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Development of an IOT based Delta Robot for Industrial Application

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Abstract

A Delta Robot has been designed and developed for faster sorting, picking and placing different objects from a moving conveyer used in production line in different industries. Because of its configuration delta robot is one of the fastest industrial robot, for this reason it is used for different commercial applications. A relatively cheaper delta robot is developed, which can serve for industrial applications. It has three degrees of freedom configuration and can be used for very high speed pick & place operations along with color sensing for sorting, picking and placing of products. Inclusion of IOT system is another added feature of this system. For this feature this robot is capable of collecting various information regarding the products and sending these information to the central server. The structural analysis of various parts and assembly was done using analysis software ANSYS 15. Based on this design, the fabrication of the device is done, the controller for the operation of the robot as well as for IOT system is developed.

Keywords : Delta robot, High speed operation, Production line, Structural analysis, IOT system.

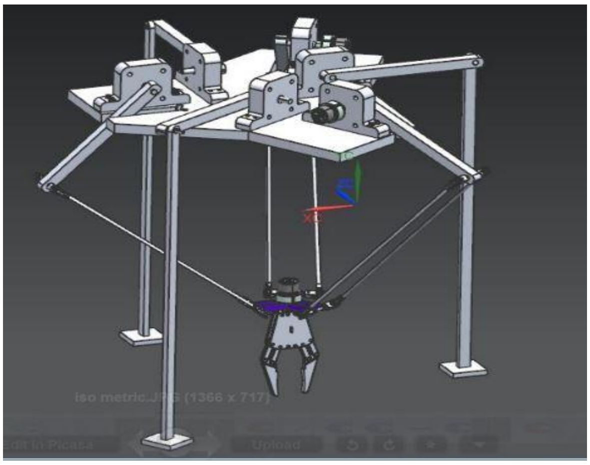
1. Introduction

An industrial robot is defined by ISO 8373 as an automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axis. Industrial robots have been used for a wide range of applications including pick and place, painting, assembly, product inspection, quality control and testing. The earliest known industrial robot, conforming to the ISO definition was completed by Griffith P. Taylor in 1937 and published in Meccano Magazine, March 1938. The first company to produce a robot was Animation, founded by Devol and Joseph F. Engel berger in 1956. In 1969 Victor Scheinman at Stanford University invented the Stanford arm, an all electric, 6-axis articulated robot designed to permit an arm solution. In 1981,Sankyo Seiki, Pentel and NEC presented the SCARA robot, a completely new concept for assembly robots. The delta robot was invented in the early 1980s by a research team led by Professor Reymond Clavel for manipulation of light and small objects at a very high speed. The delta robot has undergone various transformations in the past few decades and it is one of the most efficient solutions for industrial pick and place applications. R. Clavel [1] discusses about the basic structure and working of the delta robot. André Olsson [2] has framed the forward and inverse geometric kinematic model for the delta robot, the velocity and acceleration kinematic model and the dynamic model of the delta robot using the conventional approach for solving the dynamics of the parallel manipulators. Alain Codourey [3] has framed the velocity and acceleration kinematic model for the delta robot. M Lopez, E Castillo, G Garcia, and A Bashir [4] have formulated the inverse, direct, intermediate Jacobians for the Delta robot.

