Design and Static Analysis of Robotic Arm using Ansys

Anurag singh, Rashmi Arora, Yashpal Singh Chouhan

Abstract*: In this paper, analysis and exploration is done of the stresses and total deformation incited for a specific payload of a robot. A five degree of freedom (DOF) robot arm has been selected for stress and deformation evaluation. The design and model of the five DOF robot arm has been fabricated by Solid works and the whole structure evaluation has been executed by ANSYS software. In present world, robots are used in different fields especially where accuracy is needed. A model design development methodology utilizes the finite element analysis (FEA) for designing the robotic arm. In the past few years, the modelling, construction, and evolution of robot arm have been very dynamic research fields all over the world. In this paper, the simulation of a robotic arm is done with the help of ANSYS software, and many systemic aspects of a robotic arm are explored. The main purpose is the evolution of a design which has the ability to guessing the robot arm precision, under definite arm postures and maximum stress circumstances. Dissimilar nozzle weights are forced, and final data at various situations are equated to discover the feeble portions, so further structure upgrading should be possible.

***Keywords*: Finite Element Analysis, Robotic Arm, Shear Stress, Total Deformation**

I. INTRODUCTION

In automobile industries, construction and many different manufacturing sectors, different types of robots are used having many human beings like functioning. These robots have a robotic arm that is different in shape, size, and function according to our needs. These robotics arms are very often like a human arm and operate in a different production piece of function. A robot is a structure that includes sensors, control systems, manipulators, power supplies and software's all working jointly to accomplish a work. Designing, building, programming and doing analysis of a robot is a combination of physics, engineering, mathematics, and computing. It's anthropomorphic or human-like functioning embraces few sensory pieces of equipment that are used to the interface and connect the device with the other part of devices to take effortless or essential judgment to run adequately.

A robot has a mechanical manipulator (MM) and a controller for the movement of the arm and executes much-interconnected activity that it contains joints and links for orientation and place the end of the manipulator respective to its base [1]. Examination of the finishing Solid Works design is completed by ANSYS WORKBENCH. Many weight cases throughout FEA to confirm that the robotic arm design can bear the forces acting at the time of arm movement [2]. It is repeatedly appropriate to execute simulations proceeding to compare with actual robots. Simulations are uncomplicated to frame, affordable, quicker and extra appropriate to use. Constructing innovative robot designs and executing trials or tests takes less than a few hours, and also a simulated robotics design or model is more economical than actual robots and physical domain structures, and gives a chance to choose superior design structure. Simulation always executes rapidly than actual robots, and entirely specification can show on the monitor. The skill to set up an instantaneous 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. The modelling and simulation of robot structures by the use of diverse software programs will shorten the procedure of design, assembly, and analysis of robots in the actual world. Also, it protects time and money and will play a vital part in the assessment of manufacturing mechanization, which may be capable to simulate unwraps an extensive variety of choices to answer various difficulties innovatively [3]. So, basically for planning the design of the robotic arm structure the essential job is to examine the total deformation and shear stress value. Gasparetto *et al*. [4] examined a technique and demonstrating has been done on mechanical robots of less mass dependent on unbending connection outline method. In view of the limited component technique Ghiorghe [5] decided the ideal standards for the structure constraints considering the conditions of diminishing the material used to construct the robot. Ying Huang *et al*. [6] directed an analog simulation analysis with the help of FEA. Jeevan and Rao [7] conducted the experiment and did the FEA analysis of structural design and noticed that round type assembly tolerates more vibrations than rectangular type robot arm assembly. Ristea [8] compare the result of composite material and aluminium for construction of robot. Zhang and Cai [9] suggested a technique of recompense on the inaccurate model with the 6-pivot robot's factors of kinematic assembly and the joint point and found that the fundamental factor of the dynamic mistake is the distortion of the associating bars. Pradeep Kumar Dhote *et al*. [10] considered an industrial robotic arm and for a particular weight circumstance, they calculate the stress and deformation analysis. They did their simulation by MATLAB and compare their theoretical data with the MATLAB resulted data.

