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Design and Development of Multipurpose Delta Robot

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Abstract: This report represents an designing and simulating ideal pick and place robot which should carry out the operations in minimum time and should also be cost efficient. It is four degrees of freedom parallel configuration used for very high speed pick and place operations. The objectives of this report are designing a Delta robot capable of carrying 1kg payload, achieving a cycle rate of 120 cycles per minute covering a work volume of 400x300x200 mm3. The project involves Kinematic & Dynamic modeling of the robot for the above specifications. 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, are calculated based on the maximum acceleration requirements and the inertia of the system. The project further involves the structural analysis of the robot which deals with the proper sizing of the mechanical structure which should be capable of withstanding the high torque and acceleration required for smooth and fast motion. The future work involves integrating the mechanical system with the control system and programming the system for a particular application.

I. INTRODUCTION

Parallel robots have advantages for many applications in the fields of robotics, such as rigidity, speed, low mobile mass 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 factory.

A. Kinematics Of The Robot

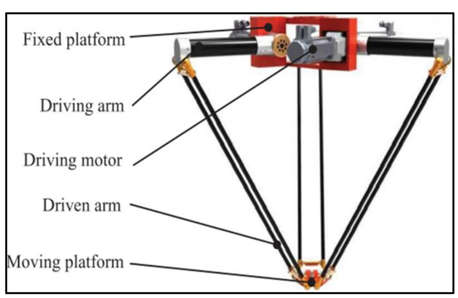

Fig. 1 Kinematics of Robot

The Delta robot consists of a moving platform connected to a fixed base through three parallel kinematic chains. Each chain contains a rotational joint activated by actuators in the base platform. The movements are transmitted to the mobile platform through parallelograms formed by bars and spherical joints.

Forward kinematics involves the computational method to identify the configuration of the robot in Cartesian space while specifying the joint space parameters.

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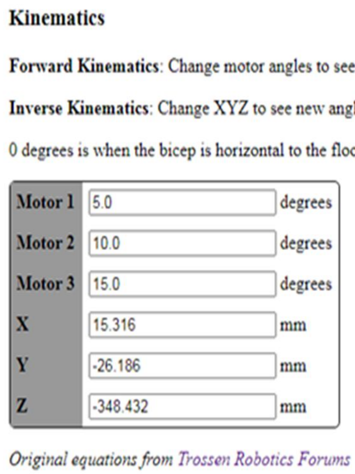

B. Design

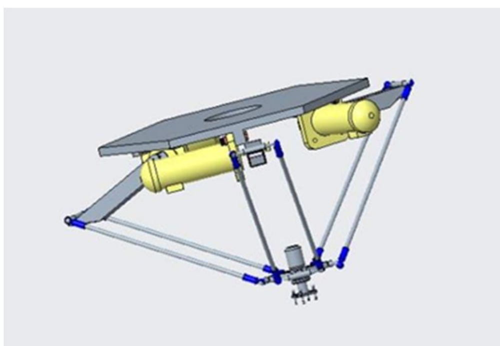
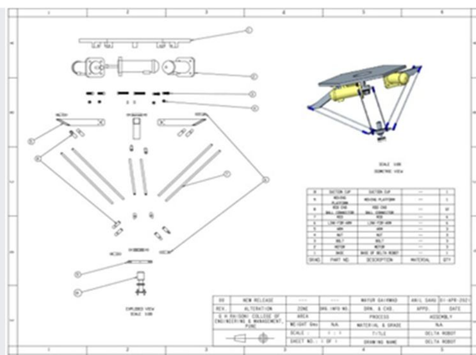

Fig. 2 CAD model Fig. 3 CAD Model

C. Material Used

The materials selected for the manufacturing of the body is:

1) Mild Steel (grade 250)

2) Aluminium

Because the Acrylic material is very difficult to be get modelled as the cylindrical one. Thus it has been rejected. The cubical base frame is manufactured using the Mild Steel and the other parts like the upper plate, lower plate, distal link, parallelogram link and the gripper will be manufactured by using the Aluminium with less strength. The material has been selected based on the yield strength of the material (193MPa).

