Design and Development of 2 DOF Robot System

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Abstract— The design, analysis and implementation of a robot system, which is expressed towards its performance with an analytical model by using ANSYS is presented in this article. Analysis of the Gripper in motion plays an essential role in design and implementation of a robot system control. The projected work was focused to control the two Degrees of Freedom motion of the robot arm by varying its velocity and acceleration to achieve any accessible point in an amorphous region. Also static analysis of gripper and shaft is performed in ANSYS. And Kinematic analysis of model is performed in Excel. The present paper discussed about the mechanical configuration, analytical modeling, software and hardware of the above said work.

Key words: DOF, Modeling, Static and Kinematic Analysis, Pick and Place, Servo Motor, Multi Body Dynamic Analysis

I. INTRODUCTION

The most important applications of industrial robots are material handling, welding, assembling, dispensing and processing where the manipulator of robotic arm needs to perform pick and place operations incessantly.. Modeling, analysis and implementation of a serial robot arm implicates the study of its kinematic behavior. Kinematics gives the motion of bodies without concern of the forces or moments that cause the motion. Analytical study of the motion of a robot manipulator is called robot kinematics.

In this paper we design model in solid edge and perform static analysis in ANSYS, also perform kinematic analysis.

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A. Problem statement

Design and Development of 2DOf Robot system to do courses in automatic control principle and modern control engineering as well as electrical motor control. Also application of the same is Pick-Place Operation with the payload capacity 0.1kg. and Velocity control for 1m/s and Acceleration control for maximum acceleration 1m/s^2. Analysis of the gripper for the same payload capacity in ANSYS. and Kinematic analysis of model.

B. Objective

The objective of this experiment is to:

1) Mechanical design of model in 3d software which satisfies the given data by client
2) Static and kinematic analysis of the model.
3) Payloads: It should be able to lift a load at least 0.1 kg.
4) Trajectory path follower: Both arms should be able to turn in 360 degrees clockwise and anticlockwise at one place.
5) Teaching different positions and doing 'pick & place' task in auto-mode.
6) Multi body Dynamic analysis of model

II. LITERATURE REVIEW

In the literature survey, we reviewed the past research and the literature meaning that covered under this project. We studied the basics of the robotic system and the different Two degrees of freedom Robots available in the market.

Following are some of the important reviews of different researches and scientists.

Ambuja Singh et. all. [1] Studied the Robot kinematics the basis of robotics research, provides the basis for robot path planning I.e. trajectory and motion control.

Amey V. Sutar and Dr.S. S. Ohol [2] The main motivating force behind this project was to have a portable robot to perform urban reconnaissance and surveillance for security purpose, as well as to perform urban search and rescue for civil defense pu rpose

Chetan S. Jadav and Jignesh R. Gautam [3] In this paper they discuss about Multi body analysis. A multi body system is a group of interconnected rigid and deformable components, each of which may undergo large translational and rotational motions.

Luo Haitao et. all. [4] In this study, taking the joint angle control of two DOF robot arm as an example, we mainly discuss the control method about co-simulation.

Y. D. Patel and P. M. George[6] From the studies that Forward kinematic analysis and inverse analysis of 2DOF robot is presented to predict singular configurations.

III. SELECTION OF THE MATERIAL

A. Metal

Aluminum HE30 (AA6082) and Mild/ low carbon steel (AISI 1018) are selected for manufacturing robot. Properties of both the materials are as per standards

IV. DESIGN CALCULATION FOR MOTOR SELECTION

A. Given Data by Client

1) 2DOF movement
2) Pick and place with gripper
3) Trajectory path follower
4) Use Ac servo Motors
5) Maximum Link Lengths
   - L1 = 250mm with rotational angle 270°
   - L2 = 500mm with rotational angle 300°
1) Compatible with GT 400 SV PCI Googoltech motion controller.

B. Calculating Gripping Force

The calculation of the minimum gripping force that the robot gripper must apply will include the mass of the part that must be moved, the friction coeff. Between the finger material and the part.

- F: Gripping force [N]
- u: Coefficient of static friction
- m: Mass of the part [kg]
- g: Gravitational acceleration [9.81 m/s^2]
- a: Acceleration (if it is significant)
- η: Factor of Safety

$$F = \frac{\eta m\,(g + a)}{2\mu}$$

Since each application has its own friction coefficient, the safety factor should be enhanced respectively for a low friction or high friction use.