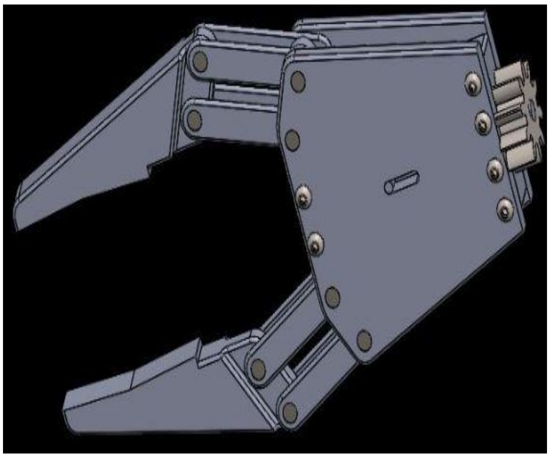
2. Design & Construction

A. Description of the apparatus

Delta Robot is a parallel 3 DOF robot designed by Professor Raymond Clavel for realizing very high speed pick and place operations. The basic advantages of the delta robot conform to that of the parallel robot. The basic structure of the delta robot is explained with the help of Figure. The delta robot consists of two platforms: the upper one with three motors mounted on it, and smaller one with an end effectors. The platforms are connected through three arms with parallelograms. The parallelograms restrain the orientation of the lower platform to be parallel to the working surface (table, conveyor belt and so on). The motors set the position of the arms and, thereby, the XYZ position of the end effectors, while the fourth motor is used for rotation of the end effectors.



Fig,1: Delta Robot



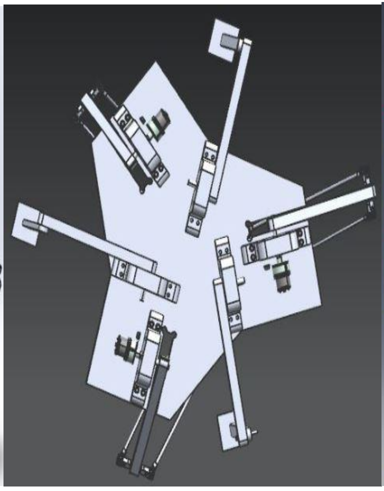
Fig,2: Gripper

B. Mechanical design of delta Robot

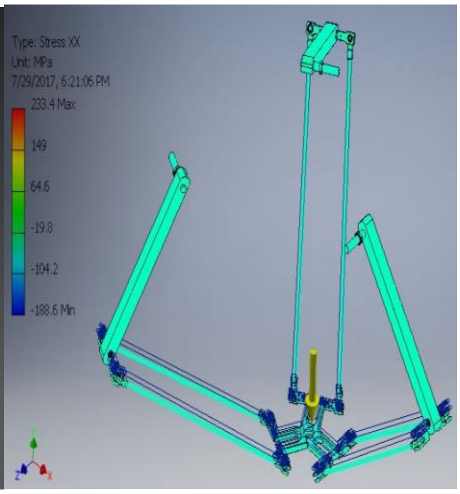
The mechanical design involves the design of the various subassemblies and mechanisms within the system such as the Top plate, Arms structure, gripper and the traveling plate.

Top plate holds the motor and gear box and acts as a support structure. Arms structure holds the traveling plate and positions it at the desired position. Gripper pick & place the object. Traveling plate holds the gripper.

Fig, 3: Arms Structure



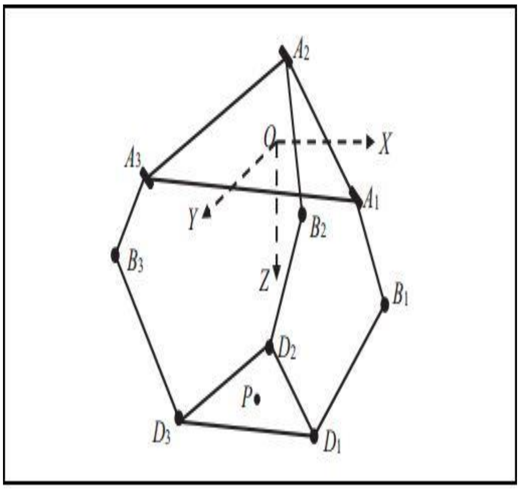
Fig, 4: Top Plate



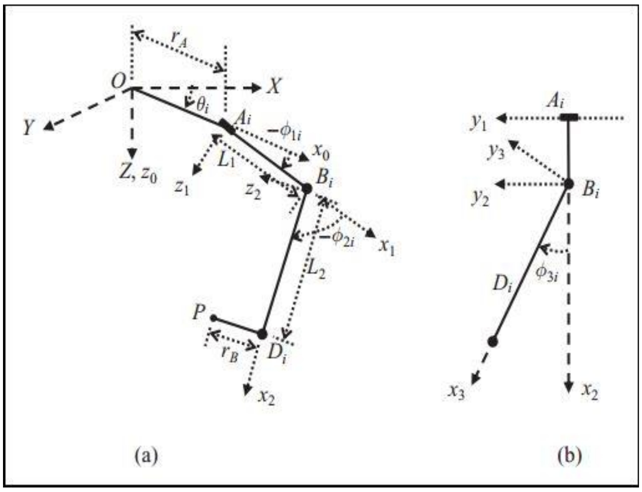
Fig, 5: Stress Simulation in xx direction

