturing process, Volume 4, Issue 2, Part A, March 2016, Pages 1423-1433)* in the paper titled "A Brief Review on injection moulding manufacturing process" has provided a review on various methods used in injection moulding process. This paper explains the significant conditions required for processing and the concepts required for developing making of the product. Various factors were researched on the idea of processing parameters. Quality and Productivity are two paramount objectives in the machining process. It was found out that quality has to be compromised at some extent to achieve great results in productivity. It's really important to optimize machining parameters to achieve this. The paper informs about the processing conditions in these moulding machines. It satisfies the processing conditions with proper quality-based manufacturing.

Taj Mohammad Khan et al *(IEEE Multitopic Conference, Karachi, Pakistan Modeling and Control of Cartesian Robot Manipulator, December 2005)* in this paper titled "Modeling and Control of Cartesian Robot Manipulator" has analyzed responses of three axis manipulator. The qualitative and dynamic responses were recorded for the same. They formed the kinematics and dynamical model of the robotic manipulator. This was achieved using C++ programming language and the results were depicted in MS-EXCEL. Multiple tests were performed and an application was formed of that of a drilling operation.

Ian Hyland *(Industrial Robot: International Journal, Robots used on plastic injection moulding machines. 2001, Volume 28, Number 2, Page 104-111)* in the paper titled "Robots used on plastic injection moulding machines" discusses about the advantages and disadvantages for the various types being used and describes the downstream processes that can be incorporated within the automated cell.

S. Senthil Kumar *(International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, 2015, Volume 4, Issue 6, Page 4887-4898)* in the paper titled "Design of Pick and Place Robot" elaborates the usage of pick and place robots in Industrial Environments. The various advantages of using Pick and Place Robot is that it increases productivity and helps in maintaining uniform quality. Various components that are most commonly used in industries have been discussed. It also enumerates the types of robots as per the applications. The paper clearly mentions the tasks that a pick and place robot can easily perform. It also discusses the various methods through which a robot can be programmed and the different programming languages used.

CHAPTER 3

DESIGN AND CALCULATION

3.1 MECHANICAL COMPONENTS USED

Table 3.1: Mechanical Components and Specification.

Sr. No	Component Name	Specification
1	Ball Screw	LENGTH: 1400 mm, Ball Screw Diameter 16mm, Lead 5mm
2	Ball Screw	LENGTH: 600 mm, Ball Screw Diameter 16mm, Lead 5mm
3	Linear Guide + Guide Block	LENGTH: 1400 mm, Guide Width: 20mm
4	Linear Guide + Guide Block	LENGTH: 600 mm, Guide Width: 20mm
5	Gears, Material Used	Aluminium and Mild Steel

3.1.1 Ball Screw.

This is a mechanical linear actuator that produces an interpretation of rotational movement to direct movement with a touch friction. A threaded shaft gives a helical raceway to ball bearings which set about sort of a precision screw. Even as having the choice to use or bear high push loads, they will do intrinsically with least internal friction. These were made to stop tolerances and are accordingly reasonable for usage in the circumstances in

which high precision is fundamental. This ball assembly goes about as the nut while the threaded shaft is the screw. As opposed to traditional leadscrews, ballscrews will, in general, be somewhat cumbersome, because of the need to have a component to re-flow the balls.

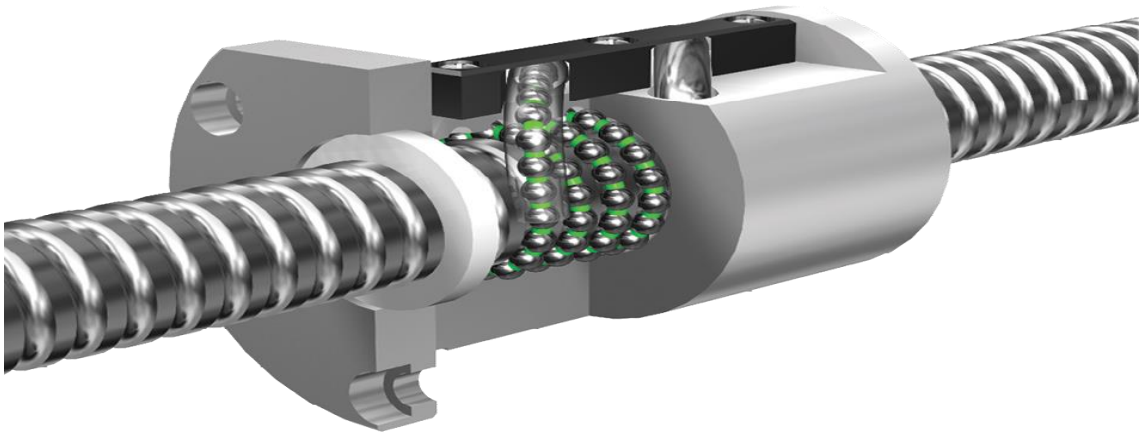


Figure 3.1: Ball Screw.

3.1.2 Linear Guide and Guide Block.

A linear guide is a direct movement part for smooth movement toward the rail without shaking. Different producers utilize various names, for example, linear guides (MISUMI) [1], LM Guides (THK) [2], NSK linear guides (NSK) [3], Linear Ways (IKO) [4] and slide guides (NB) [5].

The linear guide block gives straight movement by re-circling moving components between a profiled component and a bearing block.

Figure 3.2: Linear Guide and Guide Block.

3.1.3 Gears.

A gear or cog could be a rotating machine element that have a cut tooth or, an account of a cog-wheel, or an embedded tooth (called gear-teeth), which works with another toothed element to help in transmission of torque. Equipped gadgets can help in changing the speed, torque, and the heading of an influence source. Gears are very often producing an adjustment in torque, making a ratio, through their gear ratio, and this subsequently may well be viewed as an easy machine. The teeth on the 2 meshing gears all have an identical shape. a minimum of two cross-section gears, working in an exceedingly succession, are referred to as a gear train or a transmission. A gear can work with a linear toothed part, called a rack, delivering translation instead of rotation.

Figure 3.3: Gear.

A rack and pinion gear system are a kind of linear actuator that contains circular gear (the pinion) connecting with a linear gear (the rack), that works to translate rotational movement into straight movement. Moving the pinion into rotation makes the rack be driven linearly. Driving the rack directly will make the pinion be moved into the rotation. This rack and pinion drive system can utilize both straight and helical gears. Helical gears are favoured because of their calmer activity and higher burden-bearing limit. The greatest power that can be transmitted in a rack and pinion mechanism is controlled by the tooth pitch and the size of the pinion.

Figure 3.4: Rack and Pinion Gear Assembly.

3.1.4 Materials.

- Aluminium:

  It is the synthetic component with the symbol of Al and the atomic number of 13. It is a shimmering white, delicate, non-attractive and pliable metal within the boron group. By composition, aluminium makes up of about 8 percent of the Earth's crust surface, where it's the 3rd most copious component and furthermore the foremost inexhaustible metal. Event of aluminium diminishes within the Earth's mantle beneath, nonetheless, the central ore of aluminium is bauxite. Aluminium metal is very reactive, with the top goal that local examples are uncommon and constrained to extraordinary diminishing situations. Rather, it's discovered joined in additional than 270 unique minerals.

  It is being utilized for making the x-axis and y-axis on which the ball screw assembly will be mounted to accomplish the linear movement among the axis. Which thus will give the way to the robot.

- Mild Steel:

  Mild steel could be the kind of steel with an occasional percentage of carbon – it is called "low steel." Although the ranges fluctuate contingent upon the source, the measure of carbon commonly found in steel is 0.05 percent to 0.25 percent by weight, though higher carbon steels are normally depicted as having a carbon content from 0.30 percent to 2.0 percent. Any further carbon than that's included, the steel would be named forged iron.

  It is being utilized for making the base of the robot.

3.2 DESIGN AND ANALYSIS

The design of the Robot was made using SolidWorks 2020. Analysis of the Design was also done using SolidWorks. The three analysis that were completed were

- Stress Analysis: The analysis is carried out using SolidWorks Software. The following steps are used:

  (1) Click Simulation Setup.

(2) In the graphical area, select the component on which the stress analysis has to be performed. The part that is under Selection in Property Manager.
(3) Enter the Start Time and the End Time for analysis. Enter an isolated time value, and enter the same value for Start Time and End Time. Also select time values from the Motion Manager timeline.
(4) Click on Add Time.
(5) Repeat these Steps 3-4 to calculate stress analysis on other time intervals.
(6) Press OK.

- Displacement Analysis: The analysis is carried out using SolidWorks Software. The following steps are used:
  (1) Select Prescribed Displacement which is available under External Loads drop-down.
  (2) Specify Direction for Displacement.
  (3) Amount and Direction of prescribed translation or rotation is also specified.
  (4) Result can be achieved using List Result Force Option and the stress is calculated.
- Factor of Safety Analysis: The analysis is carried out using SolidWorks Software. The following steps are used:
  (1) After completing your static study, we calculate factor of safety of our model.
  (2) Run static study, right click the Results and select New Plot, Factor of Safety.
  (3) Select All, a component or a body in component.
  (4) Select a failure criterion from the Criterion List or select Automatic.
  (5) Under Property, a custom title should be entered.
  (6) Select Stress Units. Select Yield Strength, Ultimate Strength, or User Defined options from Set Stress Limit Menu.
  (7) Select either Factor of Safety Distribution or Areas below Factor of Safety.

(8) Safety Result box displays minimum factor of safety.

