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Design and Static Analysis of 6 DOF Robot Manipulator

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ABSTRACT: In this paper, analysis and assessment is done of the total deformation and stress induced for a specific payload of a robot. A six degree of freedom (DOF) robot manipulator has been designed for stress and deformation assessment. The design and model of six DOF robot manipulator has been developed in Solidworks and the static structure evaluation has been executed by ANSYS software. In automated and moving world, robots are used in different fields especially where precision is needed. A model design development methodology utilizes the finite element analysis (FEA) for construction, and assessment of robot manipulator have been very dynamic research fields all over the world. In this paper, the simulation of robotic manipulator is done with the help of ANSYS software, and numerous systemic aspects of a robotic arm explored. The main purpose is elaboration of a design which has capability to guess the robot manipulator precision, under definite load arm postures and maximum stress circumstances. Different load are forced, and final data at various situations are equated to discover the weak portions, so further structure upgrading should be possible.

KEYWORDS: Finite Element Analysis, Robot Manipulator, Stress, Total Deformation.

I. INTRODUCTION

A robot manipulator is an electronically controlled mechanism, conforming of multiple parts, that performs tasks by interacting with its surrounding. They are also commonly referred as robotic arms. Robot manipulators are highly used in the automated industrial manufacturing sector and also have numerous other specialized operations. The study of robot manipulators involves dealing with the positions and orientations of the several parts that make up the manipulators. Our study introduces the basic concepts that are needed to describe these positions and orientations of rigid bodies in space and perform coordinate transformations. Designing, programming and doing analysis of a robot is a combination of physics, engineering, mathematics, and computing.

A robot has a mechanical manipulator (MM) and a controller for the movement of the arm and executes much-connected activity that it contains joints and links for orientation and place the end of the manipulator. Examination of the finishing Solid Works design is completed by ANSYS WORKBENCH. Numerous weight cases throughout FEA to confirm that the robotic manipulator design can bear the forces acting at the time of arm movement. The skill to set up an immediate simulation is specifically essential in the innovative stages of the design procedure. The concluding design can be adapted before we begin the expensive and time-taking operations of constructing a model. So, it is essential to accurate and computationally skilled operation dynamics which has been highlighted on a great measure in current years.

II. LITERATURE REVIEW

Table no. 1
Literature comparison

Here are some papers that were referred for the study of robot manipulator.

Name of Author	Year of publication	Title of paper	Methodology	Conclusion
Zexin Huang Fenglei Li.	2020	Modeling and Simulation of 6 DOF Robotic Arm Based on Gazebo	The Design was developed and was then analyze using MATLAB software using PID controller and Aurdino Uno. The force analysis was done using FEA.	Loads and forces vary throughout a full range of motion and operating environment.
Param Kothari.	2012	6 Degrees Robotic arm with mimicking mechanism.	Equations of six DOF was calculated and design was made. The assembly was made using blender and AutoCAD. While the work of electric circuits was done on Arduino IDE, GitHub and MATLAB.	The main people who will be benefited from the project will be the physically challenged population. Something similar has been developed certain years ago but the mechanism we are using hasn't been used yet and would provide an artificial limb with similar working but at a very lower price.
Syaban Bin Shamsulkamar.	2014	Modeling and control of 6 DOF Robotic Arm using Neuro-Fuzzy Controller.	CAD Model was developed and converted into physical model using Sim-Mechanics Simulink. Neuro Fuzzy controller is developed. the comparison between Neuro-Fuzzy controller and linear controller was made.	Result using Neuro-Fuzzy controller was observed to be accurate than liner controller.
Ozgoren	1999	Kinematic analysis of a manipulator with its position and velocity related singular configurations	Proposed inverse and forward kinematics of general 6R manipulator considering both position and velocity using exponential rotation matrix method	They have also investigated the singular configuration related to the inverse position analysis termed as (POSCs) i.e. position related singular configurations and other with the velocity is termed as (VESOs).
Aaditya Raje	4 April - 2020	Investigation on Design Parameter of Robotic arm to reduce end effector	The design for analysis was created using solidworks. After the design calculation were	Robotic manipulator links tend to bend in the minor extent under load applied to the end effector, which causes

		positioning error.	made and the design was the analyse in Roboanalyser software and calculated values and the software values were compared.	positioning error at end effector.
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After completing the Literature Survey came to know about various terms associated with the Robot Manipulator. Literature Survey helped us in finding the DH Parameters which are link length, joint angle, joint offset and twist angle. Mechanism of Robot Manipulator i.e., Forward and Inverse Kinematics was understood and calculated for some random values. The Literature Survey not only helped us in calculation methods but also to design the Robot Manipulator. It also helped us in understanding the analysis part of Robot Manipulator. We came to understand various software for doing the analysis of Robot Manipulator like, Roboanalyser, Ansys, RoboDCX, etc.

III. DEVELOPMENT OF ROBOT

The whole design of the robotic arm has been generated by with the help of solid works software. The whole design contains different portions like as Base, Body, Upper arm, Forearm, Gripper holder and Gripper. To deliver proportional motion among these portions servo motor is used. Each portion of the design has dissimilar dimensions. To deliver proportional motion among these portions, servo motor is used. Each portion of the design is having dissimilar dimensions. For this design, DC servo motor will be perfect instead of pressure driven and pneumatic actuators due to less power necessity and its light weight. Appropriate range of electrical motors in industrial robots needs a number of factors to take account for arm control, position, angular and linear motion. Sensors deliver the data about the situation of its linkages and its end effector to the robotic arm, formerly this information is prepared to the control unit and figure the reasonable sign to the motor which moves precisely.

Firstly, the whole design and design segments of the robot to the operator is made. Then all the segments are assembled which delivers the proportional motion among the segments with the help of revolute linkages through a servo motor.

