Development of Delta Robot for Pick and Place on Moving Conveyor

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Abstract— This paper deals with Development of 3-DOF Delta robot to pick and place a object from moving conveyor. The delta robot (a parallel arm robot) was invented in the early 1980s by a research team led by Professor Raymond Clavel at the Ecole Polytechnique Federale de Lausanne (EPFL, Switzerland). After a visit to a chocolate maker, a team member wanted to develop a robot to place pralines in their packages. The purpose of this new type of robot was to manipulate light and small objects at a very high speed, an industrial need at that time. The main idea of pick and place robot is to carry out the operations in minimum time and also be cost efficient. The project involves kinematic and dynamic modelling of the robot. The kinematic parameters, involving the lengths of the bicep and forearm, are calculated based on the work volume requirements and the dynamic parameters, involving the motor torque and speed. Delta robot is as an automatically controlled, reprogrammable, and multipurpose programmable in three or more axis. A Parallax system is developed to make a Delta robot pick and place parts on a moving conveyer. To achieve motion planning of the Delta robot under a control of stepper motor, forward and backward kinematics of the Delta arms is derived at first. Then, the stepper program is developed in PLC to perform the angular motion attached to the arms. Finally, product sensing and motion controller movements are integrated into one system to perform the pick and place of the products in the conveyor automatically.

Key words: Kinematics, Delta Robot, Mechatronics, Mechanical Systems, Parallel System, Pick-and-Place

I. INTRODUCTION

Parallel robots have advantages for many applications in the fields of robotics, such as rigidity, speed, low mobilemass and superior accuracy. However, the main drawback of parallel robots is their small workspace and often limited manipulability in certain areas of the space. Several research initiatives conducted in this domain, particularly those by Clavel, have led to innovative architectures such as the famous DELTA robot .The DELTA robot has attracted much attention in both academia and industry. The literature contains much information on the history and types of parallel robots. In general, the DELTA robot consists of an equilateral triangular base, with one arm (actuated via a ball joint) extending from each side. The small, triangular travelling plate is connected to each arm by a pair of parallelogram-shaped forearms. The key design feature is the use of parallelograms in the arms, which maintains the orientation of the end effecter, by contrast to Stewart platform that can change the orientation of its end effecter. Delta robots have popular usage in picking and packaging in factories because they can be quite fast, some executing up to 300 picks per minute.

II. SYSTEM DESIGN

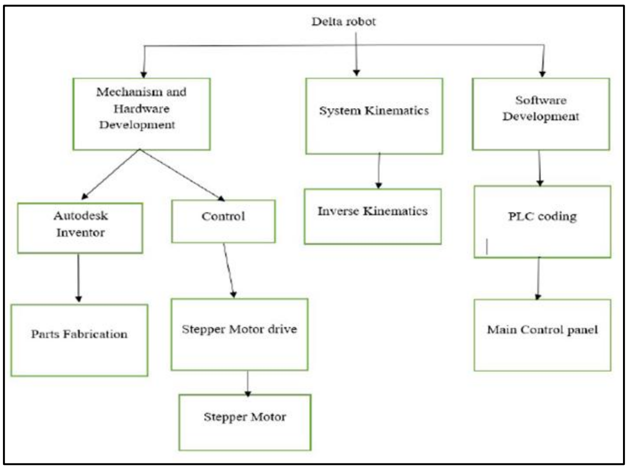


Fig. 1: System Architecture

The design of our project for Development of 3-DOF Delta Robot for pick and place an object shown above in the System Design. The planning of our project is done according to the available resources, hardware and software parts available. We have three units included Input, Process, and Output.

1) Input:

It includes AC power supply from MCB (miniature circuit breaker) to SMPS (Switch mode power supply), which converts high ac input supply to one or more lower voltage DC output. Input of pulses to the Stepper motor which is driven by stepper drives and controlled by PLC (Programmable Logic Controller).