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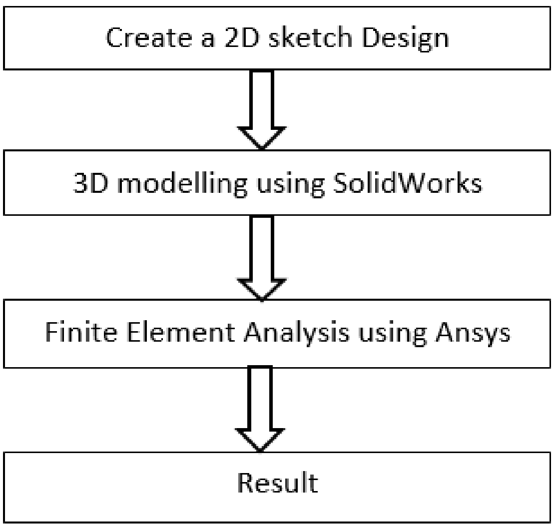
II. MODELLING OF ROBOT

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, and end nozzle. 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. The assembly of automated arm design should be organized to execute job. There are three dissimilar stages to regulate robotic arm such as awareness, observation and enactment. 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. The large amount of robots we use are mainly controlled by electric motors. Precise manoeuvre of linkages of the robots are should be controlled, which can be accomplished utilizing servo motors. Servo motors are govern by utilizing pulse width modulation (PWM) information given by the automated controller for stimulating the linkages of robotic arm. Servo motors are equipped for producing an enough torque to move an item rapidly from rest position. In this way, servo motors are regularly utilized in modern mechanical technology as an elite substitute to the stepper motors. Because of its specific movement, its make the robotic arm more trustworthy.

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. Lastly, the drawing is generated to produce the sketch of the fragments in many setups. The specification and design methodology of the structure is given below-

A. Design Methodology



The assumptions for the methodology have been considered by the above framework as shown above. The introduced model has been designed in the SolidWorks and analyzed in the Ansys.

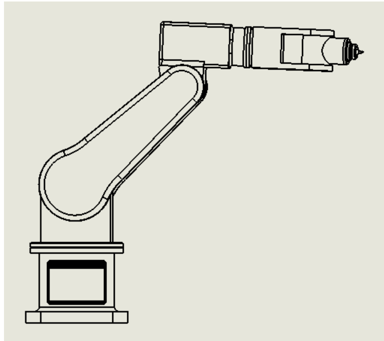


Fig. 1. 2-D design of the robotic arm

The 2D design of the robotic arm has been designed for the clear representation of the model that shown in Fig. 1 and the 3-D CAD model of robotic arm has been designed for FEM analysis in the current study. After the design on 2D and 3D model of the robotic arm, modal analysis has been investigated by FEM method in ANSYS that help to found the shear stress and total deformation of the robotic arm and the outcomes of this study has been mentioned below in result and discussion section.

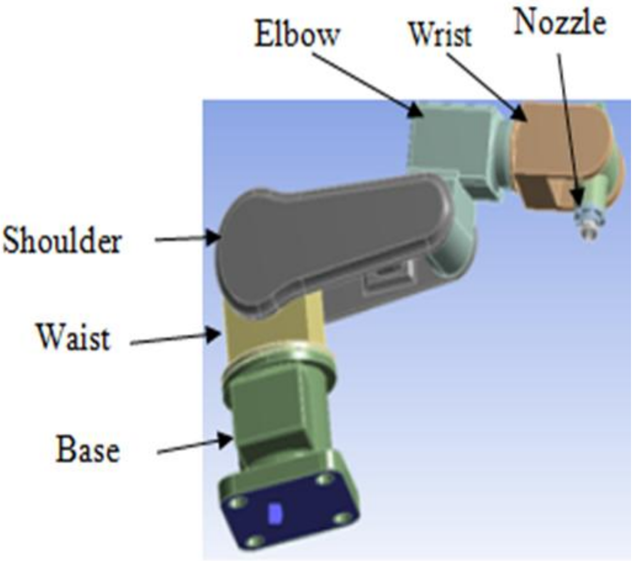
B. Specifications oF Robot Arm

This articulated robotic arm is a revolute kind that closely appears identical to a human arm.

Table I. Specification of Model [1]

Specification	Value
Degree of Freedom	5
Total Horizontal Reach	111.5 cm
Total Vertical Reach	157.1 cm
Drives	5 servo motors
Structure	a)All the axes are Self-governing b) concurrently we can control all the axes
Material	Aluminium Density- 2.7g/cm3 Poisson's Ratio- 0.334

The shoulder that is fixed on the base which can give the movement of the arm up to 90 degrees will likely be turned from level to vertical on each side. The length of the shoulder part is 500 mm. The shoulder uses widespread gauge servo, gives the torque estimated to lift the rest of the robotic arm part. The elbow (length 215 mm) part of the design is attached to the shoulder part of the design and can move up to -180 to 90 degrees. The wrist (length 220 mm) part of the design attached to the elbow and can move up to 360 degrees. The nozzle (length 120 mm) part of the design is attached with a wrist and can move up to -90 to 90 degrees. The robotic arm design consists of several portions as shown in Fig. 2.