C. Calculation Data

m = 100 gm
g= 9.8 m/s^2
a = 1 m/s^2
μ = 0.19 (Coefficient of static friction for aluminum)
η= 1.5

$$F = \frac{1.5 * 0.1\,(9.8 + 1)}{2 * 0.19}$$

$$F = 4.2\ N$$

D. Specification of Gripper Motor

Model No OMPMDC13
Power 0.5HP
Rated Torque 1.977 Nm
Rated RPM 1800
Torque Constant 0.4 Nm / Amps
Rated Current 26.4 Amps
Rated Voltage 12 V AC

E. Calculating Axial Force

For gripper operation there is rack and pinion arrangement
Pinion radius 14mm
Axial force = torque/radius

$$F = \frac{T}{R} = \frac{1977}{14}$$

$$F = 141N$$

For Link 1 motor:
Link length 1, r = 180mm = 0.18m
We required maximum torque at 90°
Hence, Θ= 90°
Ƭ = FrsinΘ
Ƭ = 2.5 Nm
As we have selected the pulley of Ratio 1:2
For torque expansion so,
Diameter of Pulley 1 = 30mm
Diameter of Pulley 2 = 60mm
So required torque = $\frac{2.5}{2}$ = 1.25Nm
Hence we have to select below motor for this Required torque.

F. Specification of Motor and Drive

AC Servo Motor
Model No EP 60SM00630
Watts 200W
Rated Torque 0.65 Nm
Peak Torque 1.8 Nm
Rated RPM 3000
Torque Constant 0.4 Nm / Amps
Rated Current 1.5 Amps
Rated Voltage 220 V AC
Encoder output range 2500
Dual Axes Drive with Encoder for Motor
Model: SPM-2X-5A-220V-E1
Rated Current: 5 Amps
Peak Current: 10 Amps
With incremental Encoder feedback

1) 3D Modeling of Robot

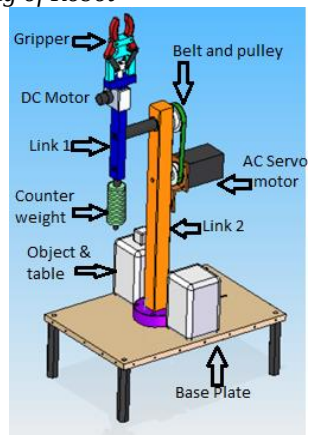

Fig. 1: Assembly of Robot Systems

V. STATIC ANALYSIS

Static Analysis of gripper and shaft performed in ANSYS. From analysis we get Von-misses stresses, deformation and factor of safety