2) Process:

Firstly we have to calculate inverse kinematic equation to find the position of end effecter depending upon that we will get the link length. After getting that we have to design the CAD model of our system. Now coming to the electronics part Stepper motor should be connected to Stepper motor driver, which is controlled by PLC. When digital data is fed to the motor driver then stepper motor start rotating as per the program. Now the rotation of stepper motors is depending on input from PLC ladder program in parameter of pulses. Depending on all this we will get the synchronization of three motors as per coordinates determined. Pneumatic suction pump with suction pad is used to hold a object in air, which is operated using 24V DC 3/2 solenoid valve.

3) Output:

Rotation of motor shaft as per required and effective synchronization of three motors will be achieved. So the end effecter will reach the desired position to pick and place the object

A. Mechanical System:

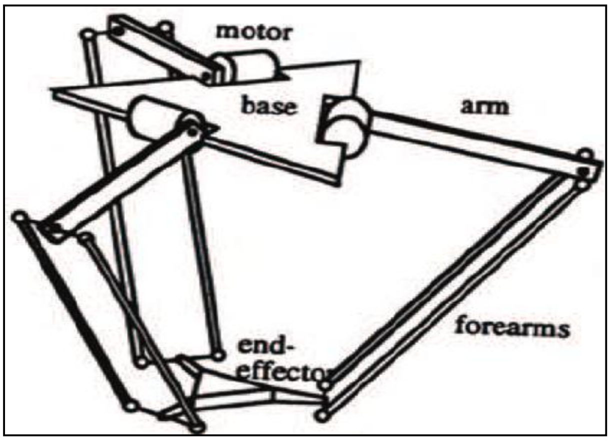


Fig. 2: Structure of delta robot

A mechanism of delta robot consists of forearms, biceps, ball joints, Base plate, L-Shaped clamps and end effecter. L-Shaped clamps are clamped on the base plate using mechanical fasteners. Motors are fitted into the L clamps. Biceps are fitted on the motor shaft using Allen headed bolt to prevent slip of biceps from shaft of motor. Using Ball joints and Pins, biceps is connected to the forearms. At the end all three forearms are attached to common triangular end effecter plate. Material used for base plate and L-shaped for mounting is MS(mild steel) and aluminium for forearms, biceps and end effecter for light weight structure which is carried by motor shaft. Weight ratio of base plate will be more with respect to structure of mechanism so it will damp the vibration

1) Stress Analysis:

Von Mises stress is a value used to determine if a given material will yield or fracture. It is mostly used for ductile materials, such as metals.

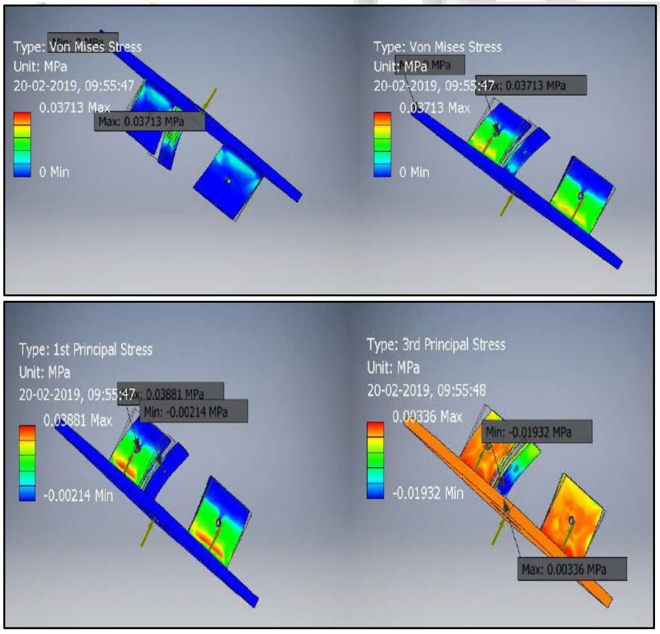


Fig. 3: 3D model of base plate with Von mises stress analysis

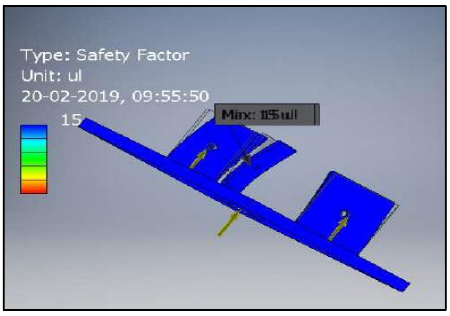


Fig. 4: Factor of Safety

Analysis by using MS plate we achieve more factor of safety that is of 15ul. Mass Density 7.85 g/cm^3, Yield Strength 207MPa