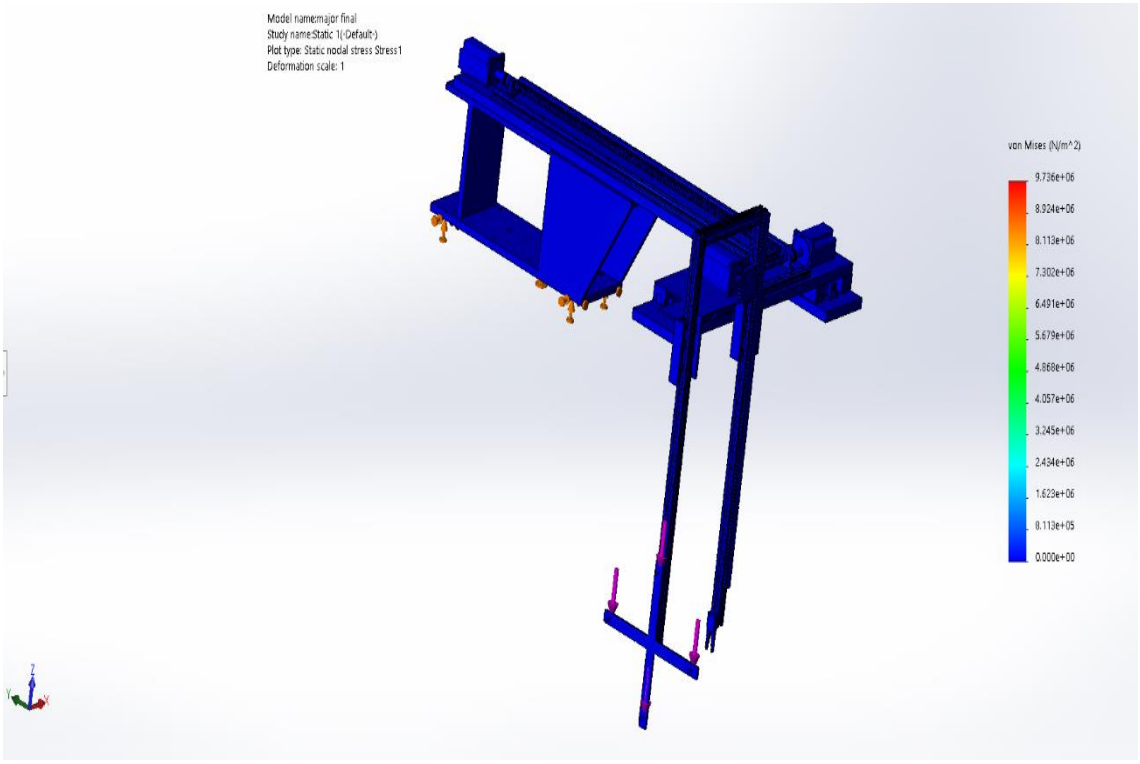


Figure 3.5: Stress Analysis.

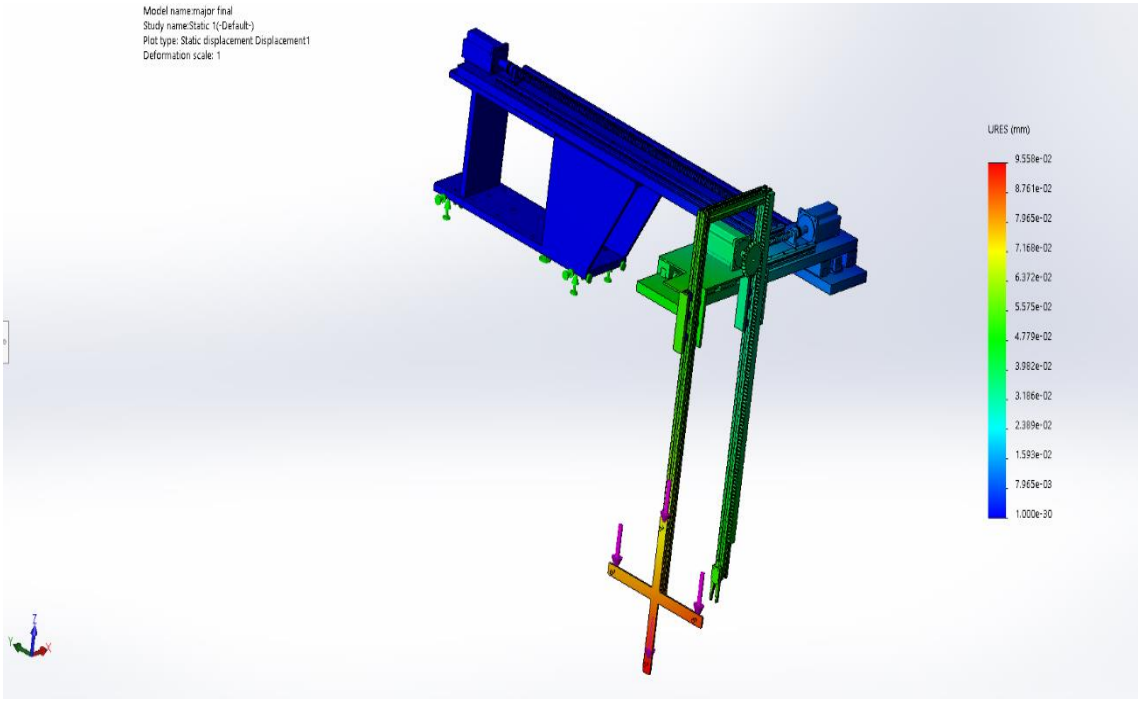


Figure 3.6: Displacement Analysis.

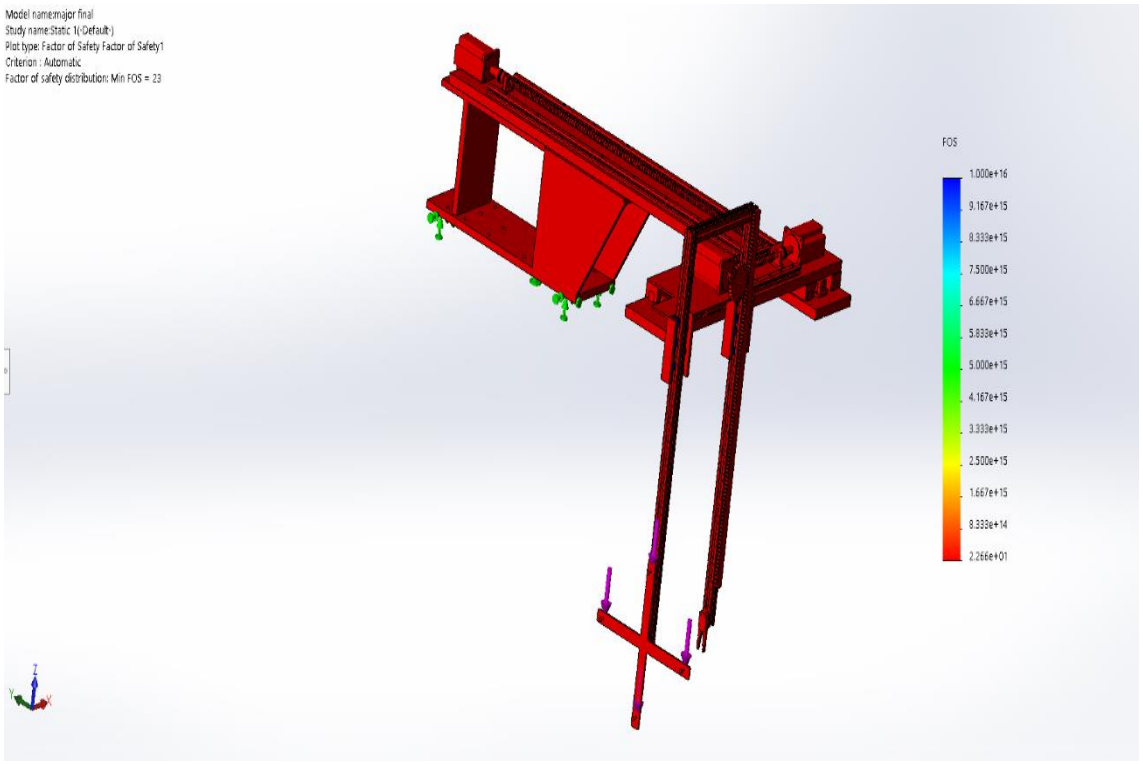


Figure 3.7: Factor of Safety Analysis.

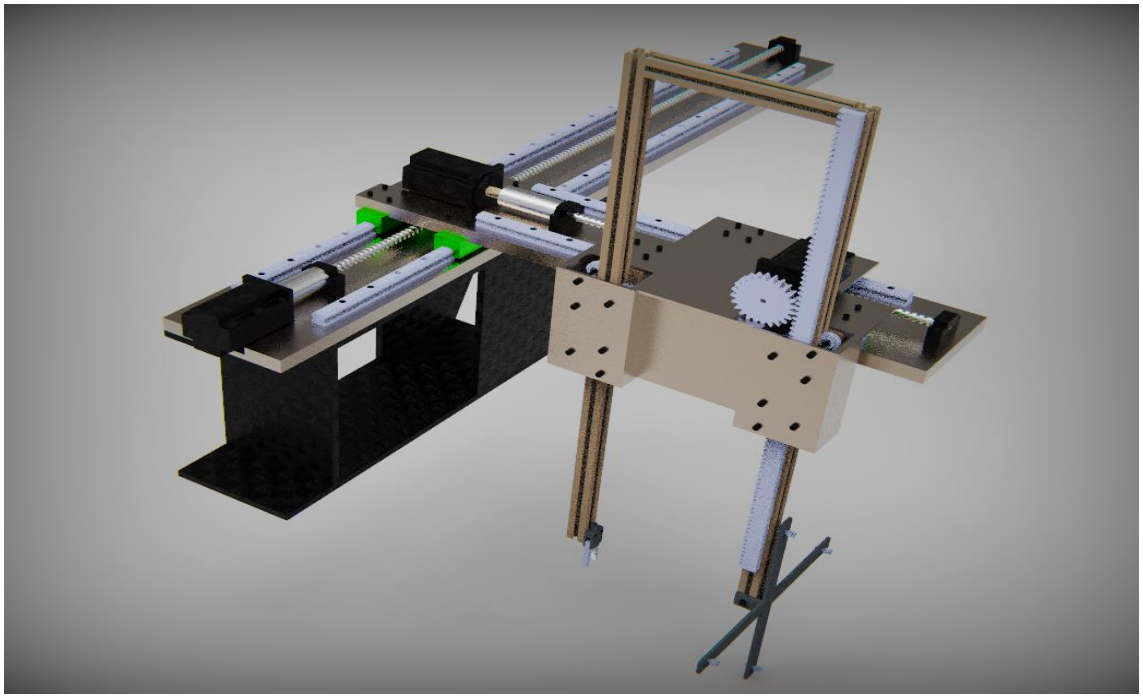


Figure 3.8: Isometric View of CAD Design.