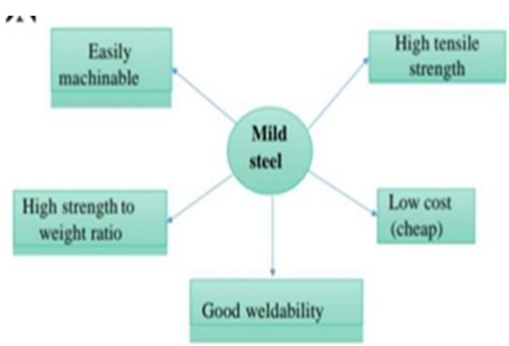

Fig. 4 Material Properties

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D. Work Volume Analysis

The desired work volume is usually described in terms of maximum reach diameter of the delta robot which was decided to be 600 mm.Optimized Input kinematic parameters for the desired work volume:

- Bicep length = 194.70mm
- Forearm length = 388.66 mm
- Base triangle side length = 173.32 mm
- End effecter triangle side length = 53.72mm
- Ball joint pivot angle range = +/- 60 degrees

Motor axis revolute joint restriction = - 60 to +130 degrees

Base radius (f)	173.32 mm	Distance from center of machine base to center of each motor shaft. More than likely this is the middle of the side of a triangle, NOT the corner.
Bicep length (rf)	194.79 mm	Distance from motor shaft to elbow
Forearm length (re)	388.66 mm	Distrance from elbow to the wrist
End Effector radius (e)	53.73 mm	Distance from wrists to the center of the hand
Base to floor distance (b)	400.0 mm	As described
Steps per turn	3200	The motor precision. 1.8 deg steppers are 200 steps per turn. At 1/16th microstepping that's 3200 steps per turn.
Rectangular cuboid envelope	X=-104.614 to 104.614 mm Y=-104.614 to 104.614 mm Z=-400 to -190.771 mm	How big a box can the end effector reach? (end effector can actually move more than this)
motor angle limits	theta 1=-70.41 to 47.07 theta 2=-77.59 to 51.84 theta 3=-77.59 to 51.84	How must the motors turn to move throughout the rectangular cuboid?
Center	(0,0,-295.386)	Where is the middle of the envelope relative to the base (0,0,0)?
Home	(0,0,-313.803)	Where is the tool when the arms are parallel to the floor?
Resolution	+/-0.349mm	How precise can the movements be?