Ultimate Tensile Strength 345MPa, Stress Young's Modulus 220GPa, Poisson's Ratio 0.275ul, Shear Modulus 86.2745GPa.

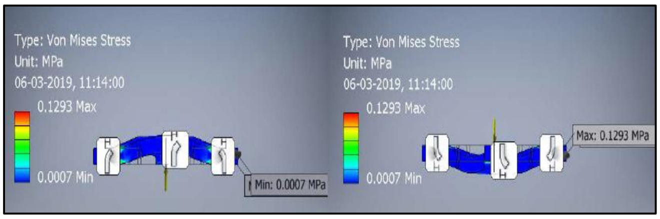


Fig 5: von mises stress analysis of end effecter

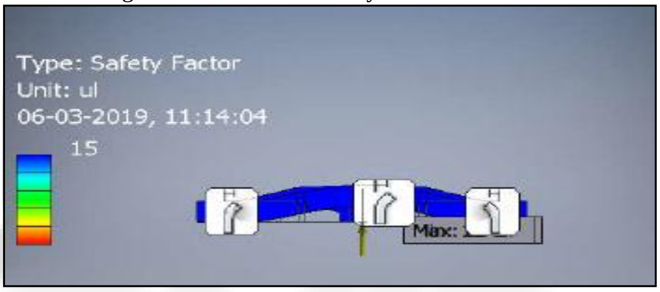


Fig. 6: Safety factor analysis of End effecter.

- FixedConstraint:1
- Reaction force -0.0075067N
- Reaction moment -0.00628488 N m
- Fixed Constraint:2
- Reaction force-4.89779 N
- Reaction moment- 0.0003362 N m

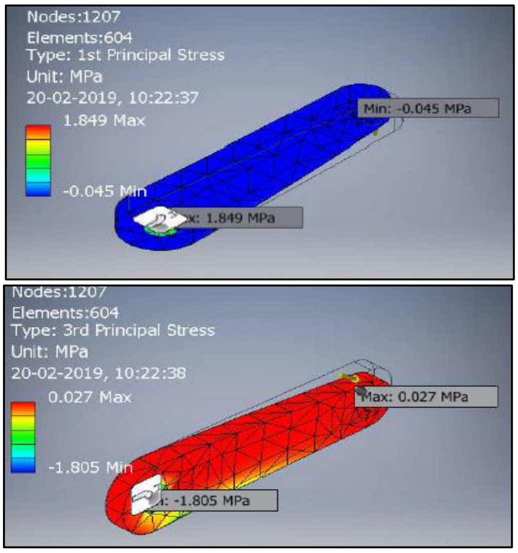


Fig. 7: Stress analysis on bicep.