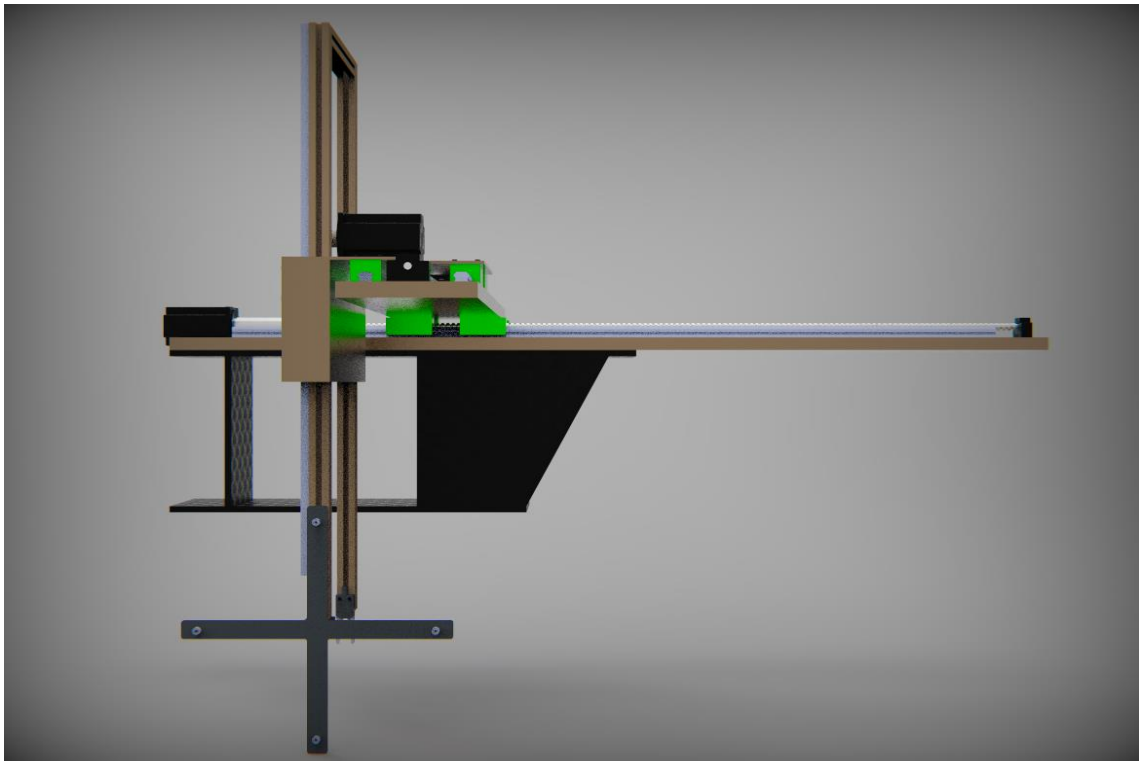


Figure 3.9: Front View of CAD Design.

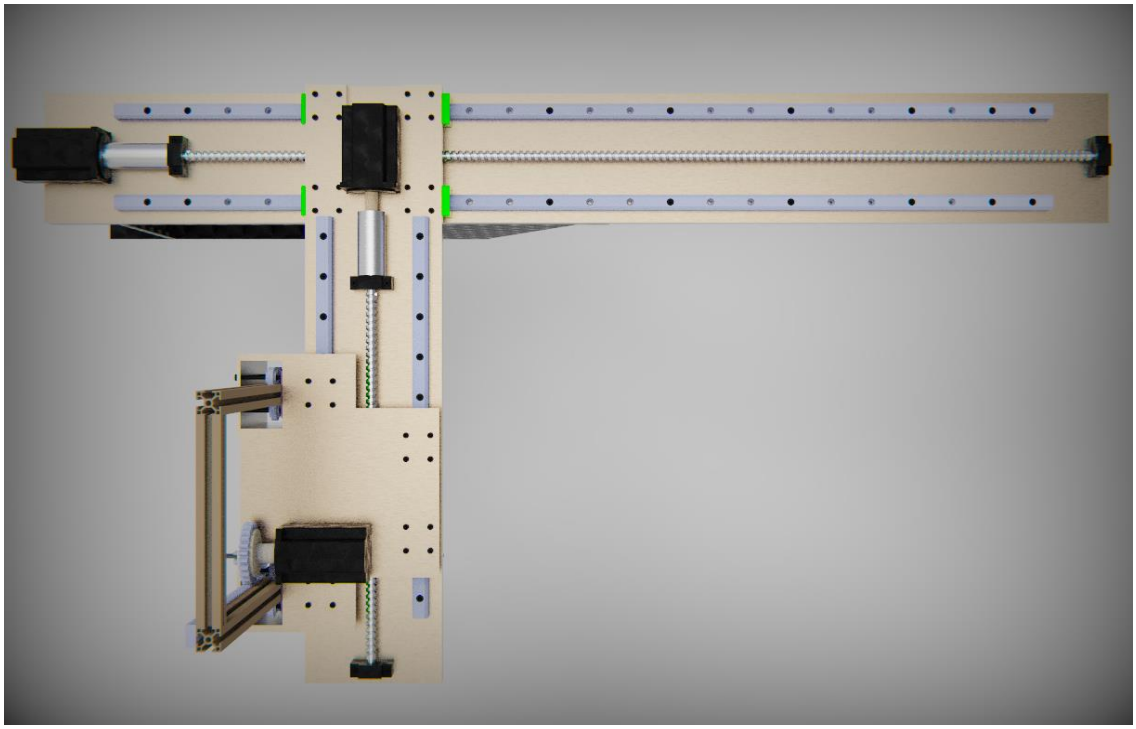


Figure 3.10: Top View of CAD Design.

3.3 CALCULATION

3.3.1 Motor Calculation

For Ball Screw Mechanism:

T_w = μMg * P/(2π) * 10^-3 (Nm)

= 0.01 * 20 * 9.8 * 5/(2π) * 10^-3 (Nm)

= 0.0015 Nm (For X-Axis)

For Ball Screw Mechanism:

T_w = μMg * P/(2π) * 10^-3 (Nm)

= 0.01 * 10 * 9.8 * 5/(2π) * 10^-3 (Nm)

= 0.0007 Nm (For Y-Axis)

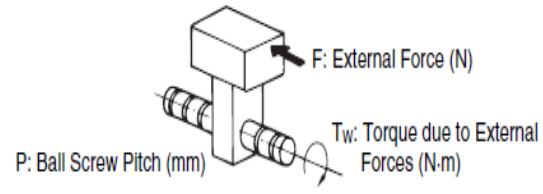
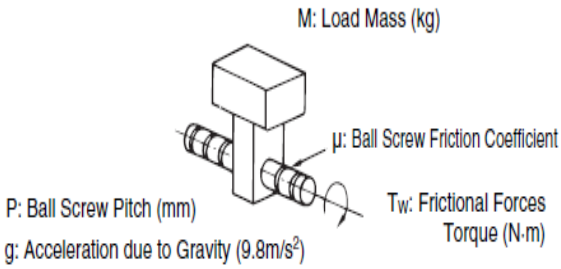
Torque against external force		$T_W = \frac{F \cdot P}{2\pi} \times 10^{-3} (N \cdot m)$
Torque against frictional force		$T_W = \mu Mg \cdot \frac{P}{2\pi} \times 10^{-3} (N \cdot m)$

Figure 3.11: Formula Used for Motor Calculation.

CHAPTER 4

FABRICATION AND ASSEMBLY

The Mild Steel and Aluminium Materials were used for Fabrication of this robot. The Base of the Robot was made up of Mild Steel and the X and Y Axis were made up of Aluminium.

The processes involved in fabrication for Base, X and Y axis were:

- Cutting: It is a simple technique which uses the process of material removal. The equipment used in this operation is known as a bar turner. This operation provides high precision work.
- Surface Grinding: It is a procedure which helps us to obtain a smooth finish on flat surfaces. It is primarily employed in abrasive machining process within which a rotating machine is roofed in rough particles (grinding wheel) that removes chips of metallic or non-metallic substances from a workpiece, making it smooth and layered and flat.
- Drilling and Tapping: It is a process in which a hole is made and a thread is cut inside it so that a cap screw can be fixed.

  For this project M12 holes were made on the top surface of the base to attach it with the X-Axis plate. M6 holes were made to fix the linear guide and the X and Y axis plates. M5 holes were made to connect the linear block placed on X-Axis with Y-Axis.

Figure 4.1: Fabrication of Base.

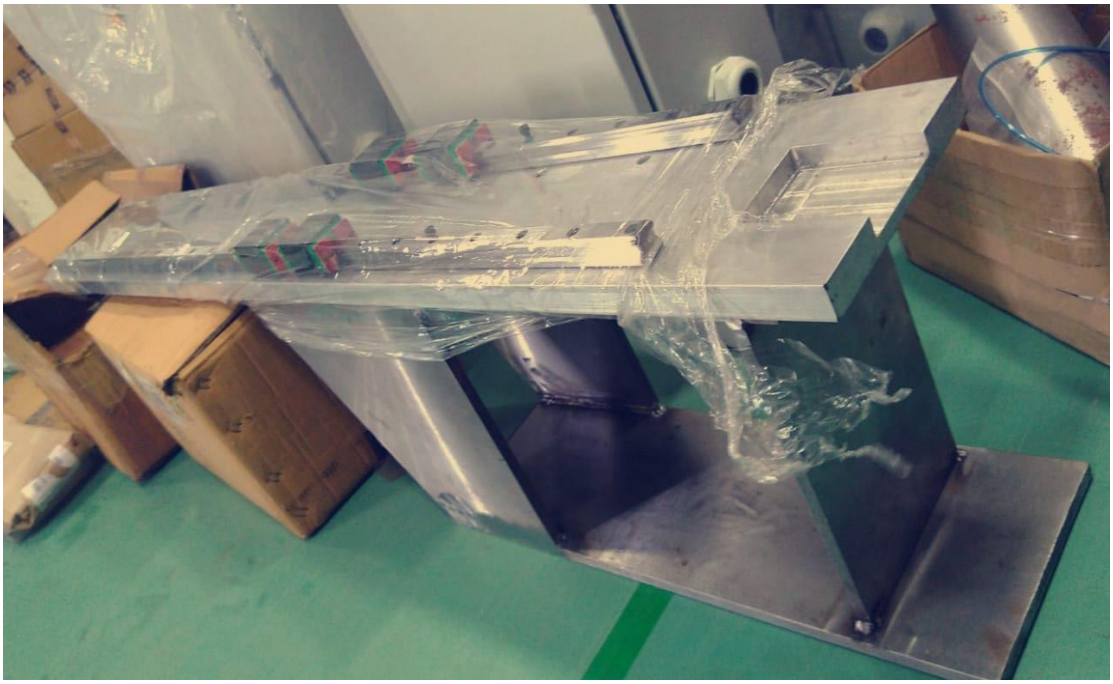


Figure 4.2: Assembly of Base and X-Axis.