1. Base

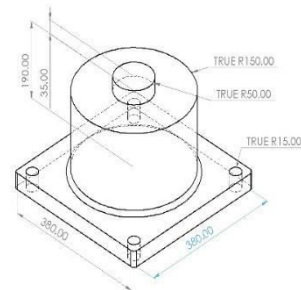
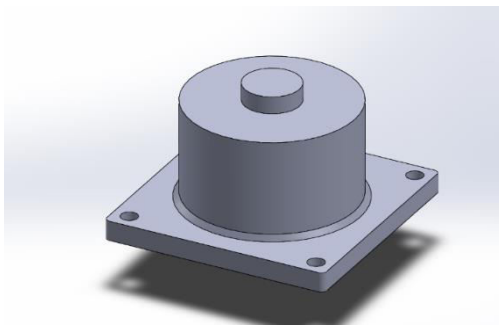
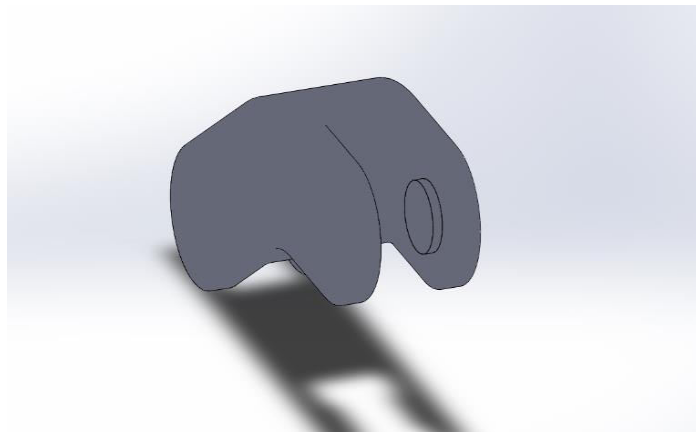
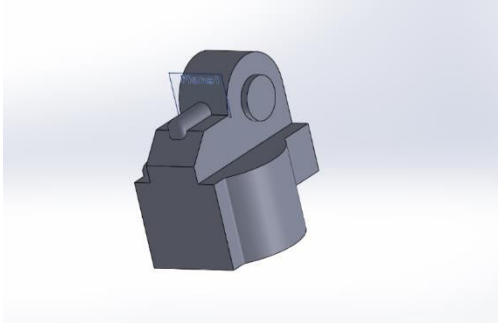
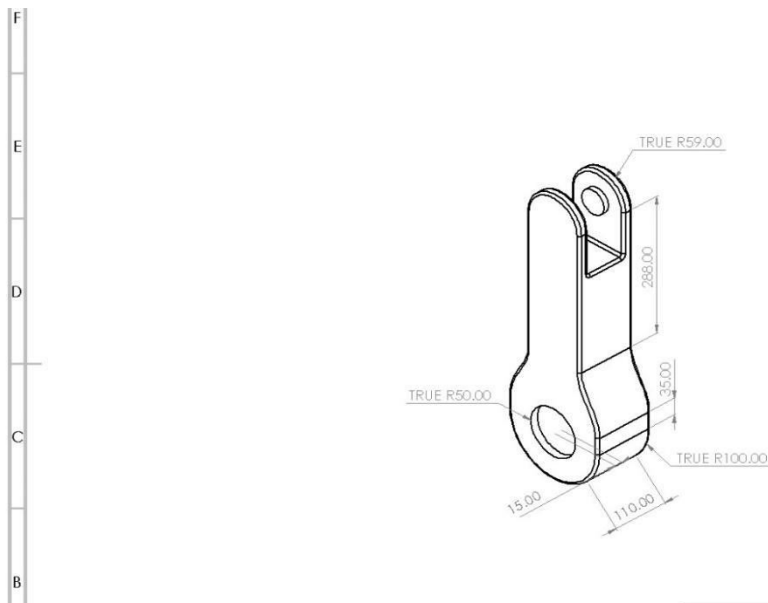
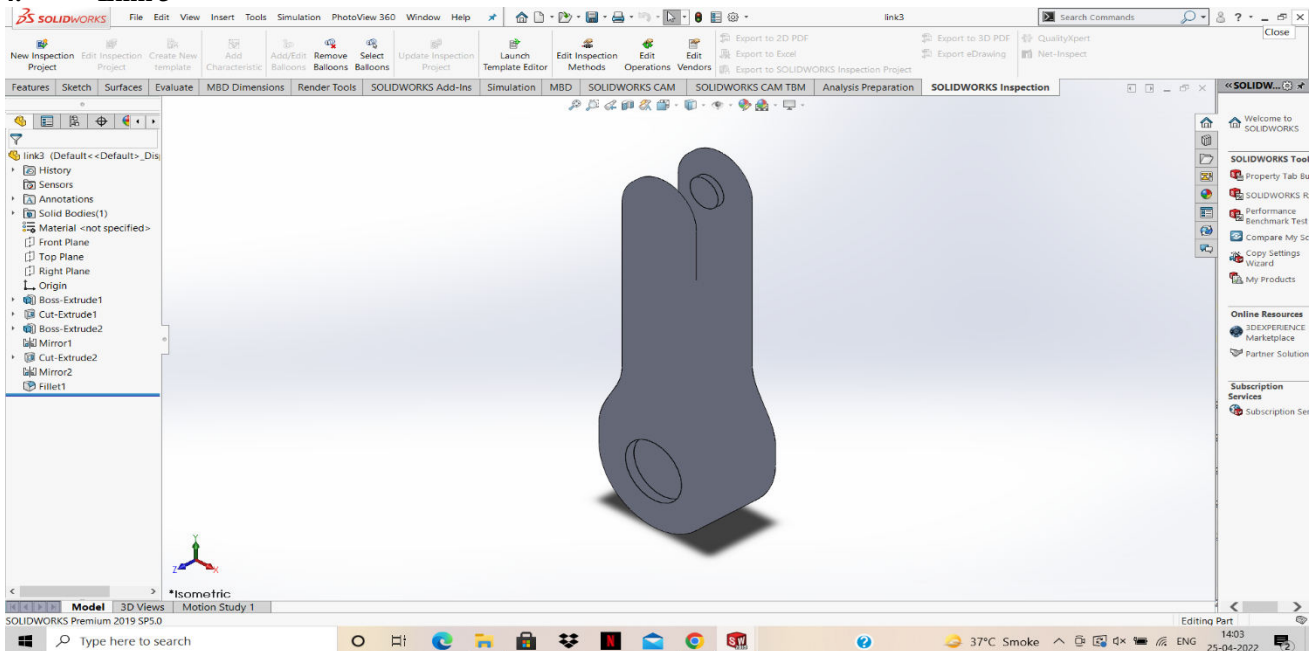