Fig. 8: Fabricated parts using plasma cutting machine

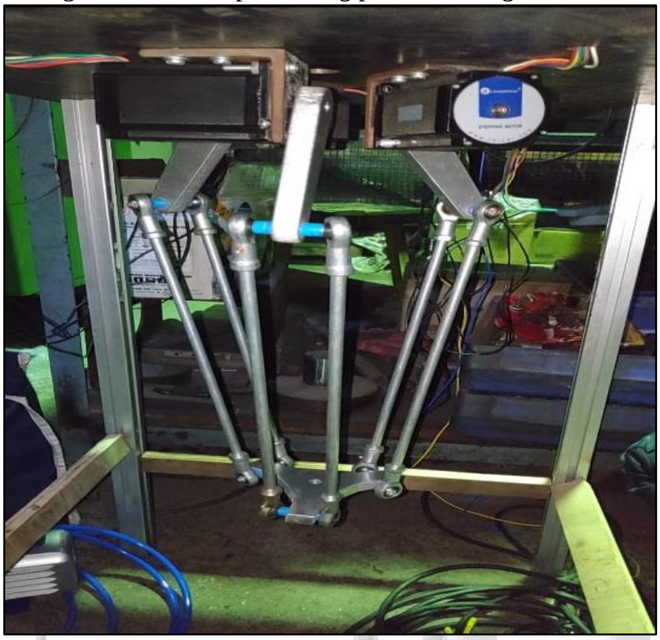


Fig. 9: Actual mechanical system

B. Electrical System:

Basically electrical system consists of PLC (delta dvp28sv series), Leadshine Stepper Motor, Leadshine stepper motor micro step drives, SMPS(230v ac input- 25v dc output), MCB(single and double phase), relays, 24v dc solenoid valve, power distributor module, resistors, jumpers wires, jumper wires.

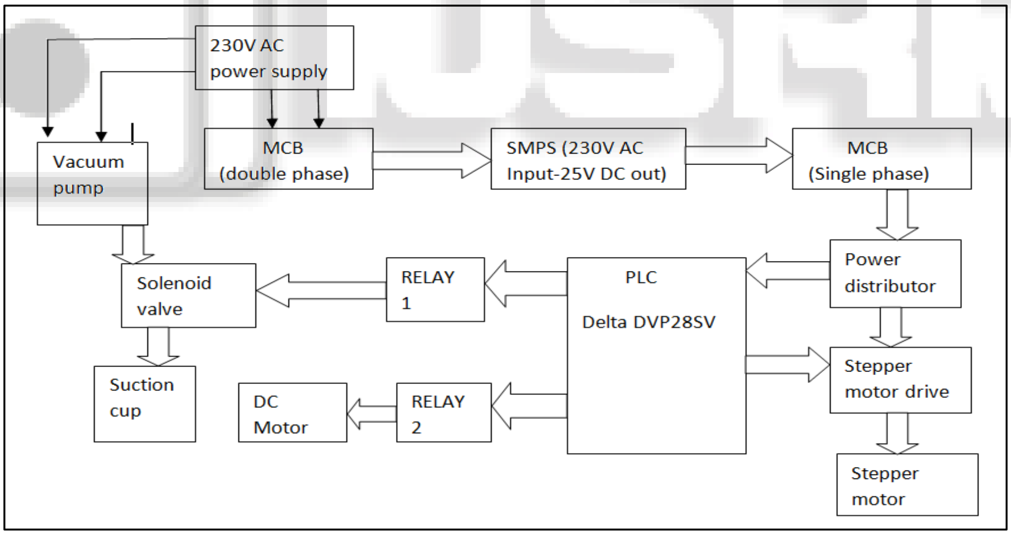


Fig. 10: Block diagram of control panel.

1) PLC

A programmable logic controller (PLC) is an industrial digital computer which has been ruggedized and adapted for the control of manufacturing processes, such as assembly lines, or robotic devices, or any activity that requires high reliability control and ease of programming and process fault diagnosis. The left-side parallel high-speed extension interface on SV series is able to connect to all kinds of network interface, e.g. Ethernet, Device Net, ProfiBus, analog and temperature modules for the demand of immediate control. 16 special extension modules (digital, analog, axis control, communication, etc.) are connectable to SV series (8 on the left and8 on the right).

