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Design and Analysis of Pick and Place Robot

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Abstract:
Robots are springing up everywhere like mushrooms having found a steady hold in the production industry. Not only do they increase the productivity and efficiency of the system, but they also improve the accuracy and the uniformity of the products. They are a sign of an ever developing technology. One of the most important indications would be the industrial pick and place robot. The main objectives of this project are to design and implement a 5-DOF pick and place robotic arm. This project can be operational in controlling, stating with simple tasks such as gripping, lifting, placing and releasing. This pick and place robot is designed by using SOLIDWORKS18 software and fabricated by using 3D-printing technology.3D-printed models are assembled with servo motors and connected with Arduino and Bluetooth module. Using Bluetooth module, arm is controlled using smartphone. The gripper should be analyzed to calculate the stress and deformation that occurs, in which the structural analysis of the gripper using the finite element method is performed.

Keywords:3D-Printing, Arduino, SOLIDWORKS 18, Servo motor, Bluetooth module.

1. INTRODUCTION

3D-Printed Pick and place robot is an emerging sector in both robotics and mechatronics, gaining momentum through its use of flexible materials in replacement of currently deployed hard, rigid metals. This pick and place robot aims at eliminating a number of issues related to the use of current robotics in industry. First and foremost, soft robots are much safer than current robots due to their lighter weight and softer materials rapidly and cheaply in comparison to rigid robots. Soft robots require the creation of a design and the purchase of cheaper materials such as Arduino, Servo motors, Bluetooth module, Screw, Bolt and nuts, etc,. 3D-Printed Pick and place robot is a young and developing industry, because it is so new. These robots largely function in the food packaging industries, utilizing anywhere from 2 fingers to pick and place objects such as circuit boards, water bottles, and even small retail products. In this project summarizes the design, fabrication and analysis processes of the pick and place robot. The end product is then used in picking and place of several products in the industry like other machines. Due to some technology developments we decided to modify the material for entire pick and place robot throughout the fabrication process. The pick and place robot is designed in the Solid works 18software. Ergonomics is also considered as one of the most important design aspect. Analysis of the final CAD model is done on ANSYS WORKBENCH 14.0. Different load cases are considered during finite element analysis to ensure that the gripper assembly can endure the forces acting during the gripper motion.

2. PICK AND PLACE ROBOT

Pick and place robotic arm is a system which can be designed in many different ways according to its applications. They heavily depend on joints, which are used to join or connect the two consecutive bodies in the robot and can be rotary joint. Joints define the movement of the arm.Armdecide the degree of freedom of the components. Consequently all robotic arm consists of following basic components.

- Controller
- Manipulator
- Grippers
- Power source

DESIGN OF PICK AND PLACE ROBOT

The mechanical construction in this project is to build and assemble the robotic arm body. After giving a thorough consideration of all the preceding works in this field, a five degree of freedom manipulator having variable programmed motions to carry out variety of tasks in diverse environments is chosen. This is a five-axis manipulator designed to pick and place objects like chips, memory cards, processors, etc.

It is driven by six servomotors and has a gripper as end-effectors. The gripper has two fingers grasping and manipulation of objects as big as a 150 ml cylindrical bottle and having a weight of about 150 gm throughout the arm's workspace.