CHAPTER 5

ELECTRONICS AND CONTROL

The chapter includes the information about the electrical & electronic components involved in this project as well as information on the control of robot using the PLC and its programming. Th list of the components with a brief description of each component is given in the table below.

Table 5.1: Electrical and Electronics Components.

Sr. No	Component Name	Quantity	Brief Description
1.	Mitsubishi FX5U Programmable Logic Controller	1	Controller for the robot
2.	Mitsubishi Servo Motors	2	Actuators for motion of robot
3.	Mitsubishi Servo Motor Amplifier	2	Motor Driver for the motors
4.	Limit Switches	4	Discrete Position sensor for motion limiting
5.	Encoder Cable	2	To receive the motion feedback
6.	Motor Driver CN1 port cable	2	PLC - Motor Driver Interface cable
7.	Motor Power cable	2	Motor Driver – Motor input cable
8.	Omron SMPS	1	Distribution of various DC voltages
9.	Power Supply Cord	-	-
10.	MCB Switches	-	-
11.	Single Phase Power Supply	-	-

5.1 CONTROL

The growing level of automation in the industrial sector also demands for flexibility so as to incorporate high levels of product or mechanism variation. Keeping this in view, a Programmable Logic Controller is ideal in this scenario. The Mitsubishi FX5U PLC is latest and incorporates numerous features enabling up to even 4 axes of motion control for automated projects. The PLC has built in features for the control of Servo

motors from Mitsubishi. The various range of software from the company (MITSUBISHI ELECTRIC) dedicated for configuration of parameters of the motor drivers as well PLC programming have helped in putting together the project into action.

The MR Configurator software is a powerful software tool for testing and configuring parameters of the motor driver. The PC can be connected directly to the Mitsubishi Servo Amplifier (MR-JE-70AS) using a mini-USB cable and be configured for various parameters such as pulses, modes, direction, limitations, etc.

The following parameters as shown below are set from the MR Configurator software after connection to the Servo Amplifier directly using a Computer. The Control mode is selected as “Position Control Mode” in the given mode selection field. Also, the encoder output pulses can be set for 1 revolution of the motor shaft depending on the precision required. In the Position Control Option, the Servo Amplifier can be configured for operation in “Pulse train + Sign” in “Negative Logic” Mode out of total 6 command modes. This helps in configuring the motor to run via a PLC. The Servo Assistant dialog box enables us to test run the motors with various position commands, speeds or direction etc. One can also observe the encoder pulses count and other signals from the Servo Amplifier during the test run.

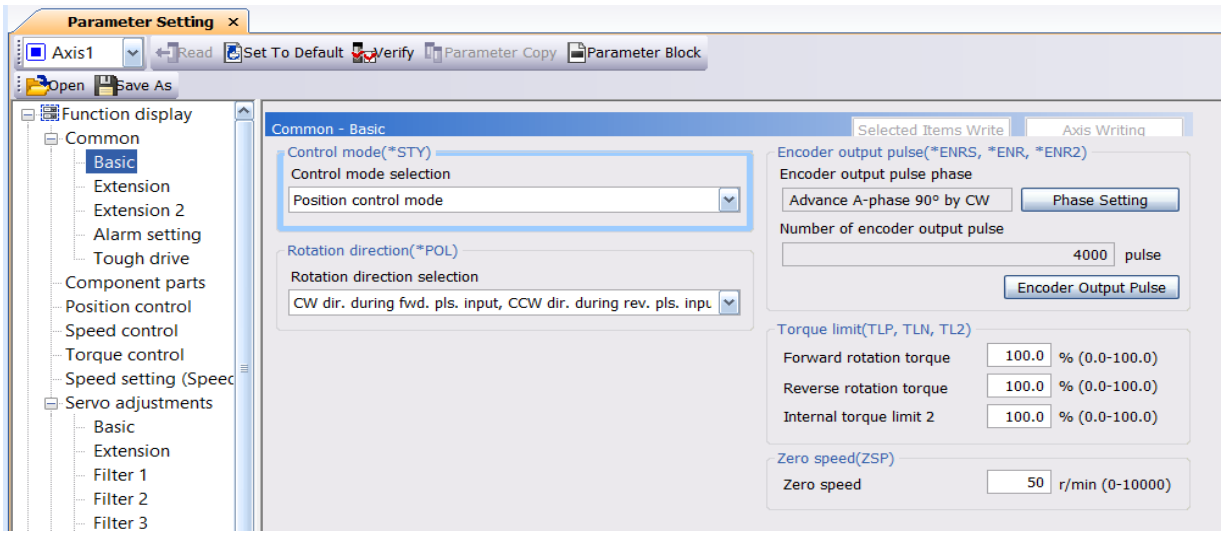


Figure 5.1: Parameter Settings (Control Mode).

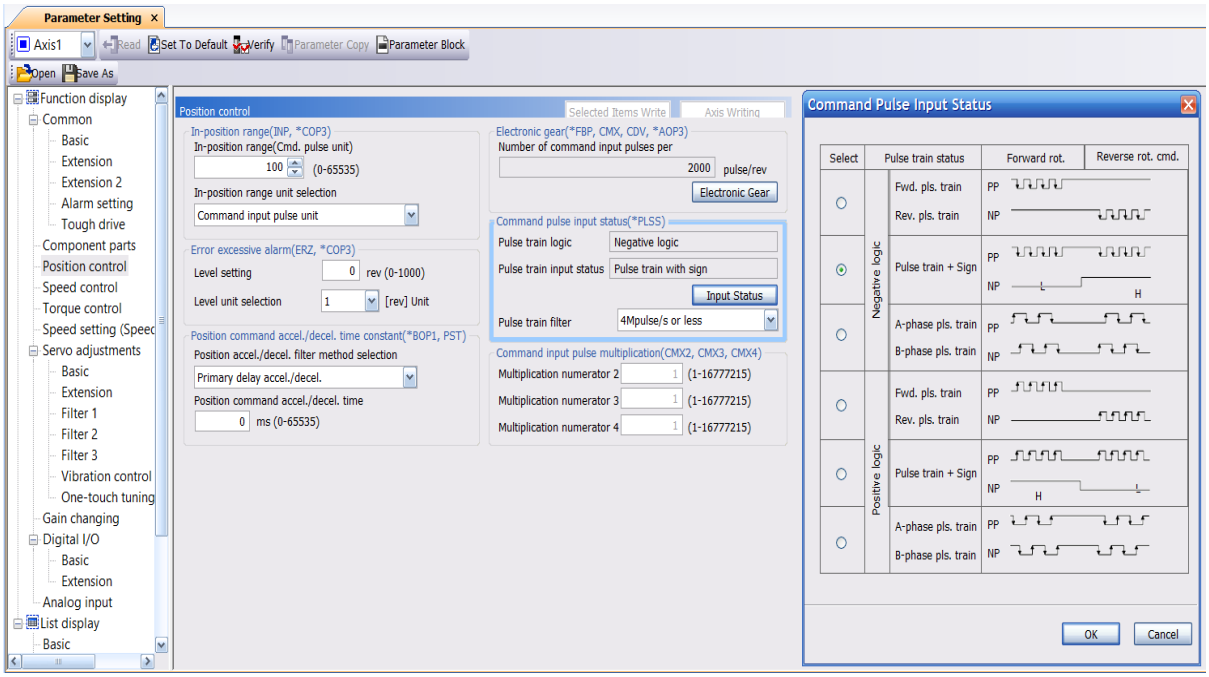


Figure 5.2: Parameter Settings (Input Status).

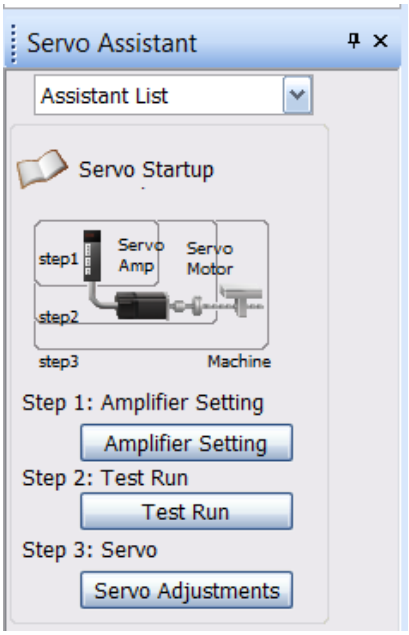


Figure 5.3: Servo Testing.

The GX3 Works on the other hand is a software that provides for the programming of various Mitsubishi computers as for in our case the FX5U CPU. The software can write

programs in ladder-logic, ST (Structured Text), FBD/LD (Function body diagram/ Ladder diagram). The robot is controlled using ladder logic programming.

Before getting into details about the control logic, the connections of various components involved is important to study based on how and in what mode the motors are to be run.

5.2 CONNECTION DIAGRAM

The following is a connection diagram of the FX5U CPU with the motor including both Servo Motor Amplifier and Motor itself. This is obtained from the training manual of MR-JE-AS type Servo Amplifiers. MR-JE-70AS is an incremental device and thus do not store the encoder value once turned off. This suggests that the motor control programming has to be done in incremental form rather than absolute form.

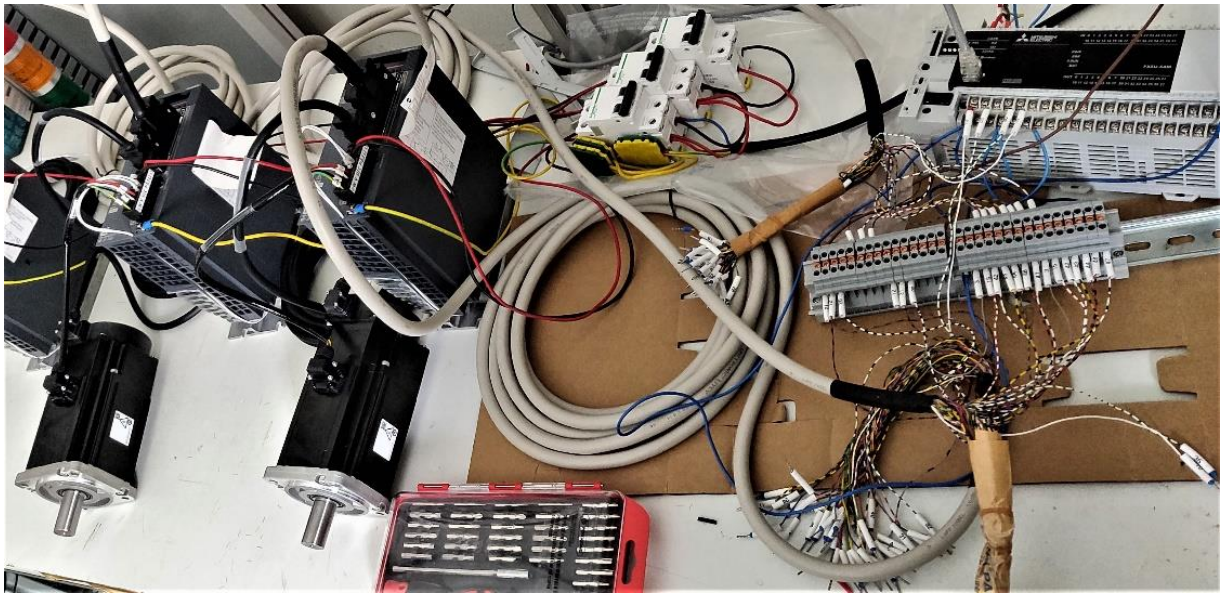


Figure 5.4: Actual Connections Image.