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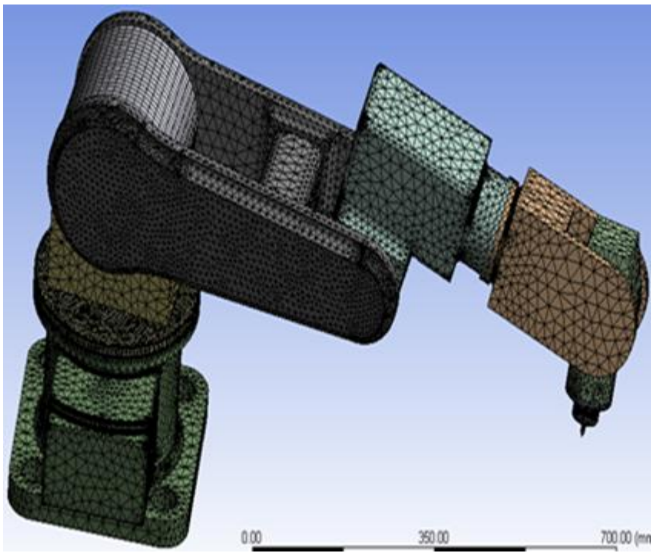


(b)

Fig. 2. (a) The complete design of the robotic arm model (b) Design of model with meshing

III. THE SOLIDWORKS MODEL AND ANALYSIS

A. Modelling of Robotic Arm in SOLID WORKS

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 five –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.

B. Finite Element Stress Analysis (FESA) by ANSYS

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 nozzle end. For this design, aluminium is picked as a standard material because of its low cost and more reliability. For examining the entire robotic arm design, the different weights considered are 0.5 N, 25 N, 50 N, 75 N, 100 N and 125 N [11]. The entire research is complete to acquire shear stresses (SS) for dissimilar weights applied, and the different data of SS gotten is written down.

C. Finite Element Model Analysis (FEMA) by ANSYS

Oscillation attributes of the structure design such as natural frequency and mode shape are calculated by the technique of modal analysis in finite element analysis. The existence of fracture or destruction in any mechanical assembly, turning machinery, reasons for impulsive disaster and makes many working complications. By this, we can identify the mistake which is the reason for modification in the dynamic response of the model. Due to the existence of fracture, a variety of parameters such as the natural frequencies, mode shapes, and amplitude of vibration takes place.

IV. RESULT AND DISCUSSION

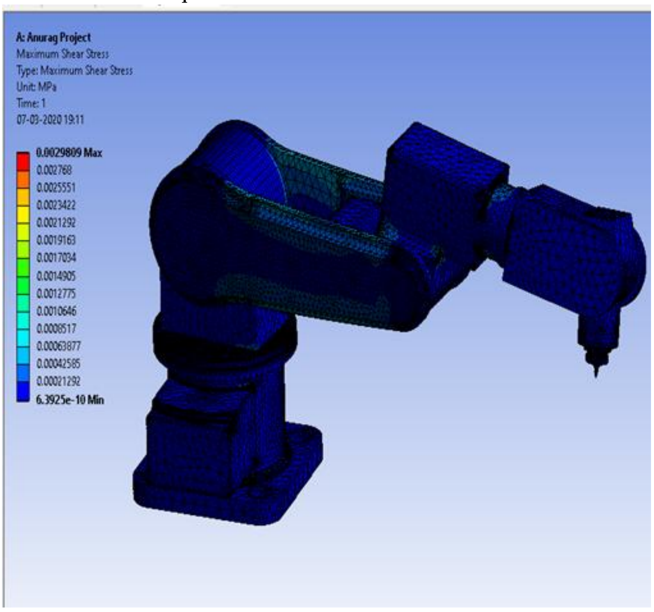
Improved mechanical design for the assemblies of the manufacturing robots has to reach the standard concerning aspect model and structure, material depletion and accommodate design to the operative necessities. For an improved model of the robotic arm design, every characteristic of industrial instruments where the different shapes can incorporate is examined. For the different load acted on the robotic arm to get the value of shear stress (**SS**) and total deformation are mentioned in Table 2.