3. Kinematics of Delta Robot

A Delta robot consists of three kinematic chains, and each chain consists of two links (AiBi and BiDi, where i =1, 2, 3, see Figure 6). Each chain links a fixed base (triangle $A_1A_2A_3$) and a moving platform (or called an end effector, triangle $D_1D_2D_3$), where three motors are mounted at points Ai to drive links AiBi. A coordinate system is defined on the fixed base, and the origin is located at its center, where the X-axis is arbitrarily defined on the base, the Z-axis is downward and perpendicular to the base, and the Y-axis is orthogonal to the X- and Z-axes. Thus, the motion of the end effector is driven by the three motors through the three kinematic chains, and the end effector has the 3-DOF translating motions. Based on the geometry of the Delta robot, each point Ai has 1-DOF rotating motions, and each points Bi and Di have 2-DOF rotating motions.



Fig,6 : Schematic diagram of a Delta robot



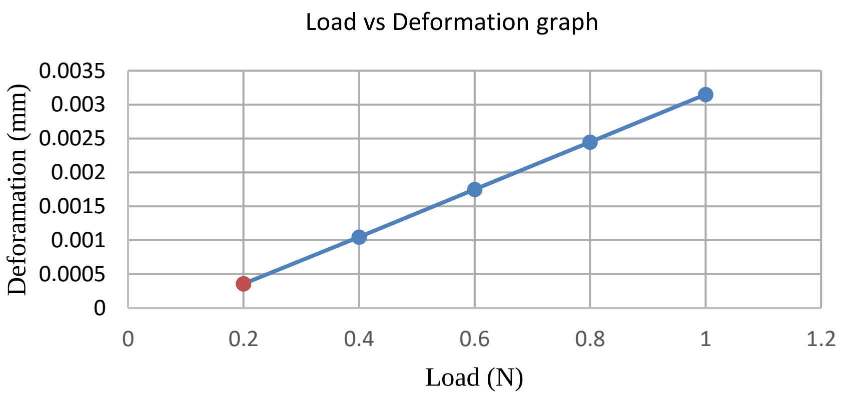
Fig,7 : Kinematic Chain from a 3-D view and (b) on the x–y plane.

Based on the geometry of the delta robot, the position of point P at end effector with respect to the XYZ coordinate is written as,

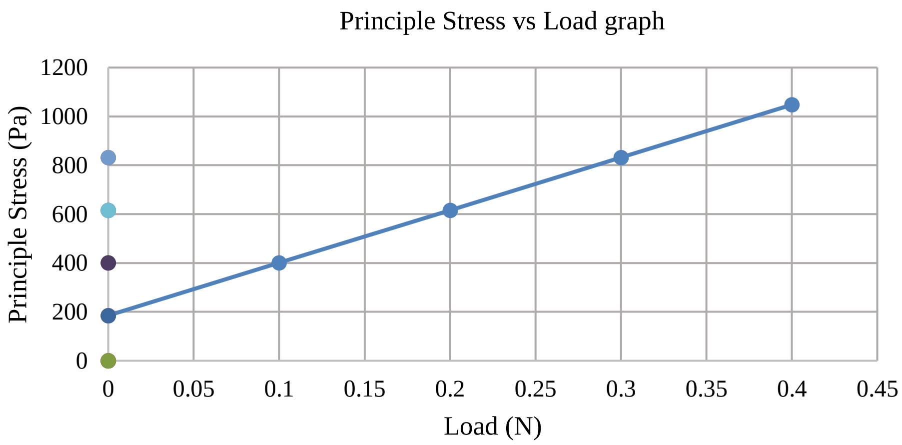
$$\begin{bmatrix} X_p \\ Y_p \\ Z_p \end{bmatrix} = \begin{bmatrix} \cos\theta_i (r_A - r_B) + L_1 \cos\emptyset_{1i} + L_2 \cos(\emptyset_{1i} + \emptyset_{2i}) \cos\emptyset_{3i}) - L_2 \sin\theta_i \sin\emptyset_{3i} \\ \sin\theta_i (r_A - r_B + L_1 \cos\emptyset_{1i} + L_2 \cos(\emptyset_{1i} + \emptyset_{2i}) \cos\emptyset_{3i}) + L_2 \sin\theta_i \cos\emptyset_{3i} \\ L_1 \sin\emptyset_{1i} + L_2 \sin(\emptyset_{1i} + \emptyset_{2i}) \cos\emptyset_{3i}) \end{bmatrix}, \text{(i=1,2.3)}$$