Fig no.1
Design and Isometric view of Base

The base bottom plate is the base part of whole robotic arm. This plate can be fixed to a mobile robot.



4. Link 3



Link 3 is responsible to position the link 4 along with the gripper. It will move in forward and reverse direction.

5. Link 4

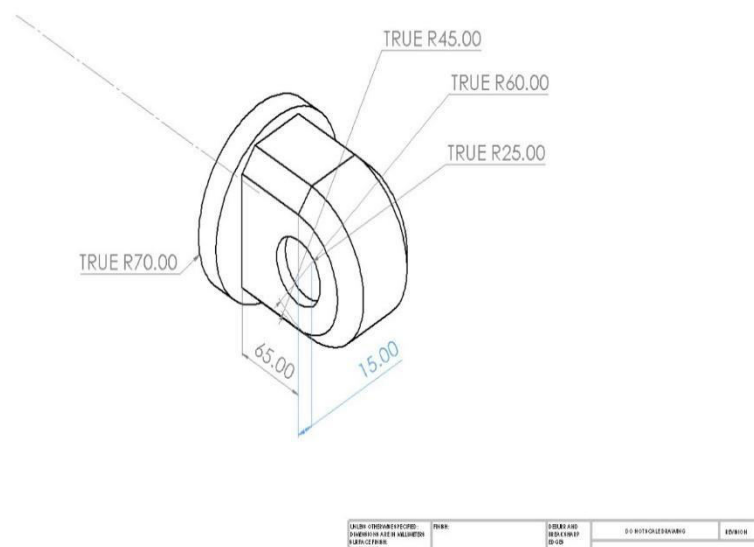
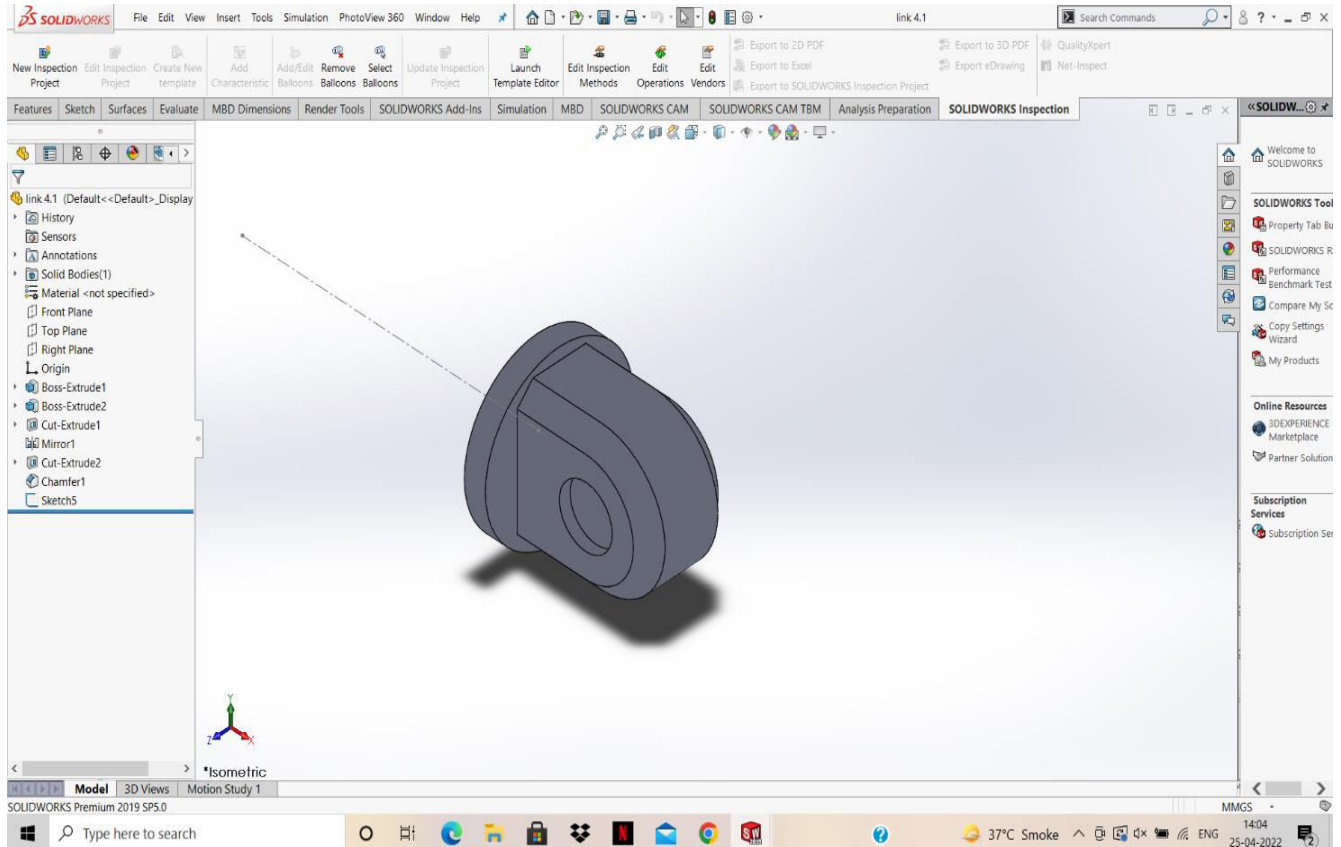


Fig no. 5
Design and Isometric view of Link 4

It holds the gripper and helps to position it along the object for the operation.