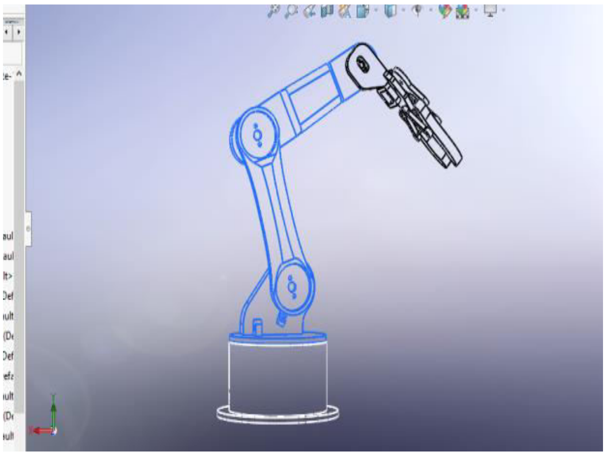
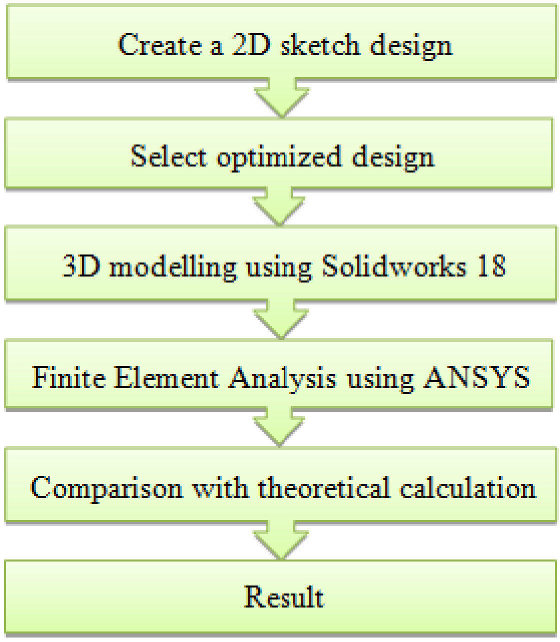


Figure.2.1 Design of pick and place robot

DESIGN METHODOLOGY



The methodology has been followed to the frame in Solidworks and analysis it in the ANALSYS software. The theoretical values are calculated and compared with actual values.

3.MATERIALSSELECTION

There are two most common materials used in this process are plastics called Acrylonitrile Butadiene Styrene (ABS) and Polylactic Acid (PLA). Acrylonitrile butadiene styrene(ABS) – it is a common thermoplastic polymer material. Its glass transition temperature is approximately 105 °C (221 °F)

Density: 0.9 g/cm^3 – 1.53 g/cm^3

Poly or polylactic acid or polylactide is a biodegradable and bioactive thermoplastic aliphatic polyester, which is derived from renewable biomass, it is typically from fermented plant starch such as from corn, sugarcane.

Density:1.210–1.430 g·cm^{-3}

The material used for fabricating the pick and place robot is ABS.

4.SPECIFICATIONS OF ROBOT ARM

This robot arm is a revolute type that intently looks like the human arm. Shoulder or midriff that mounted on the base which can move the arm upto 180 degrees, it tends to be turned from level to vertical on each side.

The shoulder utilizes extensive scale servo, give the torque expected to lift the remainder of the arm, just as any item that it might get a handle on. Joined to the shoulder piece is an elbow that can travel through 180 degrees, likewise controlled by an expansive scale servo. The wrist is comprised of one standard servo and can travel through 180 degrees, in vertical heading. Connected to the wrist is a two-fingered gripper that uses a one of a kind structure worked around a solitary standard servo.Thus the specification of robotic arm are mentioned below,

Specification	Value
Number of axes	5
Number of DOF	5
Horizontal reach	150 mm
Vertical reach	240 mm
Drives	6 servo motors
Configuration	Jointed arm(Articulated)
Work Envelope	Waist Rotation – 180degrees Shoulder Rotation – 180 degrees Elbow Rotation – 180 degrees Wrist Rotation – 180 degrees Gripper Rotation -180 degrees

5. EXPERIMENTAL SETUP ANDDESIGN CONSIDERATION

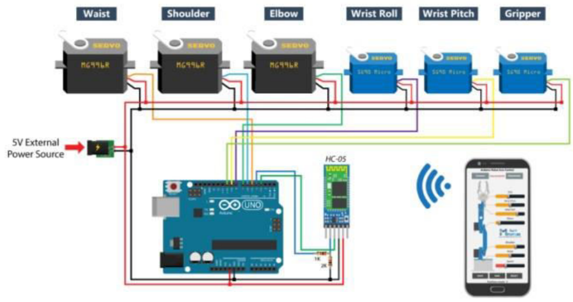


Figure.1.Design components of pick and place robot.

The system is to be designed considering certain design parameters, components wise and is fabricated with design specifications.

DESIGN CONSIDERATION

Coming up next were put into thought in the structure procedure. Electrical actuators DC servo are picked rather than pressure driven and pneumatic actuators due to the little power necessity and its light weight which is reasonable for this plan. Materials utilized for the creation were privately sourced from accessible materials. The materials which will be utilized for the structure will be light in weight to decrease the weight focus on the base and the shoulder. A continuous path controller was chosen (Arduino was used). The torque is completely adjusted by the inertia of the electric motors.