Fig. 5 Work Volume Analysis

E. 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 metal

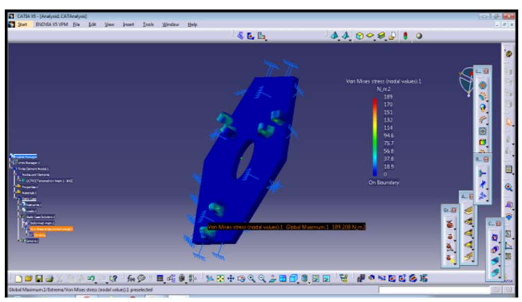

Fig. 6 Stress Analysis

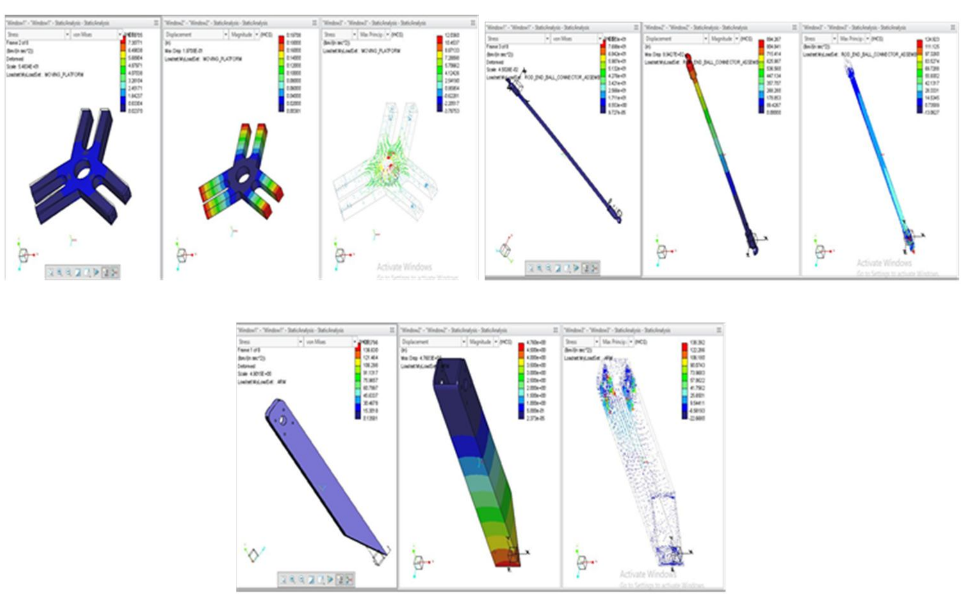

Fig. 7 Stress Analysis

F. Weight Calculation

From the cad model the calculation of the mass have been done
Weight of the body = 4.5kg
Weight of the base frame = 2.3kg
Weight of the distal joint = .5kg
Weight of the parallelogram joint = .6kg
Weight of the servo gripper = .35kg
Weight of the servo motor = .75kg
Maximum Payload of the robot = 0.3kg
The total weight that the motor have to lift = 2/3kg
A motor has to lift = 0.667 kg

G. Motor Selection

Since the delta robot has been used for accurate picking and placing of the object, the perfect motor for the operations is SERVOMOTOR. A servomotor is a rotary actuator that allows for precise control of angular position, velocity and acceleration. It consists of a suitable motor coupled to a sensor for position feedback. It also requires a relatively sophisticated controller, often a dedicated module designed specifically for use with servomotors. Servomotors are not a specific class of motor although the term servomotor is often used to refer to a motor suitable for use in a closed-loop control system.

Servo motor should be connected with some microcontroller in order to make it actuated. In the microcontroller a program will be incorporated to actuate the servomotor, in between the there is a need of motor driver circuit to make the connection of the servomotors with the microcontroller. Through the motor driver circuit the servo motor is controlled as well as drove in accordance with our need. The connection of the motor with the microcontroller can be given by:

Fig. 8 Servomotor

H. Suction Cups

The self-sealing suction cups have been incorporated in robots to improve their passive grasping capabilities. Due to the design of the suction cups, a central vacuum source can be used to effectively generate suction force from the cups and reduce the number of actuators and sensors for the robot.

Researchers from ARL designed and developed a three-finger hand actuator system using a 3D printer in order for the robot to properly utilize the self-sealing suction cups. Four suction cups run along the bottom of each finger, which contains a narrow vacuum channel running through the center. A central vacuum pump serves to power the suction cups and facilitate grasping. The fingers can also curl around the object to better grasp it and release any object in its hold by feeding back the output of the vacuum pump and emitting a burst of positive pressure.

The three-finger hand has been used by aerial systems and has demonstrated considerable success in grasping objects on the ground while maintaining flight. According to ARL researchers, the self-sealing suction cups may exhibit higher rates of success underwater due to the extra pressure from the sea depths surrounding and pressing against the object and grasper.[5] However, they noted that an underwater environment would require different manufacturing materials that would allow the suction cups to perform well in salt water, such as a thermal plastic.

Fig 9. Suction Cup

I. Economic Consideration

One of the biggest challenges when implementing this system was the economic impact of both building it and keeping it in operation. Since this robot will be used as a learning tool, it was necessary to keep costs to a minimum while still create a robust, effective system. For this reason many of the parts were custom machined out of stock or scrap metal. The most expensive components are the motors and motor controllers which were donated. Although the robot was successfully built for approximately Around RS. 1,10,000/- the cost of operation and maintenance is still a significant concern. these costs include electrical costs to power and use the robot as well as repair costs for any damaged components. Although this robot poses economic concerns. But in this project we analyzing and designing the delta robot so here adding the costing of manufacturing also And due to this our cost will be minimize.

II. CONCLUSION

To design a marketable product which could be offered for applications in industry?

The future work is to realize the robot in its physical form. In order to realize the robot in its physical form, a lot of material procurement is to be done and then the work will be to integrate the electrical and mechanical systems together and provide the end user with an easy-to-use user interface. The mechanical parts are likely to be fabricated within the industry and the electrical parts are to be optimally chosen and procured. Most of the mechanical parts will be fabricated within the industry itself except for a few parts like carbon fiber tubes for the arms which will be procured from other manufacturers. The electrical part of the robot will include servo motors and drives and the control system used to run them in an accurate and synchronized manner.

This robot is ideal to automate tasks which so far have been too fast and too complex for robots. It is also possible to support intelligent functions using Computer Vision System (iRVision). In this project we analysing and desiging the delta robot.

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