Table 2. Data of total deformation and maximum SS on six dissimilar weight conditions

S. No.	Nozzle loads (N)	Total Deformation (mm)	Maximum Shear Stress (Mpa)
1.	0.5	2.8877e-5	0.002981
2.	25	1.4439e-3	0.14905
3.	50	2.8877e-3	0.29809
4.	75	4.3316e-3	0.44714
5.	100	5.7754e-3	0.59619
6.	125	7.2193e-3	0.74524

The analysis of total deformation and stress of the model provides the basic information regarding life span, destruction and screw-up of the design. The SS for 6 dissimilar nozzle weights is presented in Fig. 3. The base portion of the modal having the most minimal estimation of SS has appeared as dull blue shading, and the top portion of the modal displays the highest data of SS has appeared as red shading.

The extreme data of SS acquired is 125 N which is close to the nozzle. Left half of the figure contains dialog box and gives the required data. The dark blue colour shows the least data, the light blue colour shows the lesser data, the yellow colour demonstrates the greater data than previous one, and red shading demonstrates the uppermost data of SS. After getting these final data of SS, a chart has been plotted by considering weight (N) in the x-axis and SS (Pa) in the y-axis and is appeared in Fig. 5. From the chart, it is very clear that as the weight expands the SS increments consistently. Furthermore, for the weight of 125 N, it is the largest data of 0.74524 MPa is acquired.



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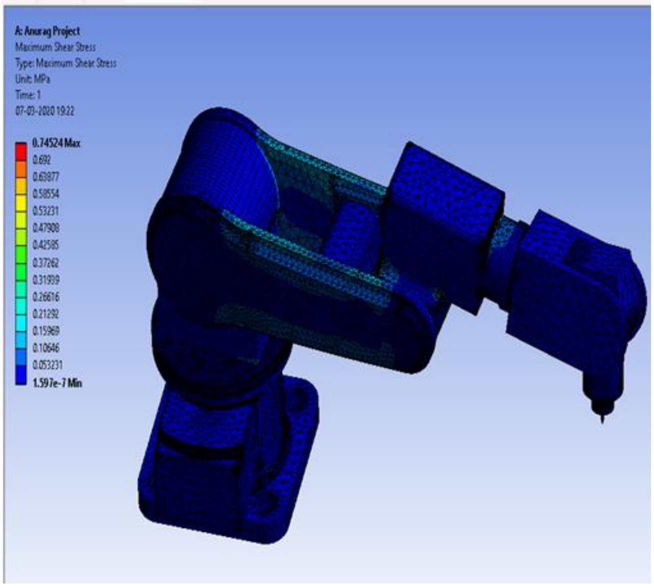
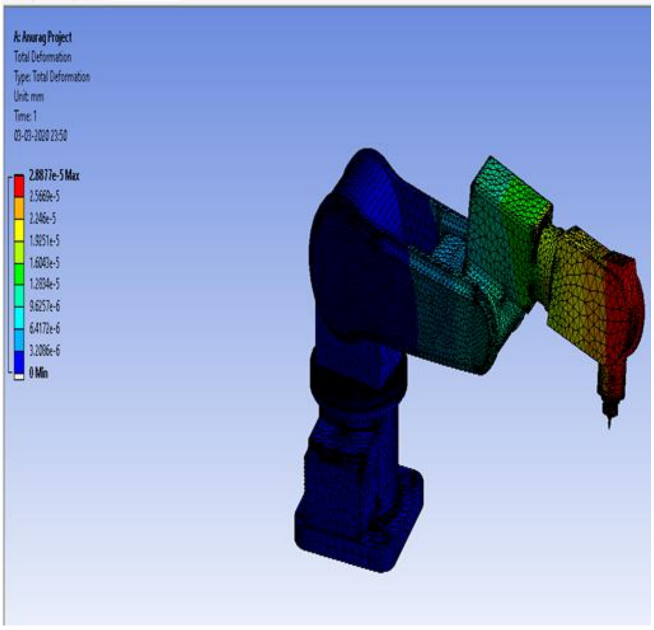


(b)

Fig. 3. Shear Stress of design structure (a) Nozzle weight of 0.5 N (b) Nozzle weight of 125 N

Shear stress of robotic arm design for nozzle weight of 0.5 N and 125 N is presented in figure 2 and we can clearly see that for load 0.5 N stress value is lower than for weight of 125 N.