4. Structural Analysis

It is the analysis of trajectories and dynamic optimization of a delta-type parallel robot, based on dynamic structural analysis. This analysis enables optimization of the robot as to materials, geometry, mass, and selection of actuators. The result is more economic and efficient structures that will meet desired operation specifications. The simulation models used two simulation software programs: a computer-assisted design program named Inventor professional and a finite element analysis program named ANSYS 15. These two simulation programs work together because of their special features, idea for design and analysis of mobile structures like robots, allowing simulation of engineering designs, assessment of their features, properties, feasibility, and profitability, and also optimization of their development and subsequent production costs. The tool Flexible Dynamic ANSYS 15.0 allows definition of the loads intervening in the dynamic analysis of the simulation model. In the case of the delta robot, the load share the angular displacements of the three motors and the force of gravity. Gripper simulation-This simulation consists of stress analysis, fatigue analysis, total deformation, safety factor, life, maximum principal shear stress, maximum shear stress, principal elastic strain etc.

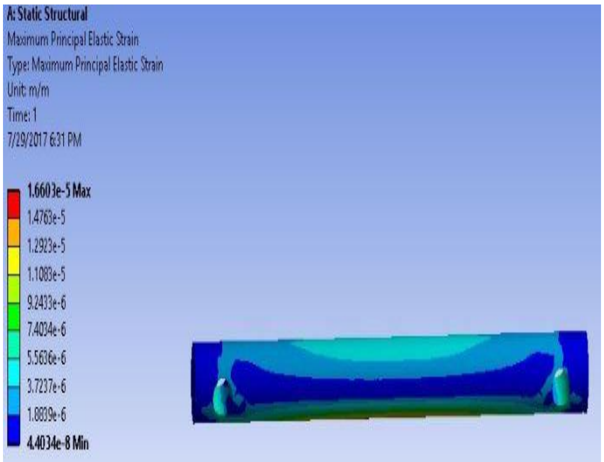


Fig,8: Load vs Deformation Graph

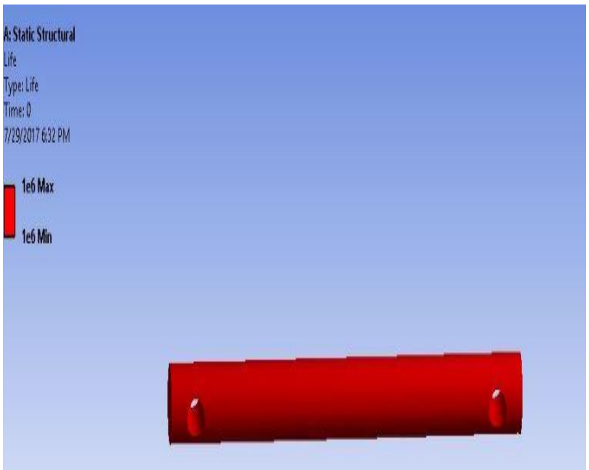


Fig,9: Principal Stress vs Load Graph

C. Linkage simulation- This simulation consists of stress analysis, total deformation, safety factor, life, maximum principal shear stress, maximum shear stress, principal elastic strain etc.