2) Stepper motor:

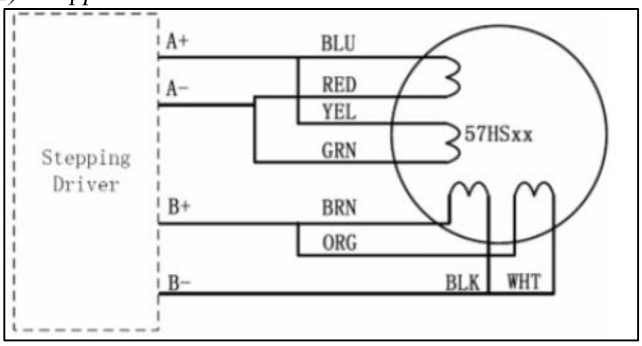


Fig. 11: Stepper motor to stepper drive parallel connection

An 8 lead motor in a parallel configuration offers a more stable, but lower torque at lower speeds. But because of the lower inductance, there will be higher torque at higher speeds.

3) Leadshine Stepper drive:

Leadshine offers a wide range of stepper drives which can satisfy requirements for most stepper motor controls. From 2 phase (4 phase) to 3 phase, 18-325 VDC to 90-230 VAC voltage input, simple step & direction control to I/O type control to CANopen/EtherCAT/RTX industrial network control , you can always find the right stepper drives for your stepper control systems.

4) Dynamic current setting

Default/Software configured (0.5 to 5.6A)

SW1 – OFF SW2 – OFF SW3 –OFF SW4 – ON (FULL 4A current)

5) Micro step resolution selection:

The motor precision. 1.8 deg steppers are 200 steps per turn. At 1/16th microstepping that's 3200 steps per turn. SW5 – ON, SW6-ON, SW7-OFF, SW8-ON.

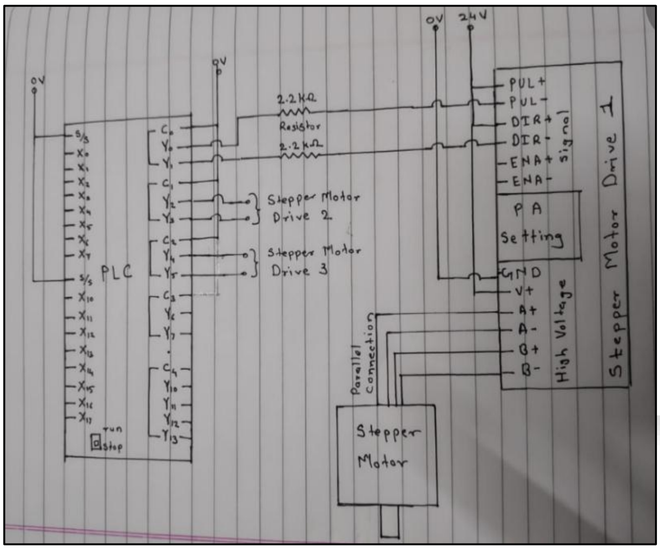


Fig. 12: PLC to stepper motor connections

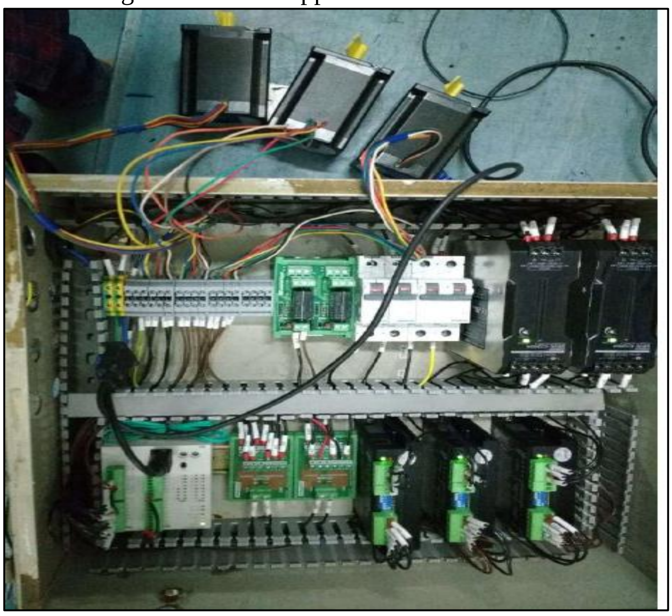


Fig. 13: Actual Interfacing of control panel with stepper motor

6) Inverse Kinematics on Marginally clever delta robot online simulation:

Marginally clever delta robot online simulation is a 3D Model Based Robotics Learning Software. It has been developed to help the faculty to teach and students to learn the concepts of Robotics. This site is useful to calculate the length of arms, biceps according to workspace. It helps to find out the degree of rotation of stepper motor shaft to reach at specific position.