DENAVIT-HARTENBERG(D-H) NOTATION

The definition of a controller with four joint-interface parameters for each connection and a precise methodology for appointing right-gave orthonormal arrange outlines, one to each connection in an open kinematic chain, was proposed by Denavit &Hartenberg ,so is known as Denavit - Hartenberg (D-H) notation. Fig 1 shows a pair of adjacent links, link(i-1) and link i, their associated joints, joint (i-1), i and (i+1), and axis (i2), (i-1) and i respectively.

A frame{i} is assigned to link i as follows:

i.TheZi -1 lies along the axis of motion of the ith joint.
ii.The Xi pivot is normal to the Zi-1 axis, and pointing far from it.
iii.The Yi axis completes the right – handed coordinate system as required.

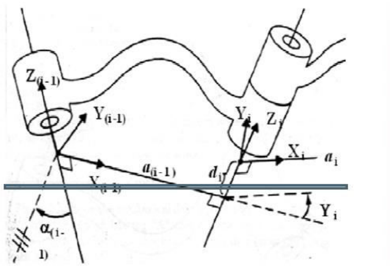
The DH representation of a rigid link depends on four geometric parameters associated with each links. These four parameters completely describe any revolute or prismatic joint as follows:

i.Connection length (ai) – separate estimated along xi hub from the purpose of convergence of xi pivot with zi1 hub to the cause of edge {i}.

ii.Link twist (αi) – angle between zi-1 and zi axes measured about xi-axis in the right hand sense.

iii.Joint distance(di) - distance measured along zi-1 axis from the origin of frame {i-1} to intersection of xi axis with zi-1 axis.

iv.Joint angle (θi) – angle between xi-1 and xi axes measured about the zi-1 axis in the right hand sense.



DH Conventions for frame assigning

Forward Kinematic

In this study, the standard Denavit-Hartenberg (D-H) [9] convention and methodology are used to derive its kinematics. Denavit-Hartenberg calculation finds the position and orientation of end-effector concerning base. Totally 20 Parameters are involved in 5- DOF robotic arm design as shown in

Table 1 :D-H Parameter for 5 DOF Robotic Arm

Joint i	Type	$\alpha_i$deg	a_i mm	d_i mm	$\theta_i$deg
1	Base	0	0	86	θ_1
2	Shoulder	90	0	0	θ_2
3	Elbow	0	96	0	θ_3
4	Wrist	0	96	0	θ_4
5	Gripper	90	0	60	θ_5

Based on the DH convention, the transform at ion matrix from joint i to joint i+1 is given by:

$$^{i-1}T_i = \begin{bmatrix} C\theta i & -S\theta iC\alpha i & S\theta iS\alpha i & aiC\theta i \\ S\theta i & C\theta iC\alpha i & -C\theta iS\alpha i & aiS\theta i \\ 0 & S\alpha i & C\alpha i & di \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (1)$$

where, Sθi=sin θi, Cθi =cos θi, Sαi=sin αi, Cαi=cos αi, Sijk=sin(∟i+ ∟j+ ┘k), Cijk=sin(┘i+ ┘j+ ∟k).

$$^{0}T_1 = \begin{bmatrix} c_1 & -s_1 & 0 & 0 \\ s_1 & c_1 & 0 & 0 \\ 0 & 0 & 1 & d_1 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (2)$$

$$^{1}T_2 = \begin{bmatrix} c_2 & 0 & s_2 & 0 \\ s_2 & 0 & -c_2 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (3)$$

$$^{2}T_3 = \begin{bmatrix} c_3 & -s_3 & 0 & (a*c)_3 \\ s_3 & c_3 & 0 & (a*s)_3 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (4)$$

$$^{3}T_4 = \begin{bmatrix} c_4 & -s_4 & 0 & (a*c)_4 \\ s_4 & c_4 & 0 & (a*s)_4 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (5)$$

$$^{4}T_5 = \begin{bmatrix} c_5 & 0 & s_5 & 0 \\ s_5 & 0 & -c_5 & 0 \\ 0 & 1 & 0 & d_5 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (6)$$