Fig,10: Max. Principal Stress

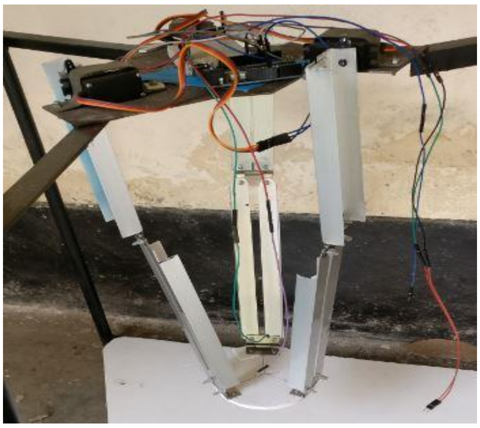


Fig,11: Life

5. Construction

In the design methodology proposed, selection of materials will be conducted by varying the construction material of theoretical piece and by means of stress analysis, so as to find the type of material that most efficiently meets operation specifications. For this analysis, aluminum and structural steel are used as study materials. There is a top plate constructed by Steel sheet, three motors mounted on it. There is also a arms structure constructed by Aluminium sheet. There is also a moving plate constructed by plastic wood which holds the gripper. Only one motor is mounted on the gripper.

Fig, 12: Top Plate



Fig, 13: Delta Robot by Aluminium & Steel Sheet

6. Working Methodology:

The design process of this robot proposed in this work will be completely performed in a Solid works Software & Inventor professional, where the robot will be simulated and actuated considering some of the elements found in commercially available or in other research works. After the design & evaluation process, each elements of the robot is manufactured by hand tools, machining process. Finally the assembly of the parts, the integration of sensors, mounting of servo motors with the main board & programming those ones are going to be carried out. Then, its parallel configuration used for very high speed pick & place operations capable of achieving at a high cycle rate along with Color sensing by color sensor which can detect any number of colours with proper programming & IOT system which provides number of specific color objects from the hardware to user.