The above given diagram gives the actual idea of connections between the components. The schematic connections diagram is also given here.

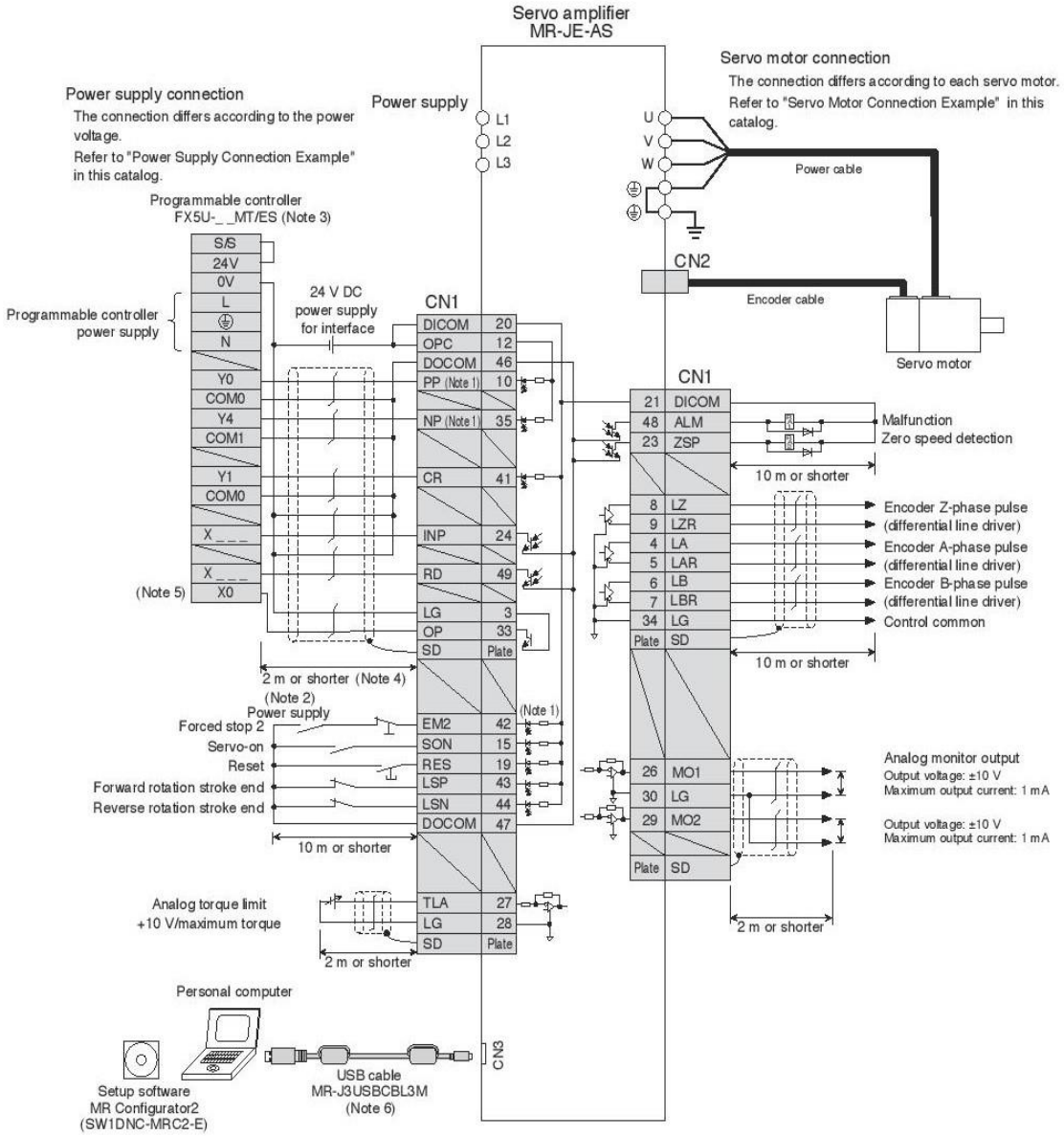


Figure 5.5: PLC – Servo Amplifier – Servo Motor Connection diagram.

Depending on what mode and how the servo motor amplifier is to be run, the suitable connections are made. The CN1 terminal from the Servo Amplifier is a -pin terminal and thus various command signals can be given to the Servo Amplifier and data can be

read in the PLC. The list of pins with their functions for Position Control mode of motor are given in the following table with description:

Table 5.2: CN-1 Pin out connection with description.

Sr. No.	Pin No.	Pin Description	Terminal
1.	**CN1-10**	No. of Pulses (Amount)	PLC Y0
2.	**CN1-35**	Sign of the Pulses (Direction)	PLC Y4
3.	**CN1-21**	Digital I/F Power supply Input (DICOM)	+24 V
4.	**CN1-12**	Open Collector Sink I/F Power Supply (OPC)	+24 V
5.	**CN1-20**	Digital I/F Power supply Input (DICOM)	+24 V
6.	**CN1-15**	Servo-On (SON)	0 V
7.	**CN1-46**	Digital I/F Common (DOCOM)	0 V
8.	**CN1-47**	Digital I/F Common (DOCOM)	0 V
9.	**CN1-3**	Control Common (LG)	0 V

The images of actual connections of the pin are shown below:

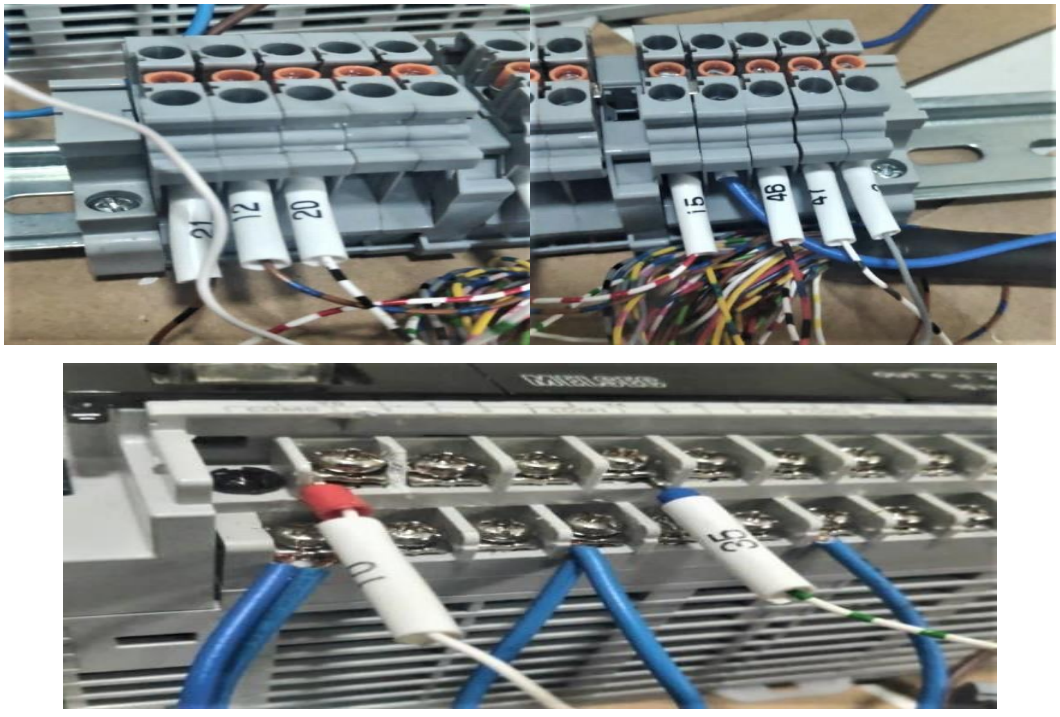


Figure 5.6: (From Left) Figure a: +24 V connection; **Figure b:** 0 V connection; **Figure c**: Pulse/Sign Pins**.**

5.3 PROGRAMMING

The programming is done in Ladder Logic language in the GX Works3 software. The software is developed by Mitsubishi for programming of various PLCs and in our case the FX5U-64MT/ES. Since the Servo Motor Amplifier is an increment type amplifier, the encoder values are not saved after the shutdown. Thus, the programming of motor operation is done in increment mode. The travel distance is written in terms of encoder pulses based on the formula involving ball screw pitch for 1 revolution. Thus, this formula helps write the actual position to be reached in terms of encoder pulses in forward or reverse direction at a definite speed with precision making it an increment type of logic.

There needs to be done some basic Axes parameter settings for the operation of motors via a PLC. Thus, the output parameters in the “High Speed I/O” option under “Module parameters” needs to be changed according to the output logic used in the program to control the motor position.

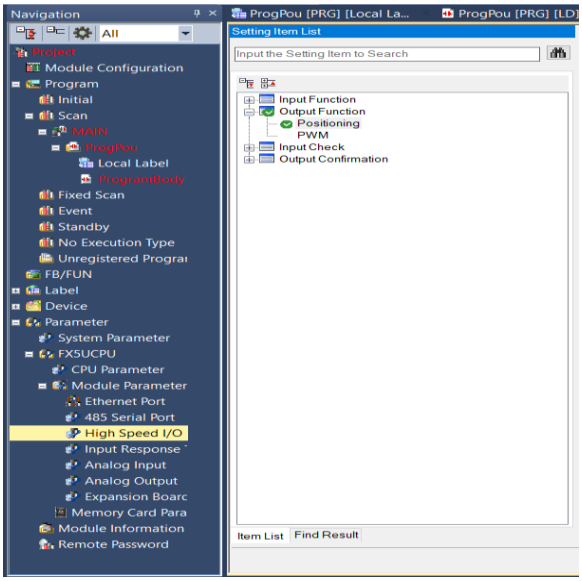


Figure 5.7: Navigation to High Speed I/O Parameters.