Total deformation of our robotic arm design for load of 0.5 N and 125 N is presented in Fig. 4. The dark blue colour shows the least data, the light blue colour shows the lesser data, the yellow colour demonstrates the higher data, and red shading demonstrates the maximum data of total deformation.



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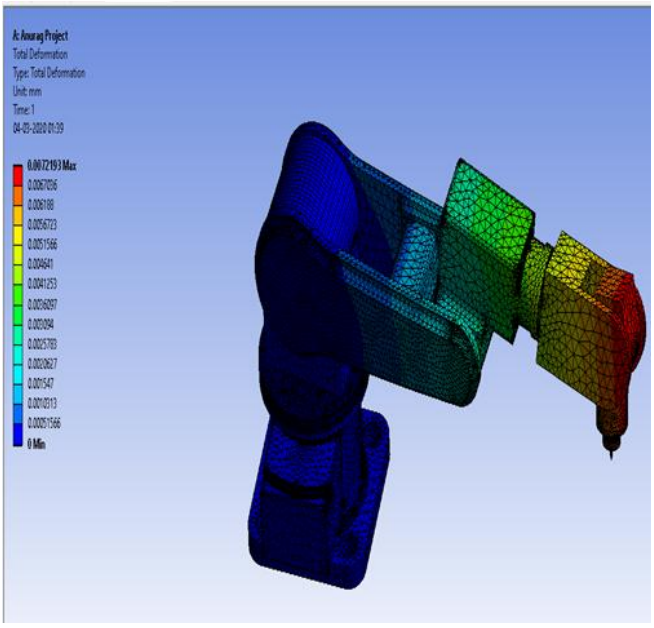

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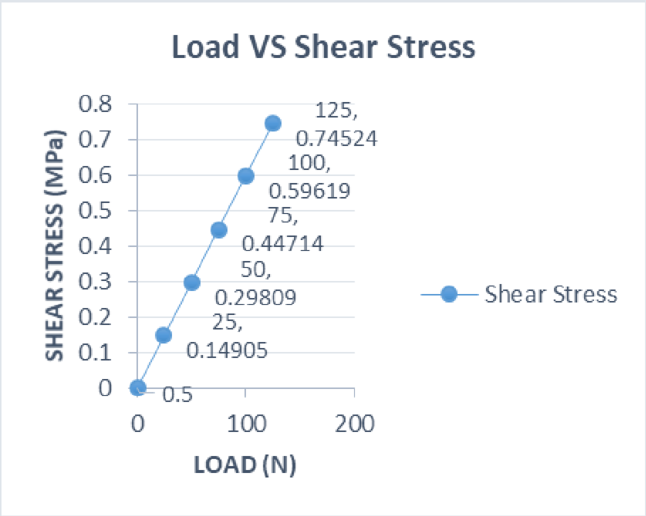
Fig. 4. Total deformation of robotic arm design (a) nozzle load of 0.5 N (b) nozzle load of 125 N

From the above Fig 4, it can be clearly seen that least deformation is occur at the lower part of robotic arm and the maximum deformation occurred close to the nozzle. As the load increases at the nozzle point it is clearly seen from the result that total deformation increases.



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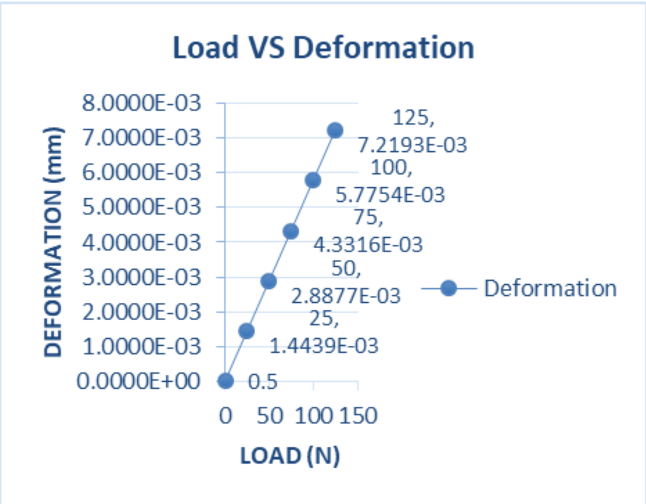

(b)

Fig. 5. Graphical representation (a) Load vs Shear stress (b) Load vs Deformation

V. CONCLUSIONS

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 5-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 and maximum shear stress 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.

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