6. Link 5

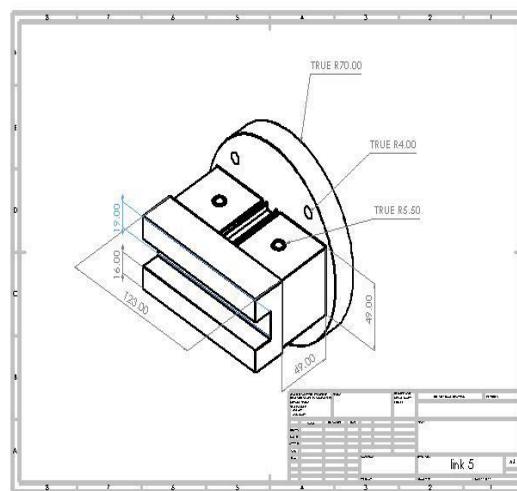
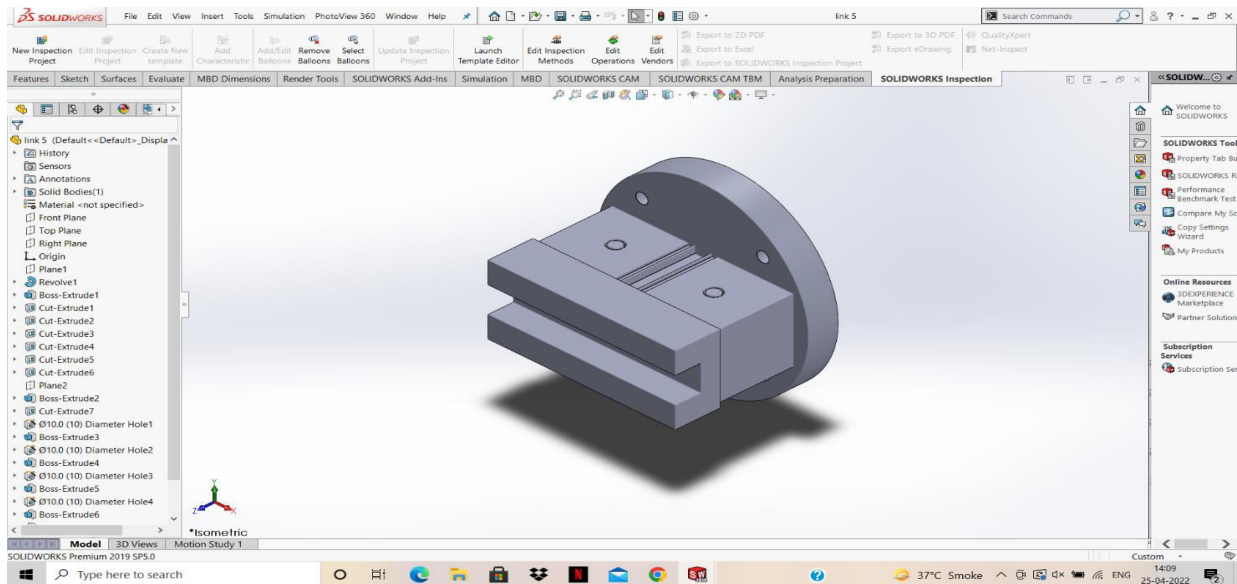


Fig no. 6
Design and Isometric view of Link 5

Link 5 acts as a holder for gripper and it has a midway passage where the gripper moves along. From this the gripper functions to wide open and close.