The Positioning block has various configuration parameters for the 4 Axes. All 4 axes can be operated simultaneously if Pulse/Sign mode is used as only 4 output Pins (Y0, Y1, Y2, Y3) are capable of generating pulses. Thus Y0, Y1, Y2 and Y3 with

respectively Y4, Y5, Y6, Y7 can be used as Pulse and Sign pins correspondingly. In the CW/CCW mode only 2 Axes can operate since it requires positive pulse train for forward rotation and negative pulse train for reverse rotation and thus making use of the first 4 pins only within 2 axes.

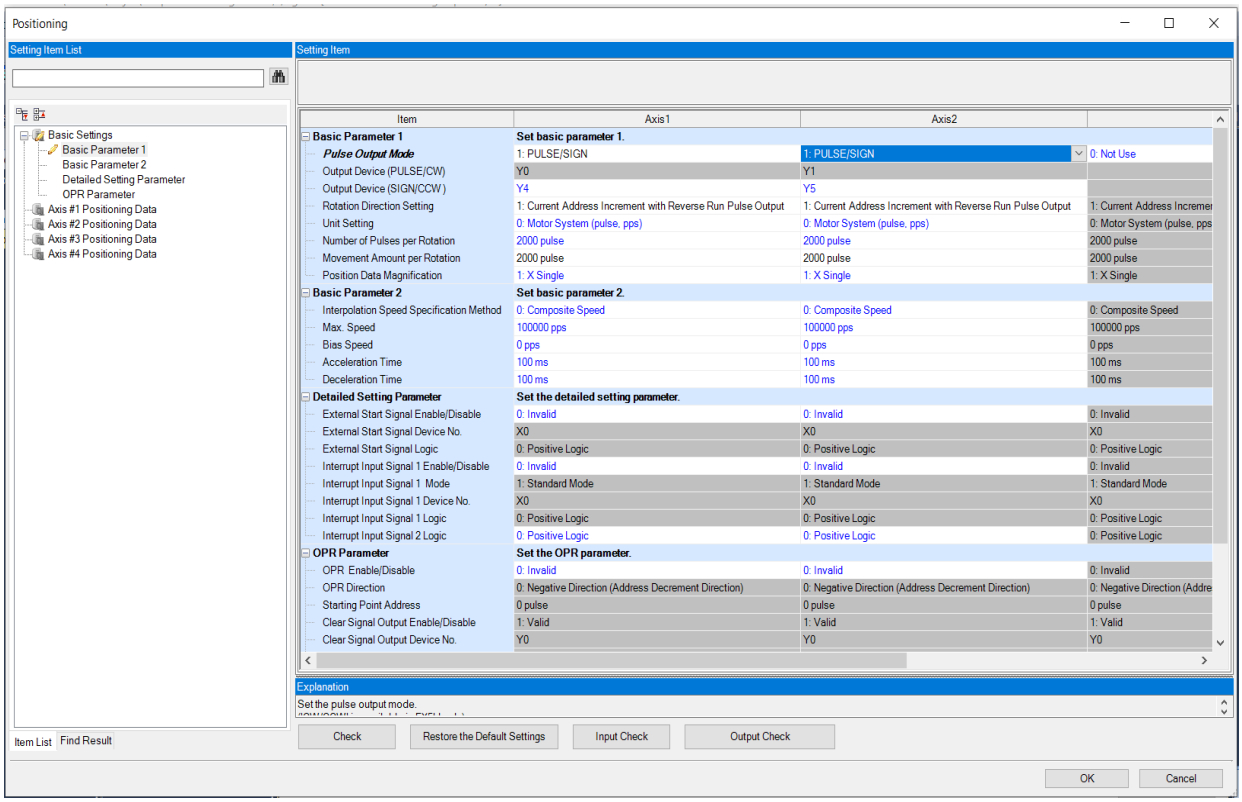


Figure 5.8: Output Parameters settings.

The next part that comes is configuring all the parameters for the axes and building the actual control logic. The following is a program snap that involves basic rotation of 2 motors by giving +50000 pulses rotation (forward) and -50000 pulses rotation (reverse) to Axis 1 and Axis 2 respectively or vice-versa according to the direction parameters set. The ladder logic for axis 1 "**DDRVI K50000 K20000 K1 M10**" describes a specific motion plan for the motor. "DDRVI" is an instruction for that axis to run in Increment Mode. The term "K50000" term describes forward/reverse rotation of 50000 pulses. "K20000" is the no. of pulses per rotation and "K1" is the axis selection term. The "M10" is cycle completer flag and it turns ON when the Positioning is completed.

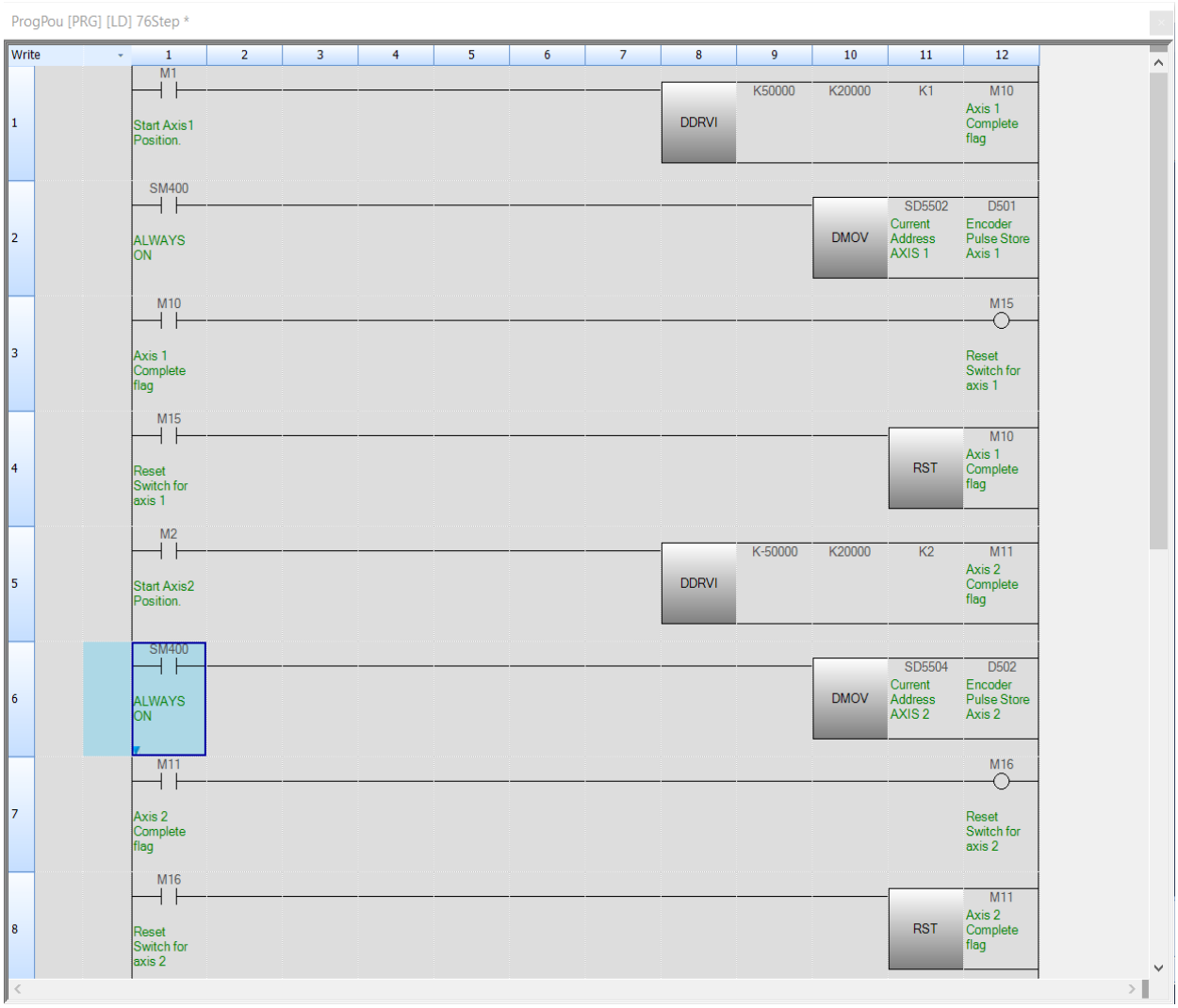


Figure 5.9: Ladder Logic Program.

This program is then incorporated with switches replacing the actual sensory signals from limit switches triggering other systems to make this system autonomous. Both the axes work in accordance with each other to complete the task.

5.4 PNEUMATIC CIRCUIT DESIGN & SIMULATION

As per the requirement of picking up 4 parts as well as the runner/sprue from the injection moulding machine, a pneumatic circuit for this particular application is designed. The vacuum generator in congruence with 4 vacuum efficiency valves as well as 4 suction cups have been used for the application. The Sprue chuck is a readily available sprue gripper that triggers gripping action when air supply is provided.

Finally, making use of air compressor, filter and regulator, direction control valves etc. with suitable hose sizes a circuit is built for the project.