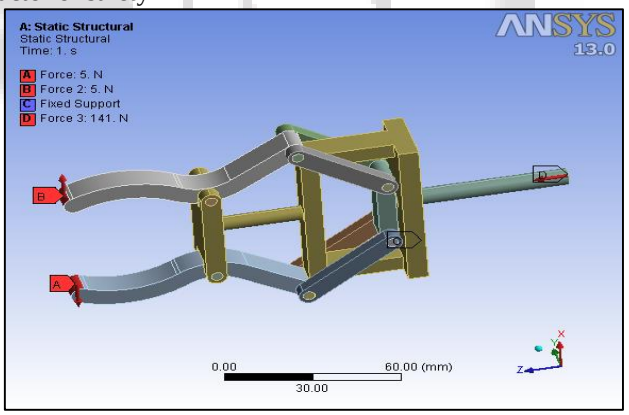

Fig. 2: forces applied on gripper

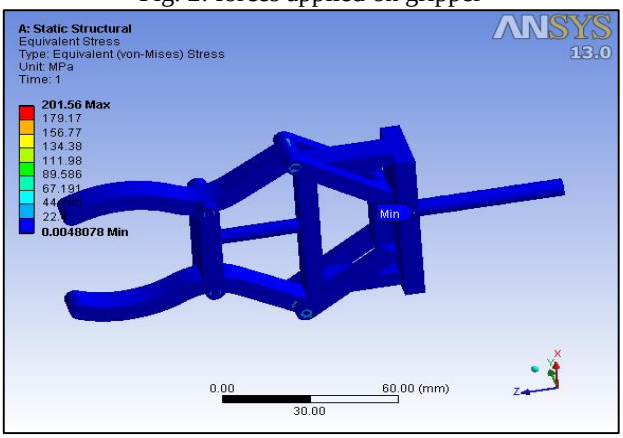

Fig. 3: Maximum shear stress of gripper

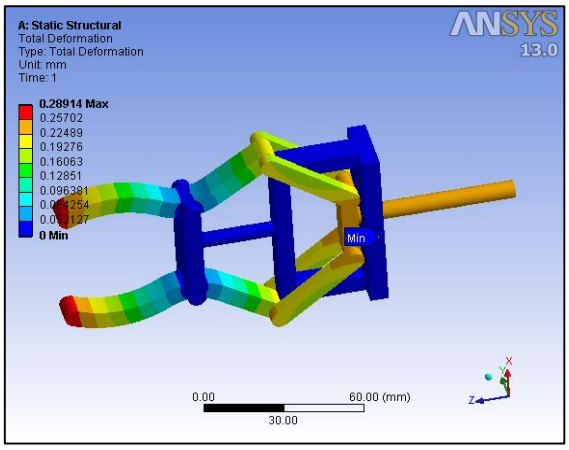

Fig. 4: Total deformation of gripper

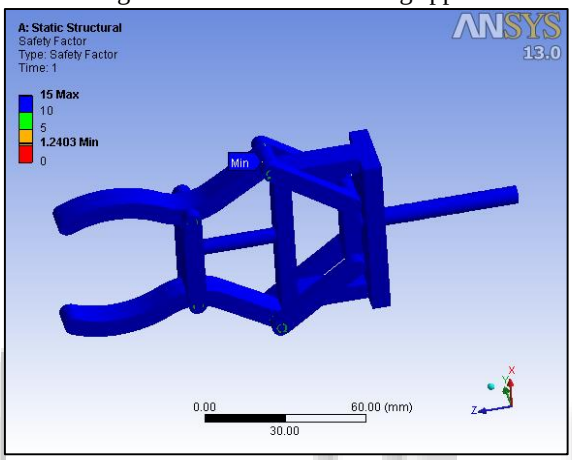

Fig. 5: Factor of safety of gripper

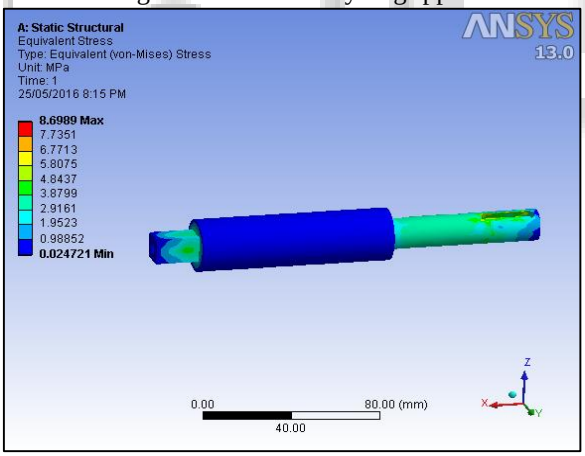

Fig. 6: Maximum shear stress of shaft

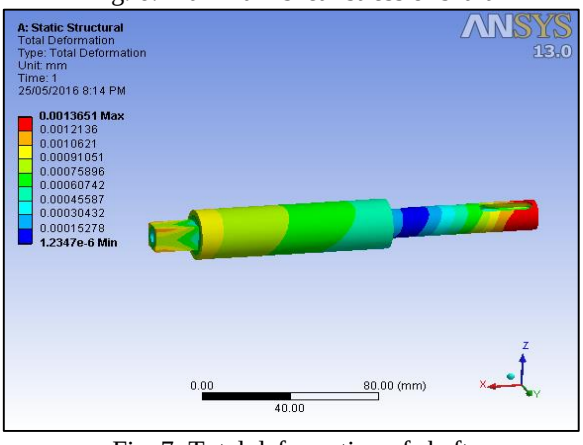

Fig. 7: Total deformation of shaft

VI. RESULTS AND DISCUSSION

Sr. No.	parameters	Values for gripper	Values for shaft
1	Maximum stress	201.56 MPa	8.69 MPa
2	Total deformation	0.28 mm	0.0013 mm
3	Factor of safety	1.2	

Table 1: Result

1) As the allowable stress for the gripper material i.e. AA6082 is 255MPa which is greater than the maximum stress in analysis, also the deformation is very less so the design of gripper is safe.
2) As the allowable stress for the shaft material i. e. AISI 1018 is 370MPa which is greater than the maximum stress in analysis, also the deformation is negligible so the design of shaft is safe,

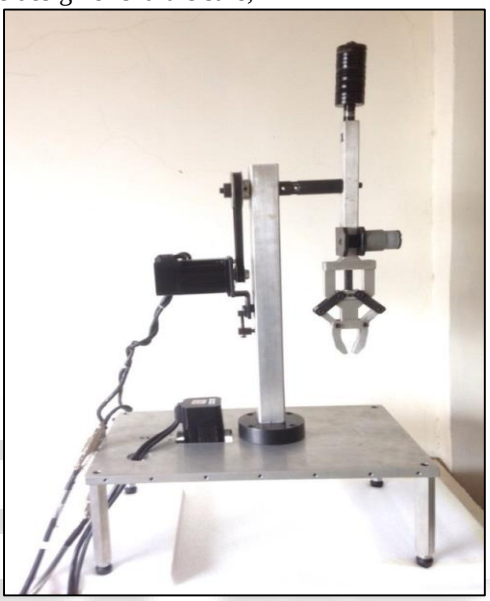

Fig. 8: Manufactured Model

VII. CONCLUSION

From the references used in this paper, we understand the Degrees of Freedom and Robot System.

1) Mechanical design of model in Solid edge has been done.
2) Static analysis of the gripper performed in ANSYS and the design is safe.
3) It is able to lift a load of 0.1 kg.
4) Trajectory path followed by Both arms is able to turn in 360 degrees clockwise and anticlockwise at one place.
5) 2DOF movement in a specified angle is achieved.

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