7. Gripper

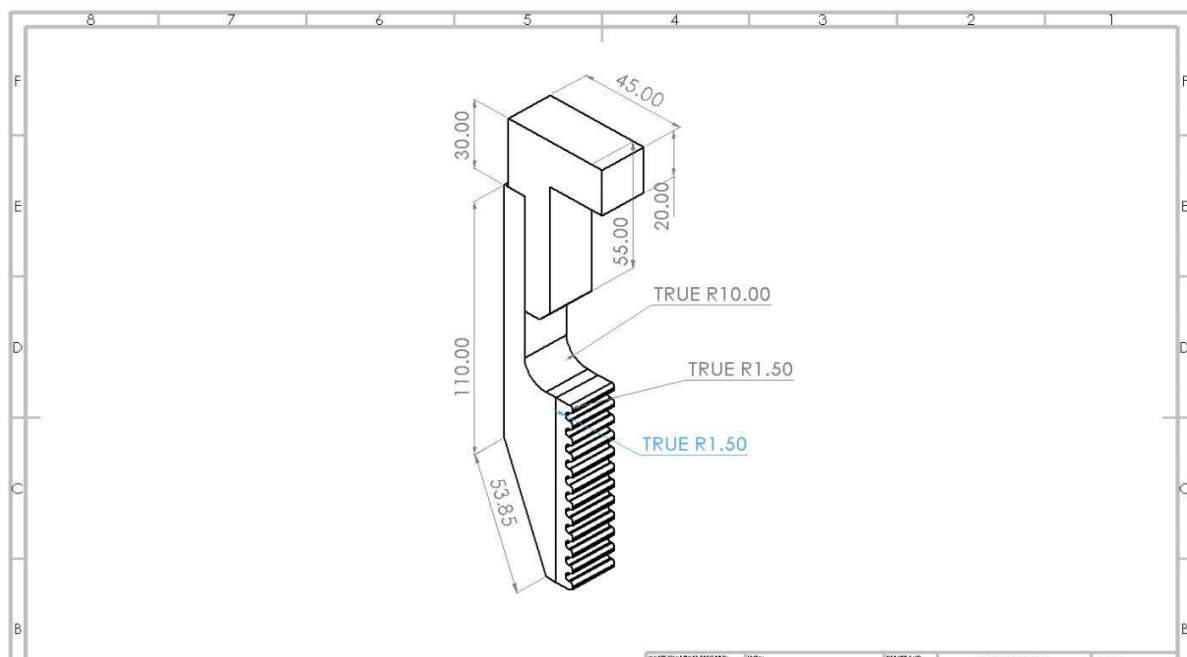
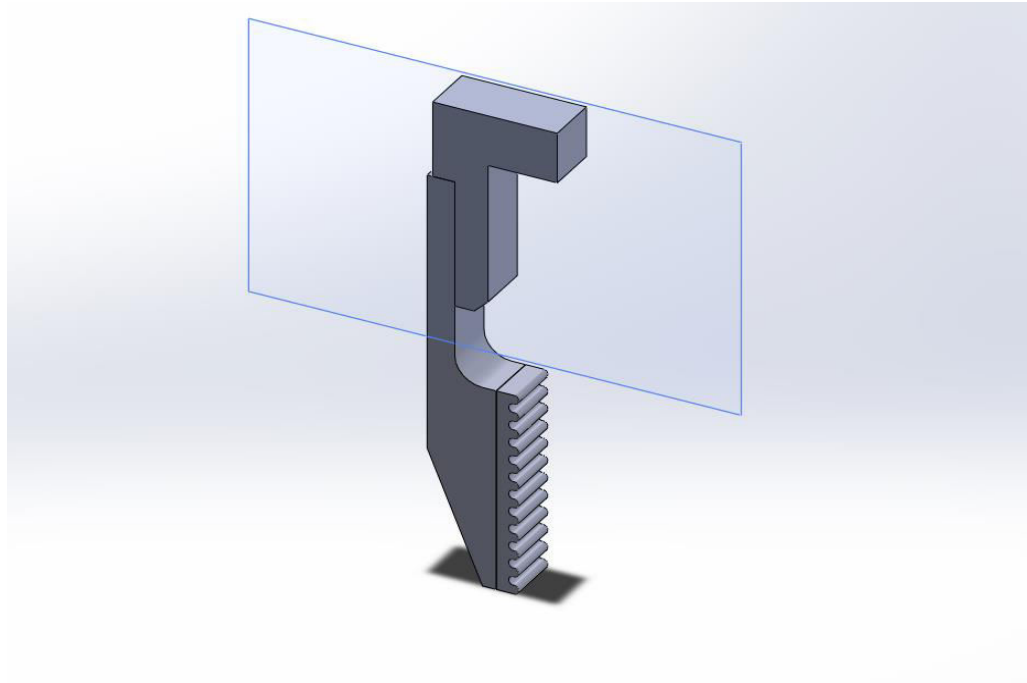


Fig no. 7
Design and Isometric view of Gripper

Gripper acts like human finger it holds a object from two opposite sides for the desired operation.

IV. FINAL MODEL AND ANALYSIS

1. Modelling of Robot Manipulator.

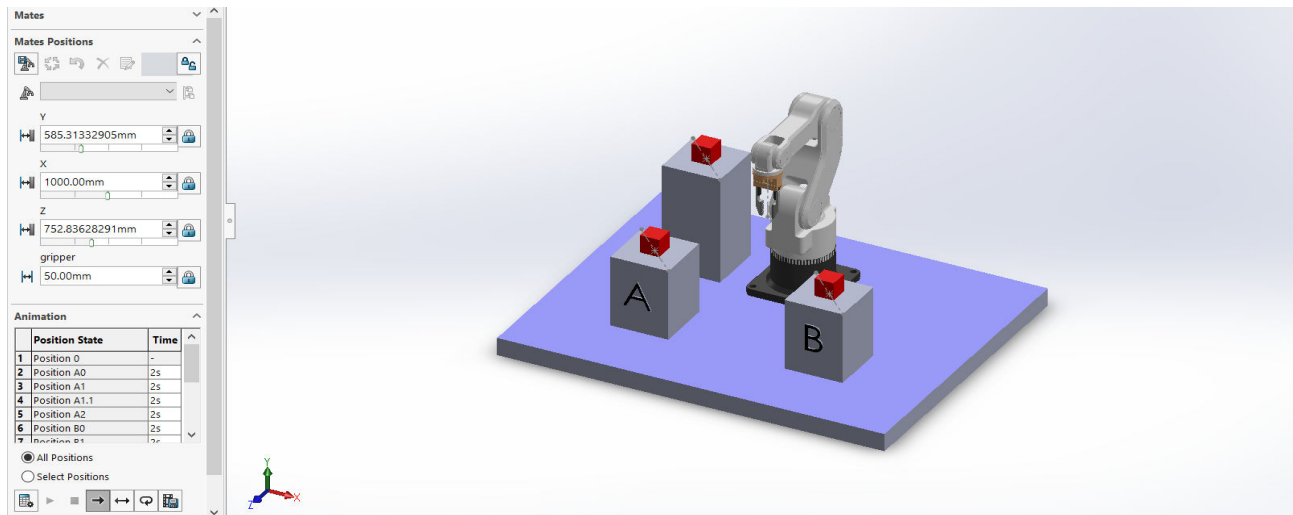
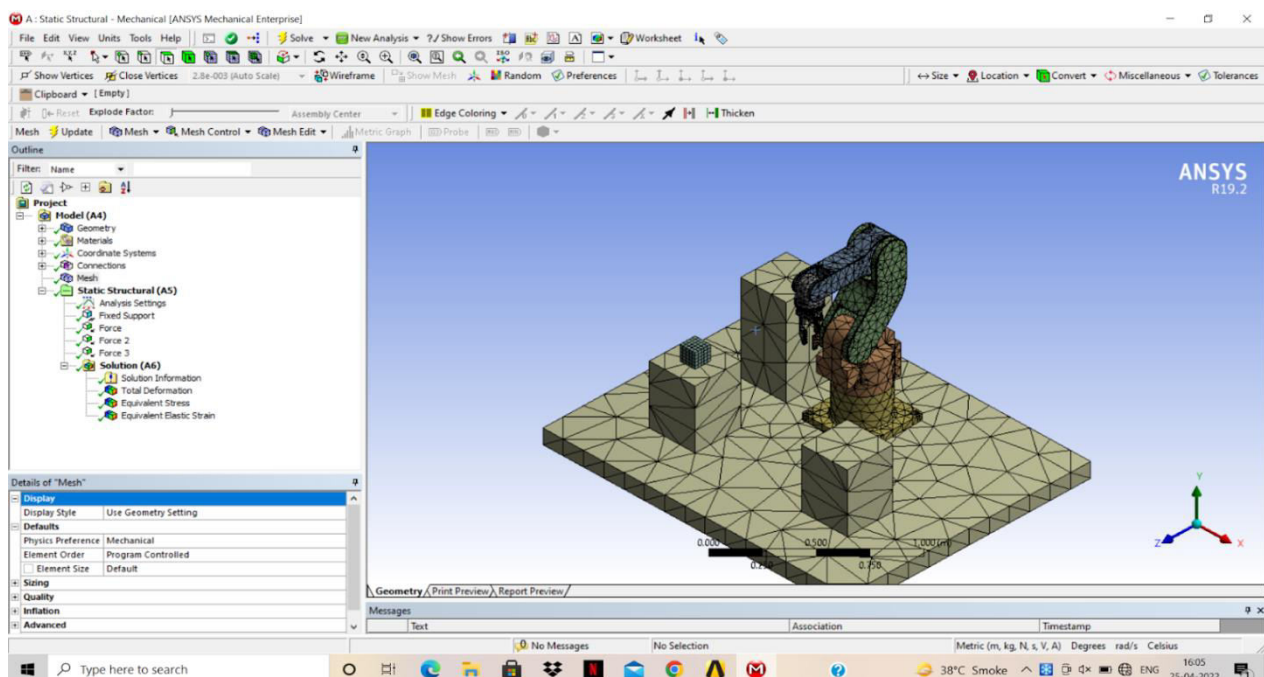