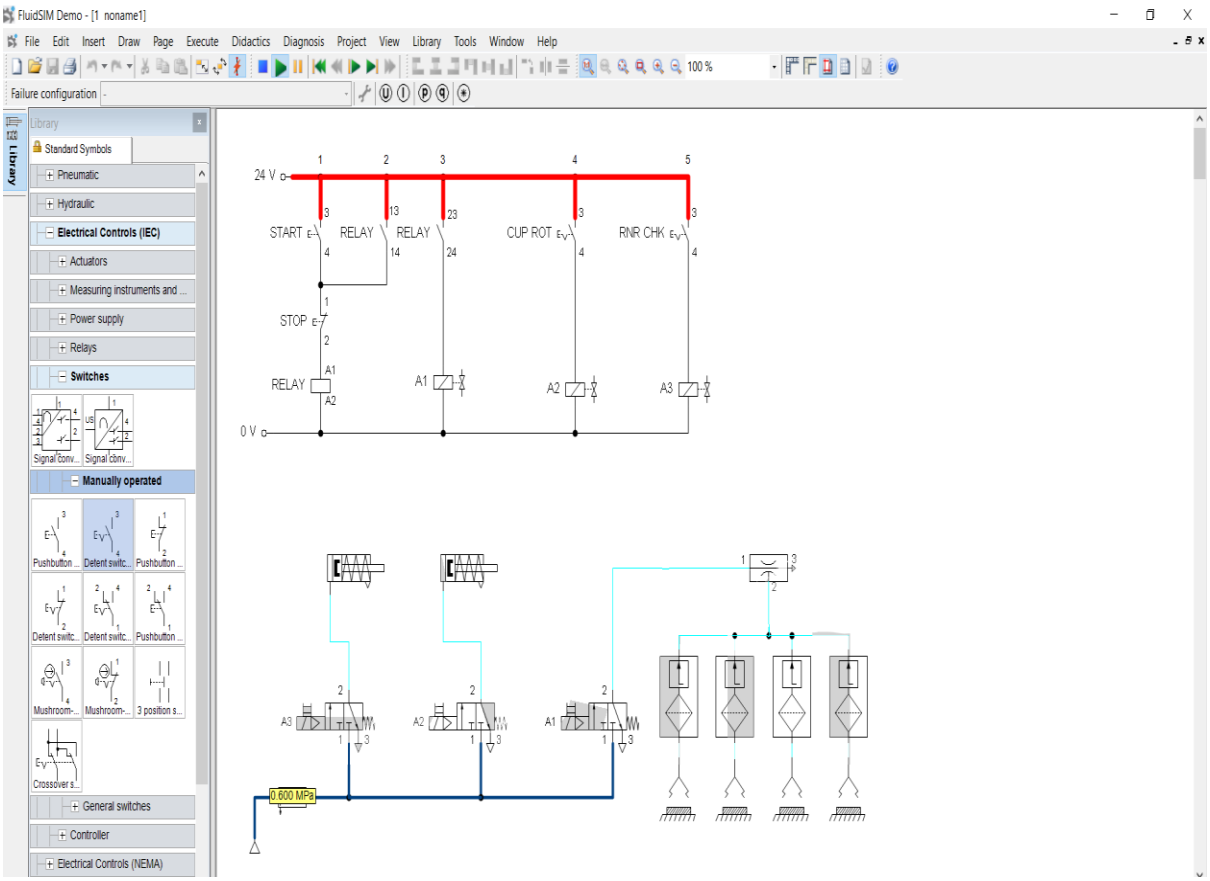


Figure 5.10: Pneumatic Circuit Simulation (Initial moment).

The above Simulation Circuit makes use of Electropneumatic medium for the actuation of vacuum cups. The electronic circuit comprises of relays for the actuation of direction control valves. These relay switches can be incorporated in the PLC by writing proper commands corresponding to the current cycle for the application. The 3 direction control valves are used for three different application. The first DCV is to actuate the cylinder that causes gripper motion, the second one to actuate sprue gripping action and the third one to actuate the vacuum grippers. The figure given below shows the actuation point in the pneumatic circuit where all the DCVs are pushed in so that the parts are picked as well as the sprue gripper is also picked. The Electropneumatic Circuit has some pushbuttons which will actually correspond to output switches from the PLC and also act as Input for some while making the complete program.

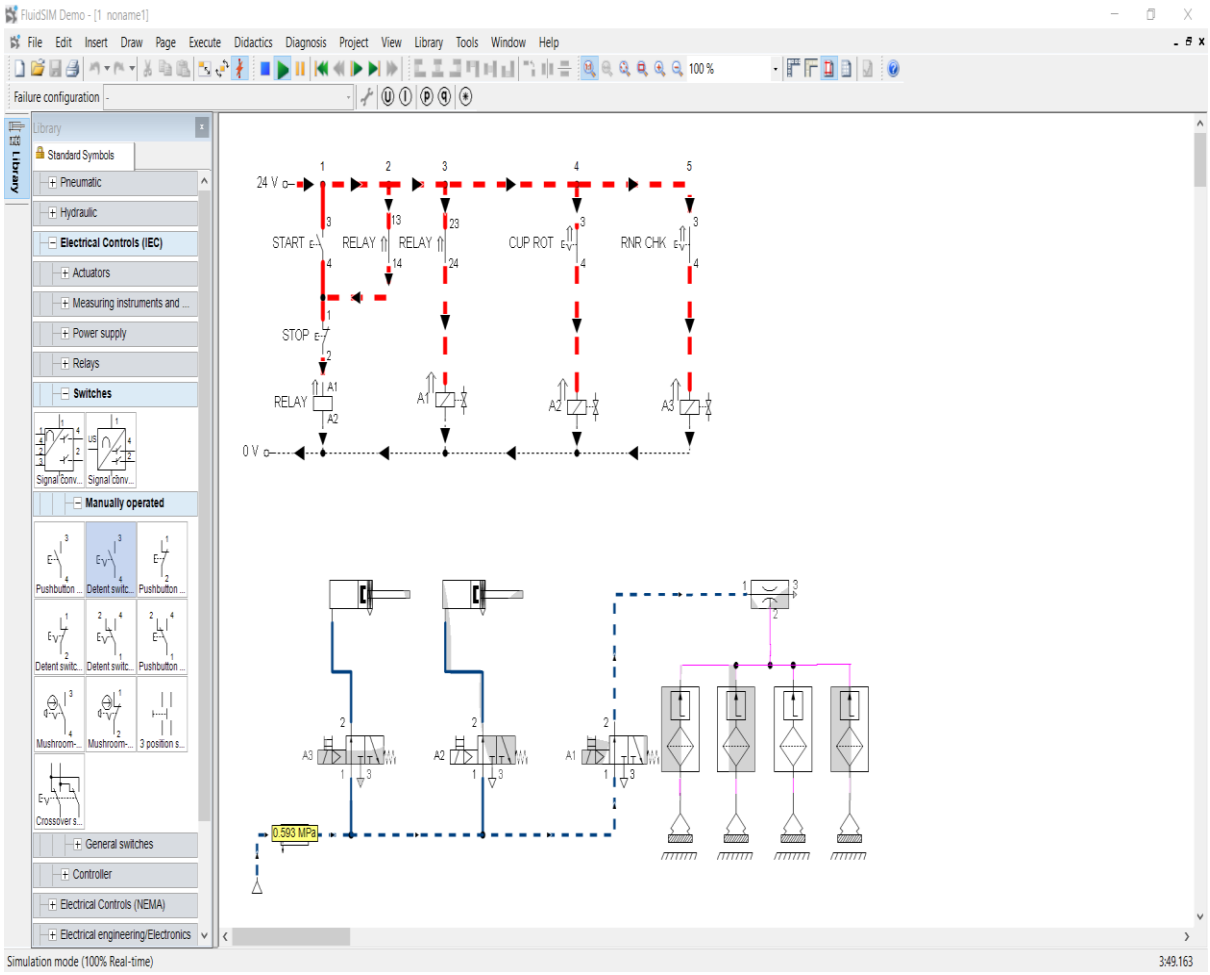


Figure 5.11: Pneumatic Circuit Simulation (Actuation moment).

This electropneumatic circuit was designed and simulated in Festo FluidSIM software which is capable of even adding weights to the parts that are to be picked. Thus, it helps in making mechanically and systematically robust system for the gripping parts. With the addition of a pressure sensor to this circuit at vacuum generator node, it will have the capability to sense if all the parts are picked up correctly or not.

5.5 PNEUMATIC COMPONENTS

5.5.1 Pressure Sensor

A pressure sensor may be a gadget for pressure estimation of gases or fluids. The pressure may be a declaration of the force required to stop a liquid from extending and is mostly expressed as force per unit area. A pressure sensor normally goes about as a transducer; it creates a symbol as a component of the load applied.

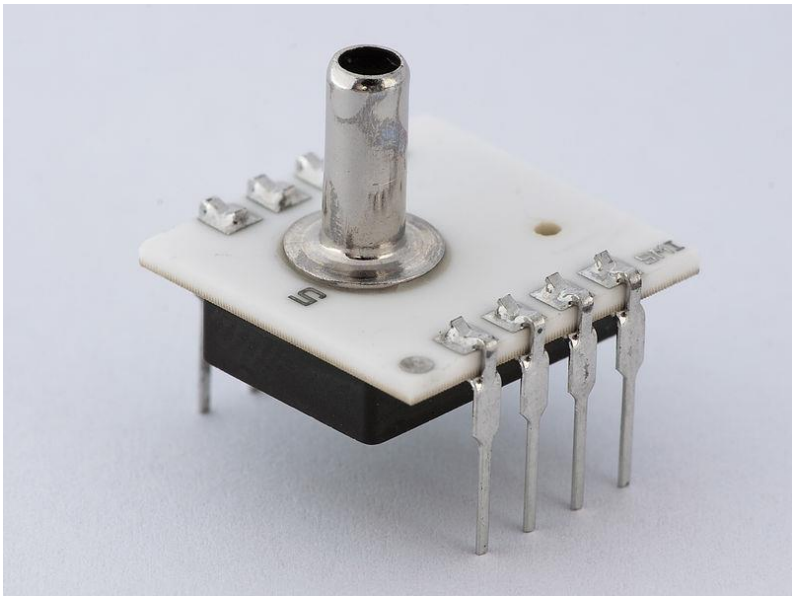


Figure 5.12: Pressure Sensor.

5.5.2 Vacuum Sensor

Vacuum sensors are utilized to gauge vacuum or sub-atmospheric pressure. Vacuum implies pressure below atmospheric. Since the true vacuum is rarely accomplished, the estimation is in regard to a close to nonattendance of gas pressure. The vacuum can be estimated utilizing a traditional pressure sensor; in any case, they regularly don't resolve incredibly low concentrations of gas because of a poor signal-to-noise proportion. Vacuum sensors depend on physical properties of gas particles that are identified with the number of such molecules per volume of space.