$$^{0}T_5 = \begin{bmatrix} c_{12}\, c_{345} & s_{12} & c_{12}\, s_{345} & s_{12}\, d_5 + c_{12}\, a_4\, c_{34} + c_{12}\, a_3\, c_3 \\ s_{12}\, c_{345} & -c_{12} & s_{12}\, s_{345} & -c_{12}\, d_5 + s_{12}\, a_4\, c_{34} + s_{12}\, a_3\, c_3 \\ s_{345} & 0 & -c_{345} & a_4\, s_{34} + a_3\, s_3 + d_1 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (7)$$

$$T_e = \begin{bmatrix} n_x & o_x & a_x & p_x \\ n_y & o_y & a_y & p_y \\ n_z & o_z & a_z & p_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (8)$$

Where Te is end-effect or transformation matrix.

$$^{0}T_5 = T_e \quad (9)$$

Where,

$nx = c_{12}*c_{345}$; $ny = s_{12}*c_{345}$; $nz = s_{345}$;
$ox = s_{12}$; $oy = -c_{12}$; $oz = 0$;
$ax = c_{12}*s_{345}$; $ay = s_{12}*s_{345}$; $az = -c_{345}$; (10)
$px = s_{12}*d_5 + c_{12}*a_4*c_{34} + c_{12}*a_3*c_3$
$py = -c_{12}*d_5 + s_{12}*a_4*c_{34} + s_{12}*a_3*c_3$
$pz = a_4*s_{34} + a_3*s_3 + d_1$

5.ANALYSIS

The Stress and deformation of gripper assembly are important in the analysis of entire pick and place robot,in which the structural analysis of gripper is done by finite analysis method.

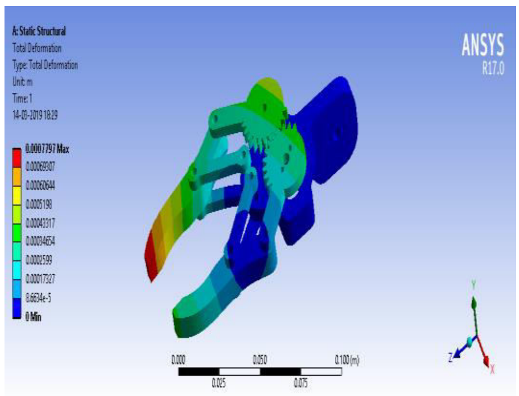


Figure.1. Total Deformation

Both the total deformation and equivalent stress reanalyzed and shown with their maximum and minimum values.

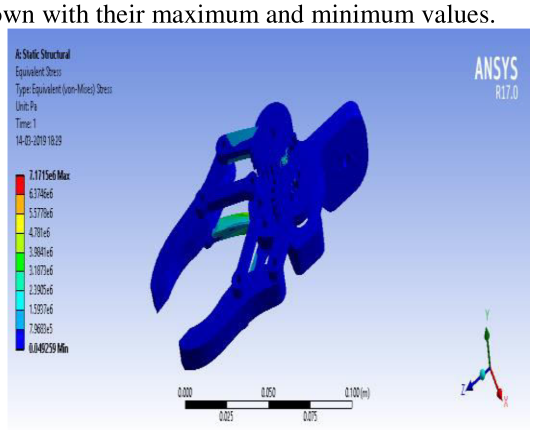


Figure.2. Equivalent Stress

Type of analysis	Total deformation	Equivalent stress
Maximum [Pa]	7.797e-004 m	7.1715e+006 Pa
Minimum [Pa]	0. m	4.9259e-002 Pa

6. RESULT AND CONCLUSION

After every one of the forces and limit conditions were connected plots of stress and deformation were examined and ends were made about the plan. This paper focus on the design, analysis and calculation of various components that is necessary for pick and place robot.We have performed various types of static analysis and applied different loading conditions on the gripper and it if found to be safe. We also learn how to select appropriate material for the safe design of pick and place robot. Successful analysis was perform on the gripper assembly of CAD modal using ANSYS WORKBENCH to determine, equivalent stresses and total deformation results. The objective of the gripper assembly design was to satisfy these functions while picking and placing of objects or any materials.

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