Fig no. 5

Final Assembly

The complete design of the model is built by the software SOLID WORKS. Initially, the design of each section of the robotic arm is built and after that, each part is assembled to develop the final design of the model. The complete design is then introduced from SOLID WORKS to ANSYS workbench software. As the design of the model is of six –degree freedom assembly and it must be stationary with the surface, when in workable condition, the lower part of the design must be act as stationary restraint.

2. Finite Element Stress Analysis (FESA).



The stress analysis is executed to trial the complete design to resist particular weight situations. In finite element analysis, the design of the model is analyzed to conclude so that it can resist the different weight situations considered earlier in the actual design robotic arm or not. It is very essential to define the rigidity of the model design. Structure design exploration has been followed up in a finite element atmosphere. . For doing the finite element analysis, the lower part of the structure must be fixed. For doing the calculation mesh dimension is considered as 0.05 mm and dissimilar mass are forced to the Gripper end. For examining the entire robotic arm design, the different weights considered are 1000 N, 2000 N, 3000 N. With the variation in load we also varied the link length of robot manipulator to check the variation under different link length and payloads. So we can come to common conclusion. The iteration performed and the values that we got have been mentioned in table no.2.

V. EXPERIMENTATION

We have performed iterations by varying link lengths and payload to check the accuracy and time consumed to perform operation. Also, it is found that static structure of robot changes by varying the same. The result of the same is given below in table no. 1

LINK LENGTH			LOAD								
L2	L3	Ratio	1000 N			2000 N			3000 N		
			Deformation	Stress	Strain	Deformation	Stress	Strain	Deformation	Stress	Strain
(mm)	(mm)	L2/L3	(mm)	(Pa)	(m/m)	(mm)	(Pa)	(m/m)	(mm)	(Pa)	(m/m)
266	162	1.64	1.67	9.59	4.8	3.34	1.91	9.66	5.01	2.88	1.45
266	177	1.5	1.77	9.5	4.79	3.43	1.95	9.58	5.14	2.9	1.43
266	192	1.38	1.65	8.81	4.41	3.35	1.82	8.76	5.03	2.64	1.33
281	162	1.73	1.65	8.82	4.4	3.31	1.76	8.8	4.97	2.64	1.33
281	177	1.59	1.72	8.97	4.5	3.45	1.79	9.05	5.18	2.69	1.35
281	192	1.46	1.71	8.8	4.43	3.43	1.77	8.87	5.14	2.64	1.34
245	162	1.51	1.66	8.81	4.44	3.32	1.76	8.5	4.99	2.65	1.32
245	177	1.38	1.70	9.49	4.79	3.41	1.89	9.58	5.11	2.85	1.43
245	192	1.28	1.72	8.79	4.43	3.45	1.75	8.86	5.17	2.63	1.32