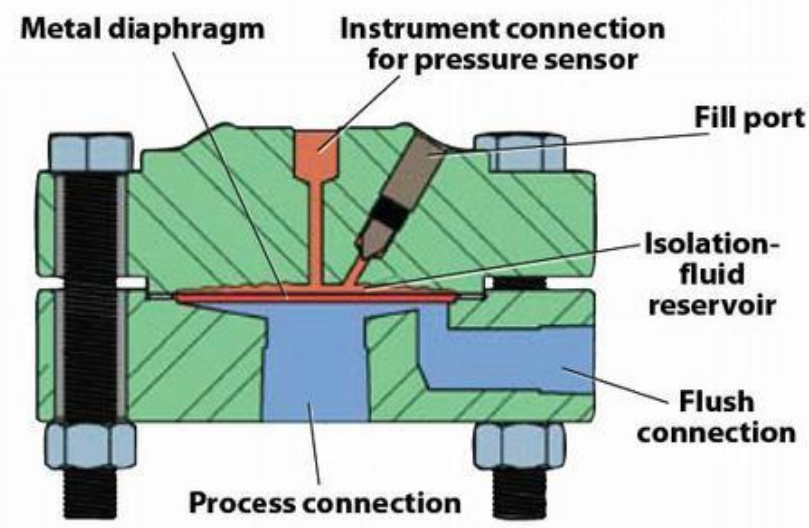


Figure 5.13: Vacuum Sensor.

5.5.3 Solenoid Valve

This component is an electromechanically operated valve system. It varies with different attributes like electrical flow rate they use, the force field required, the system that manages the fluid and the qualities of fluid control. There mechanism varies from linear, plunger, pivoted-armature and rocker actuators. This system uses 2-port system to help in the manage of stream and utilize three or more ports that will help in switching streams between the ports.

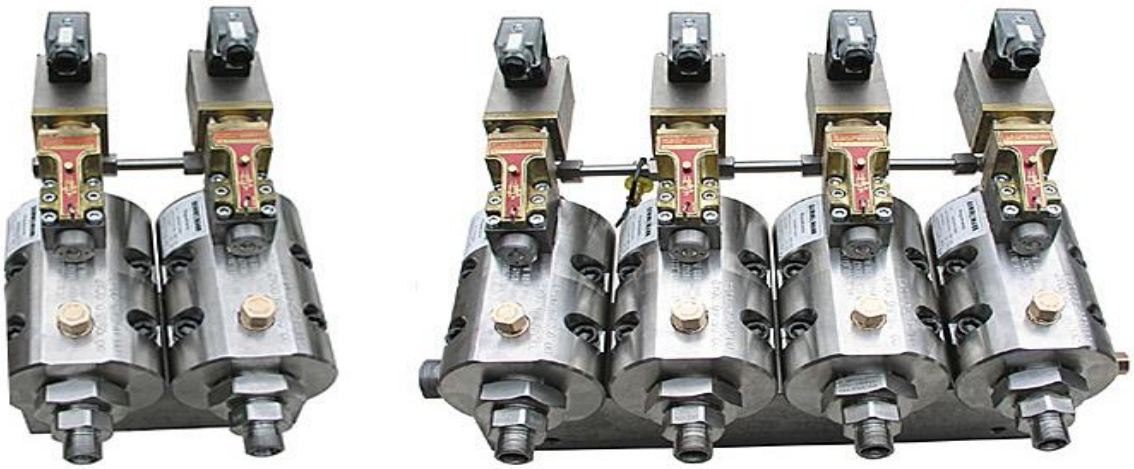


Figure 5.14: Solenoid Valve.

5.5.4 FRL Unit

Filter, Regulator, and Lubricator (FRL) compacted air frameworks are utilized to convey clean air, at a fixed pressure, and greased up to guarantee the correct pneumatic segment activity and increment their operational lifetime. The air is provided by compressors is generally sullied, over-pressurized, and non-greased up implying that a FRL unit is required to forestall harm to hardware. It can be purchased exclusively or as a bundle contingent upon what is expected to guarantee the correct air determinations are being met for downstream equipment.

Figure 5.15: FRL Unit.

5.5.5 Vacuum Generator

Vacuum generators give the vacuum level that is required for the dealing with task. The vacuum is made either pneumatically or electrically. Pneumatic vacuum generators actualize short process durations and can be incorporated straightforwardly into the framework because of their smaller and lightweight structure. Electrical vacuum

generators are utilized in applications when packed air isn't accessible or when exceptionally high pull limits are required.

Figure 5.16: Vacuum Generator

5.5.6 Pneumatic Tubes

Pneumatic tubes are frameworks that impel tube-shaped compartments through systems of tubes by packed air or by halfway vacuum. They are utilized for shipping solid items, instead of traditional pipelines, which transport liquids. Pneumatic tube systems picked up acknowledgement in the late nineteenth and mid-twentieth hundred of years for workplaces that expected to move little, dire bundles, (for example, mail, desk work, or cash) over generally short separations (inside a structure or, probably, inside a city). A few establishments developed to extraordinary multifaceted nature yet were generally supplanted. In certain settings, for example, emergency clinics, they stay boundless and have been additionally broadened and created in the 21st century.

Figure 5.17: Pneumatic Tubes.

5.5.7 Pneumatic Hoses

The fundamental capacity of pneumatic hoses is to pass on under pressure air to actuator, valves, devices and various gadgets. In any case, there is endless size of hoses available, so architects ought to think about various significant elements to choose the correct one for a given task.

Figure 5.18: Pneumatic Hoses

5.5.8 Pneumatic Distributor

The pneumatic distributor, by and large, comprises of a metallic body alongside the specific openings or pathways for the entry of pneumatic air. It is commonly utilized for the application when the pneumatic air is should have been provided along the distinctive direction from its actual direction.

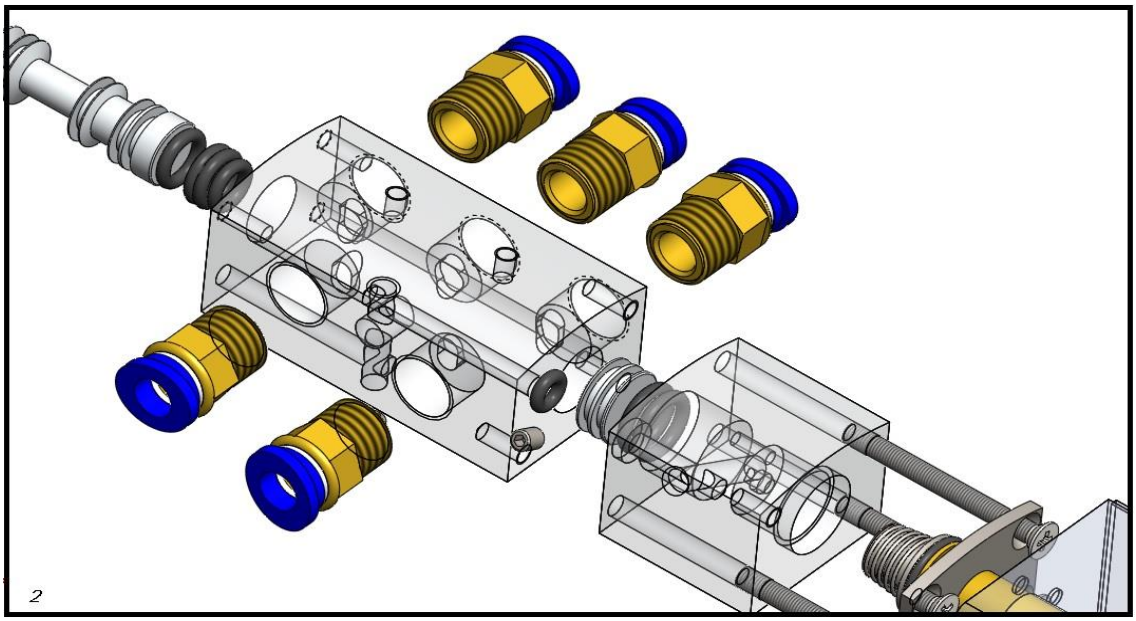


Figure 5.19: Pneumatic Distributor

5.5.9 Pneumatic Switches

A switch is an assistive innovation gadget that is actuated by a taste or a puff of air. A pneumatic switch can be utilized for working of the circuit according to the desired condition. A pneumatic switch now and again goes about as a sensor in some application circuits.

Figure 5.20: Pneumatic Switches

CHAPTER 6

CONCLUSION AND FUTURE SCOPE

Injection Molding Pick and Place robots are used widely in the MSME sectors in Indian as well as foreign countries. Our project consists of 2-DOF (P-P) configuration. This robot consists of two axis and the moment in axis is provided by the ball screw mechanism. The actuation is achieved by servo motors mechanism. The controlling for the mechanism is achieved through PLC (Programmable Logic Controllers). It has given us the most efficient control. The circuitry of the robot is fully submerged into a panel which consists all the devices as well as the power source. The motors are controlled by the motor drivers present in the panel. The PLC is programmed through the ladder logic programming.

Further the improvements in the above project can be achieved through the deployment of z-axis and the gripping mechanism with the pneumatic control. So as to achieve the gripping action and the pick and place mechanism. Furthermore, the implementation of IoT for this application will lead the robot to be successfully implanted in the industry 4.0 applications which will make it more efficient. Implementation of IoT control will make the operating of the robot more user friendly as well as the inventory control can also be achieved through this.

This robot is the best suitable choice for the most efficient production and bulk production in the Industries using Injection Molding machines. The Products from the machine can be easily picked and kept to the conveyer or the desired place with the help of this robot. The replacement of the manual labor and making the system more efficient as well as user friend. The errors caused by the manual labor work force can also be reduced and more an more production can be achieved.

The future improvement can be carried out by implementation of Z-Axis with the help of rack and pinion mechanism. More compact as well as light weight robot can be made by using different materials. Further implementation of Gripping Action will be carried out so as to achieve the desired functioning of the robot. Gripping action will be

achieved through pneumatic grippers. We can implement IoT control for the functioning of the robot. IoT enabled robot will help in maintaining the inventory of the industry. IoT enabled mechanism will also help in changing the co-ordinate of the robot with the help of android application. With the help of IoT based control the robot can be deployed in the applications in Industry 4.0.

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APPENDIX

A- CONFIRMATION LETTER

NR Tech Poly Plast LLP
No.797, Thiruvallur High Road, Andersanpet, Nemam, Chennai - 124.
Cell : 74017 46468 / 97866 77225 / E-mail : nrtechpolyplastllp@gmail.com

Dear Sir,

"Design and Development of Injection Moulding Removal Robot"

Along with the names of project members

1.Animesh Ghoshal (RA11611018010025)

2.Satyapalsinh Gohil (RA11611018010042)

3.Atif Akhtar (RA11611018010099)

4.Satyam Dudhagara (RA11611018010102)

We are willing to bare the cost for the design and development for this robot, This services develop in industry.

Thank you

NRTECH POLYPLAST LLP.

HRM.

INJECTION MOULDING TAKE OUT ROBOT

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