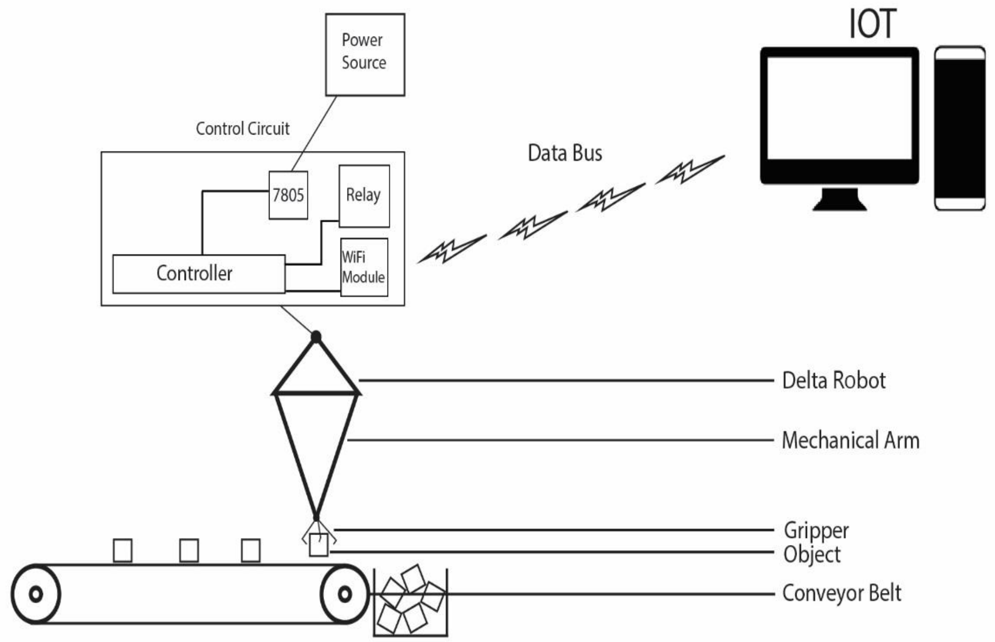


Figure No 14 : Schematic Diagram of a IOT Based Delta Robot

Table 4.1 : Comparison of speed between Robotic gripper & Delta robot

Objects	Weight(gm)	Time required for Pick& Place by gripper (Second)	Time required for Pick & Place by Delta Robot (Second)
Rubik,s cube	64	24	18
Body Spray	43	28	20
Coke can	250	25	19

Sorting objects by Colour Sensor:

The robot is intended to use a sensor colour to identify objects and classify them according to its colour. TCS3200 is a colour sensor which can detect any number of colours with proper programming. Each sensor array is selected separately depending on requirement. Hence, it is known as a programmable sensor. The module can be featured to sense a particular colour and to ignore the others.[5]

7. Internet of things (IOT system)

The Internet of Things (IOT) is expected to offer promising solutions to transform the operation and role of many existing industrial systems such as transportation systems and manufacturing systems.[6]. Commonly accepted definition for IOT is a dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual 'Things' have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network [7] [8]. In this project this robot is capable of collecting various information regarding the products and sending these information to the central server.

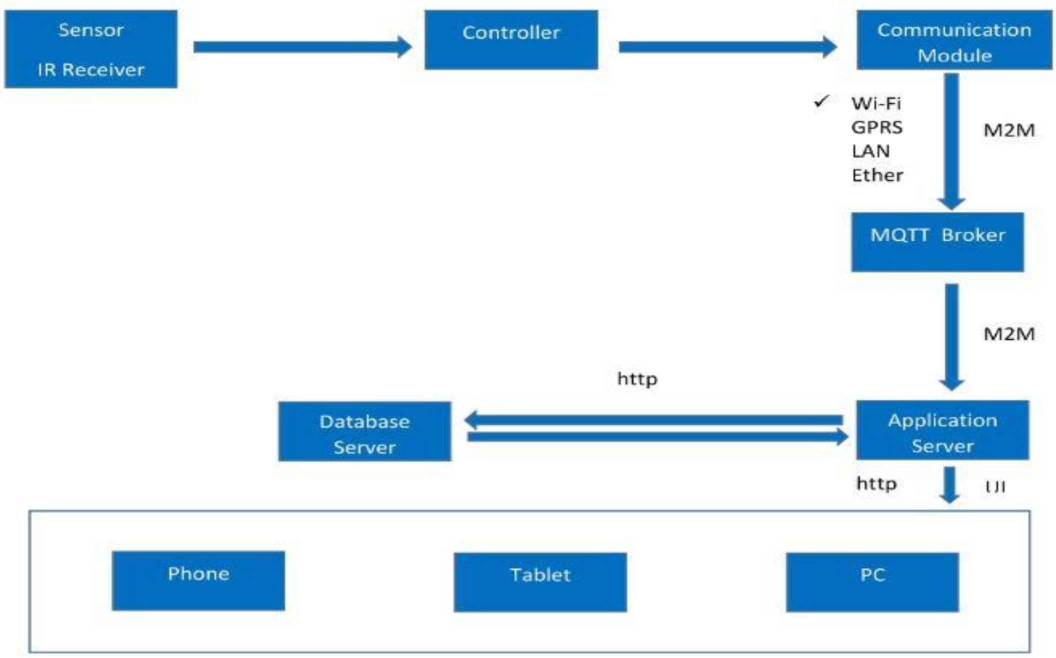


Fig. 15: Block Diagram Of IOT system

Conclusion:

This paper illustrates the development of a delta robot for faster sorting, picking and placing different objects from a moving conveyer used in production line in different industries. The simulation for designing the robot structure was carried out with design software. Based on that design the fabrication of the device was carried out. Automatic detecting and picking system for sorting objects was done. IOT system for acquiring data from real environment and sending it to the central server for monitoring and control was also carried out.

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