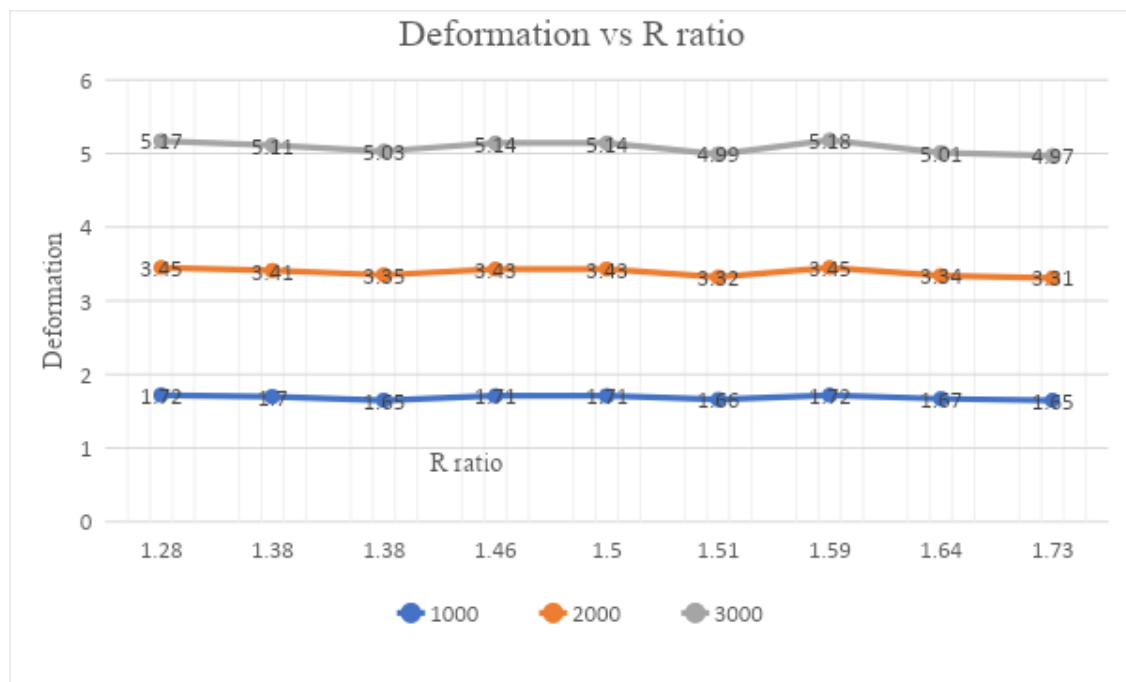
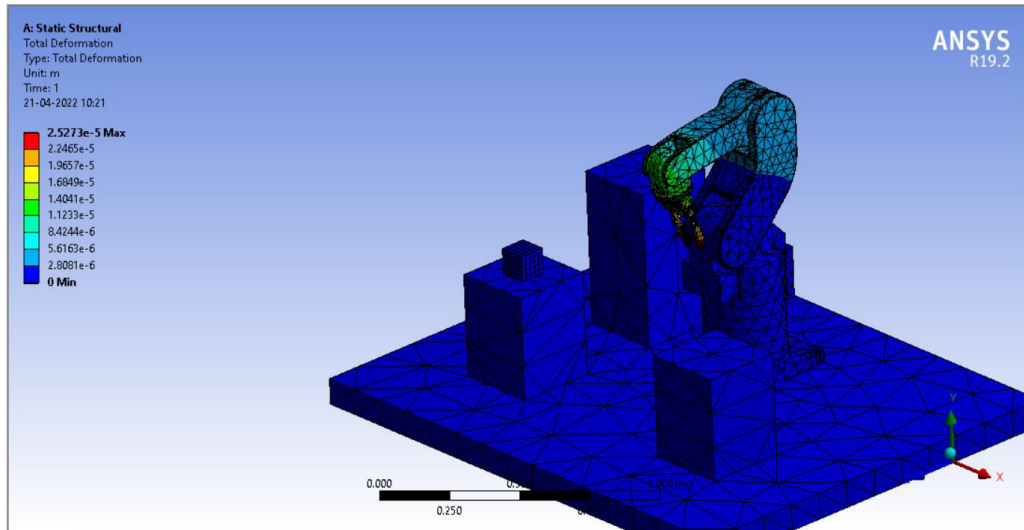
$$R = L2/L3$$

VI. RESULT AND DISCUSSION

Improved mechanical design for the assemblies of the manufacturing robots has to reach the standard concerning aspect model and structure, material depletion and accommodate design to the operative necessities. For an improved model

of the robotic arm design, every characteristic of industrial instruments where the different shapes can incorporate is examined.