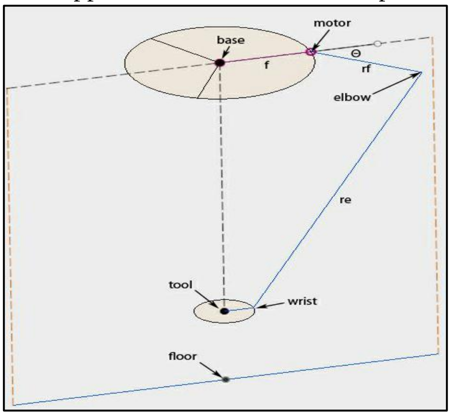


Fig. 14: Robot mechanism dimensions

Workspace is calculated by putting dimension of mechanism, which is approximately calculated from -78.5mm to +78.5mm in X and Y direction.

Base radius (f)	65	mm
Bicep length (rf)	100.0	mm
Forearm length (re)	300.0	mm
End Effector radius (e)	50	mm
Base to floor distance (b)	480.0	mm
Steps per turn	3200	
Rectangular cuboid envelope	X=-78.525 to 78.525 mm Y=-78.525 to 78.525 mm Z=-378.49 to -221.44 mm	
motor angle limits	theta 1=-42.92 to 92.23 theta 2=-48.52 to 92.31 theta 3=-48.52 to 92.31	
Center	(0,0,-299.965)	
Home	(0,0,-281.274)	
Resolution	+/-0.353mm	

Fig. 15: Workspace calculation

C. Calculation of degree change of shaft position.

Forward Kinematics: Change motor angles to see new XYZ position. Inverse Kinematics: Change XYZ to see new angles.

We are using Inverse kinematics, one position is set to pick an object and second position to place an object on running conveyor

.0 degrees is when the bicep is horizontal to the floor

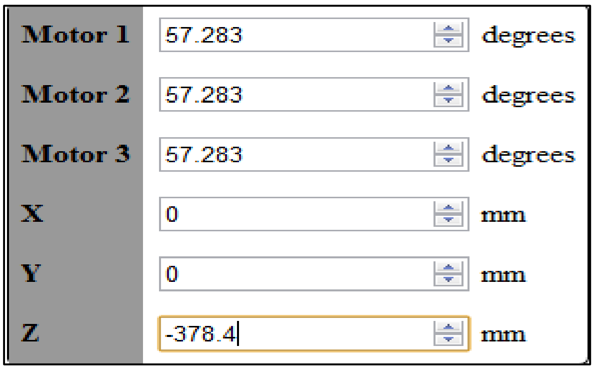


Fig. 16: set to home position

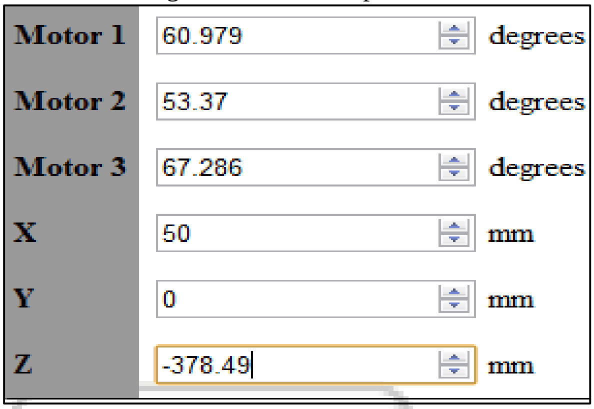
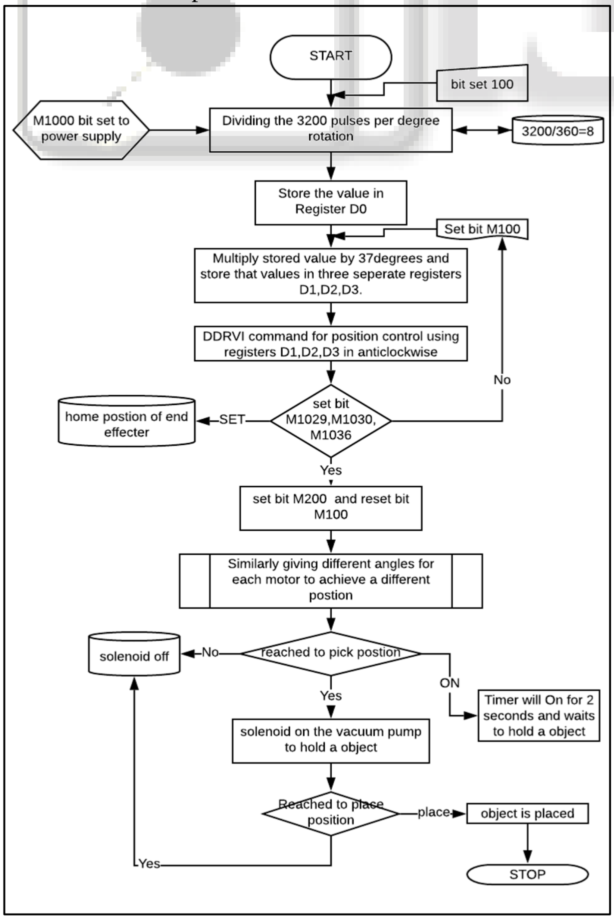


Fig. 17: New position in X-axis

Similarly we can achieve any position by putting desired coordinates. We will get the all three motors angular position .then this values will be entered in PLC ladder logic where the actual implementation is done.



III. System Working

In our system a simple application of pick and place an object from one position to another is done. Object might be anything like coins, rectangular packets, biscuits, chocolates etc. Sensing of object is done by a sensor on the moving conveyor. As it detects the object, linkage mechanism i.e. end effectors will reach to the position by angular position control of stepper motor according to pulses given to it. This pulse varies the angular position uses PLC ladder logic, positioned to the place of sensed object. Position control is achieved by developed plc program using WPL soft delta software. After reaching to pick position, vacuum suction pump gets started by 24V solenoid valve. A Suction Pad is attached to the center of end effecter which will suck the object and hold the object in air. Then after end effecter will go to the other position according to the command given by plc, where the object is to be placed . Vacuum suction stops after reaching to the placing position. This causes object is release from gripping section and placed in moving rack.

IV. Conclusion

We have successfully designed type of pick and place robot called as DELTA robot capable of carrying 1kg payload, achieving a cycle rate of cycles per minute covering a work volume of 100x100x100 mm3. The kinematics and the dynamics of the delta robot were studied and the model was developed. The kinematic and dynamic analyses were done to meet the work volume and cycle time requirements respectively. Most of the mechanical parts were fabricated within the industry itself except for a few parts like carbon fibre tubes for the suction which will be procured from other manufacturers. The electrical part of the robot will include stepper motors and drives and the control system used to run them in an accurate and synchronized manner. Programmable Logic Controller is used as a control system which will synchronize the all three motors for application. The control system has been decided to be a PLC provided by the industry. The control algorithm is developed in WPL soft delta plc software.

V. Future Scope

The future work involves integrating the mechanical system with the control system and programming the system for a particular application. Our main focus to develop this project to design a delta robot for packaging and production system having minimum cost and maximum efficiency. They're certainly becoming a main stream alternative for high speed picking and placing applications. It was that for the longest time we were limited to slower articulated arm technology or slightly faster SCARA technology, and now with Delta robots we're able to get the heavy components up in the air, onto a super structure, and really increase speed because in many cases we're moving much less mass. "So, they're great for when you've got to go fast. In extension to this using vision camera increases the preciseness of object tracking. 3D printing is achieved by using vision camera and dedicated controllers of delta.

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