1. Total Deformation



2. Equivalent stress.

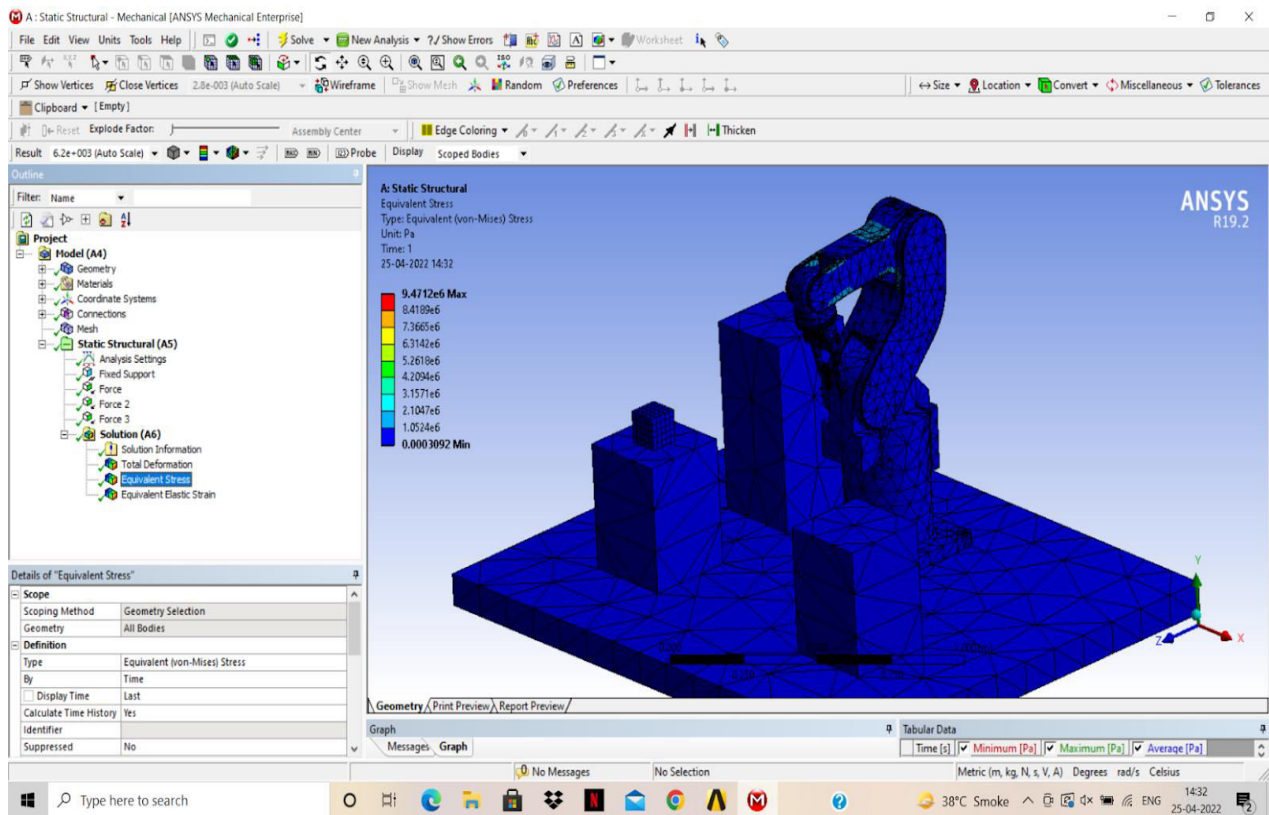
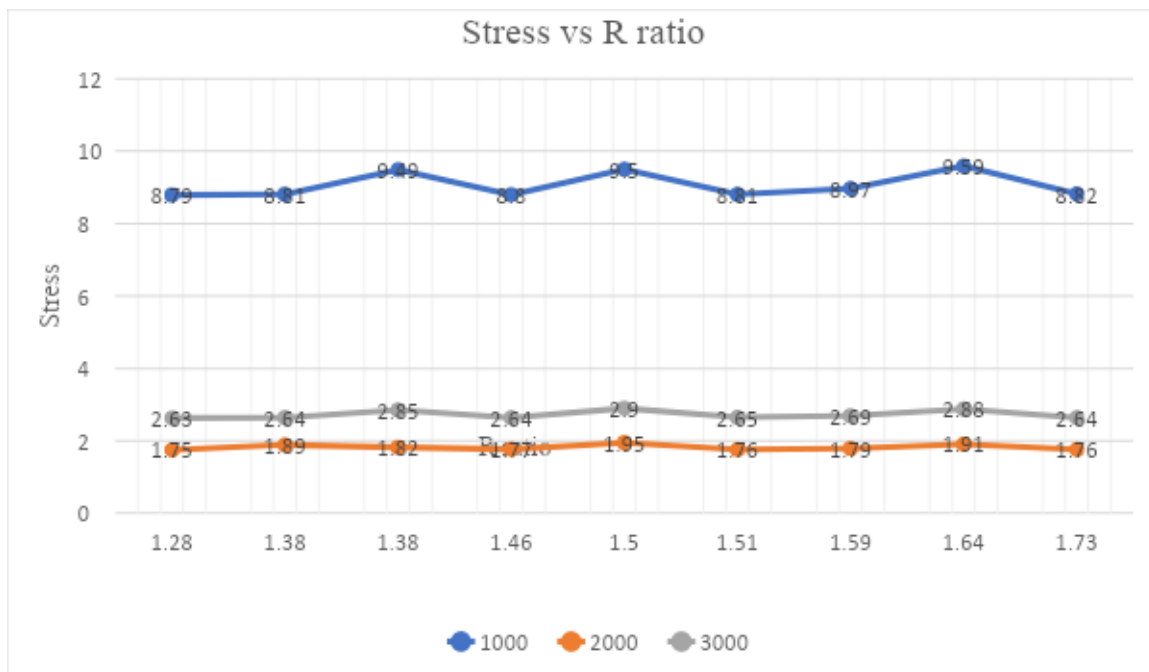


Fig no. 9 Shear Stress in ansys



The base portion of the model having the most minimal estimation of total deformation and shear stress has appeared as dull blue shading, and the top portion of the model displays the highest data of deformation and stress has appeared as red shading.

Left half of the figure contains a dialogue box and gives the required data. The dark blue color shows the least data, the light blue color shows the lesser data, the yellow color demonstrates the greater data than then pervious one and red shading demonstrates the uppermost data of total deformation and shear stress. Form the above fig no it can be clearly seen that least deformation occurs at the lower part and maximum deformation occurs at the gripper. As the load increases the total deformation also increases.

VII. CONCLUSION

In this paper the ideal robotic arm has been designed using specialized software. Ideal robotic arm, as defined in this paper, is that which is designed for minimum weight, can withstand the highest levels of allowable stresses while carrying different payloads, has an efficient performance index and reduce the overall manufacturing and operational costs of a robot. The main target is to decrease the mass of the structure and lowering its physical distortions to enhance the stiffness of the design model we chosen or any static model by applying different force condition. The weight conditions, number of links in the robotic arm to be designed is assumed and some further external circumstances are well-defined earlier. This work is made promising by executing an automated collaboration between the solid works and ANSYS software packages. This work validated the mechanization of ideal design process in terms of a 6-degree-of-freedom industrial robotic arm. The outcomes gotten from the ANSYS software with mesh size of 0.05 are significantly decent where analysis on total deformation, equivalent stress and equivalent strain are done. For simulation of the static robotic model or any mechanical robotic arm, the execution of a finite element constructed design is very much needed. Like this, with the help of finite element model analysis (ANSYS), the extreme data of the different aspects can be figured out which can cause to failure of the model design

VIII. FUTURE SCOPE

1. Inverse Kinematics approach for design and analysis.
2. Different end-effector to demonstrate different applications.
3. Dynamic Analysis to study forces acting on body.

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