DESIGN AND STATIC ANALYSIS OF WEIGHT LIFTING ROBOTIC ARM

PROJECT REPORT

Minor project-2

Submitted by –

Ravishankar Tiwari

20UME134

Vishal Kumar Ram

20UME098

6th Semester-2022

Under the esteemed guidance of

DR. SUBRATA KUMAR GHOSH

Assistant professor

DEPARTMENT OF MECHANICAL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY AGARTALA

WEST TRIPURA PIN-799046, INDIA

CERTIFICATE

National Institute of Technology, Agartala

It is to certify that the entitled project "**Design and Static Analysis of Weight Lifting Robotics Arm**" has been submitted to the department of Mechanical Engineering, National Institute of Technology Agartala for the fulfilment of 6th semester minor project.

Ravishankar Tiwari (20UME134)

Vishal Kumar Ram (20UME098)

Supervisor:

Dr. Subrata Kumar Ghosh

APPROVAL SHEET

This report entitled "**Design and Static Analysis of Weight Lifting Robotics Arm**" by

RAVISHANKAR TIWARI (20UME134)

VISHAL KUMAR RAM (20UME098) is approved for the minor project of 6th Semester Bachelor of Technology in Mechanical Engineering.

Examiners:

Supervisor:

Dr. Subrata Kumar Ghosh

Assistant Professor

Date: 08.05.2023

Place NIT Agartala

ACKNOWLEDGMENTS

There are numerous people to whom I owe a great deal of gratitude and without whose constant help, guidance and stewardship this endeavor never would have come to fruition. Primarily I would like to thanks Assistant professor **Dr. Subrata Kumar Ghosh** sir, who were endlessly patient and kind and who found time for me even when they had none. An engineer's conceptions are often limited by the talents of his machinists, but this was hardly true in my case. The bulk of the machining was done at the Mechanical Department machine shop by central workshop I would also like to thank the members of the Composites Group for their assistance. Finally, nothing would have been possible without the unwavering support of the group to whom this work is dedicated.

ABSTRACT

In this Project, 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 SOLIDWORKS and the whole structure evaluation has been executed by SOLIDWORKS. 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 arobotic arm is done with the help of SOLIDWORKS, 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.

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I. INTRODUCTION

The term robot is derived from Czech word "robota" which means forced labor. Nobody has ever given a precise explanation of what a robot is, although each of those definitions more or less means the same. To make things simpler, "Robot is a combination of electronics, mechanics and programming which senses it's surrounding through its sensors processes the sensor information and does something in response". The response can be locomotion or manipulation, like turning on a LED, rotating a wheel, moving an arm, raising an alarm and so on. The branch of computer science and engineering which deals with robot design, construction, application and operation is called Robotics with applications in computer science, physics, engineering, defense and even many household devices.

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 andconnect the device with the other part of devices to take effortless or essential judgment to run adequately.

A robot has a mechanical manipulator 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 SOLIDWORKS. Many weight cases throughout FEA to confirm that the robotic armdesign 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 andexecuting trials or tests takes less than a few hours, and also asimulated 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 specificationcan show on the monitor. The skill to set up an instantaneoussimulation is specifically essential in the innovative stages ofthe 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 andcomputationally 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 ofdesign, 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. So, basically for planning the design of the robotic arm structure the essential job is to examine the total deformation and shearstress value. examined a technique and demonstrating has been done on mechanical robots of less mass dependent on unbending connection outline method. Inview of the limited component technique decided the ideal standards for the structure constraints considering the conditions of diminishing the material used to construct the robot.

II. MODELING 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, fore arm, and end nozzle. To deliver proportional motion among these portions' servo motor is used. Each portion of the design has 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 forarm 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 number of robots we use are mainly controlled by electric motors. Precise man oeuvre of linkages of the robots are should be controlled,which can be accomplished utilizing servo motors. Servo motors are governed by utilizing pulse width modulation 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, it makes 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 component, specification and design methodology of the structure is given below-

III. MAIN COMPONENTS OF A ROBOT

❖ **Control System**: the CPU that directs a robot's task at high level.

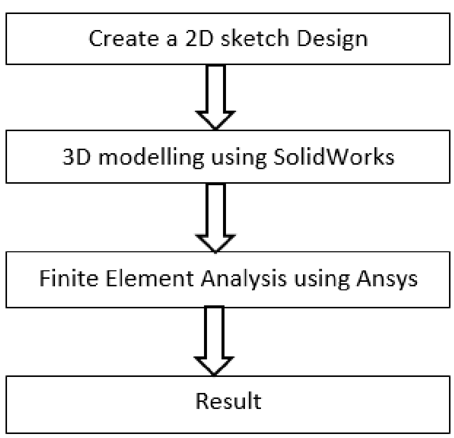
❖ **Sensors:** a component that provides electrical signals to allow a robot to interact with the world.

❖ **Actuators:** the motor parts that are responsible for a robot's movement.

❖ **Power Supply:** the battery that supplies power to a robot.

❖ **End Effectors:** the exterior features of a robot that allow it to complete a task.

A. <u>Design Methodology</u>



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

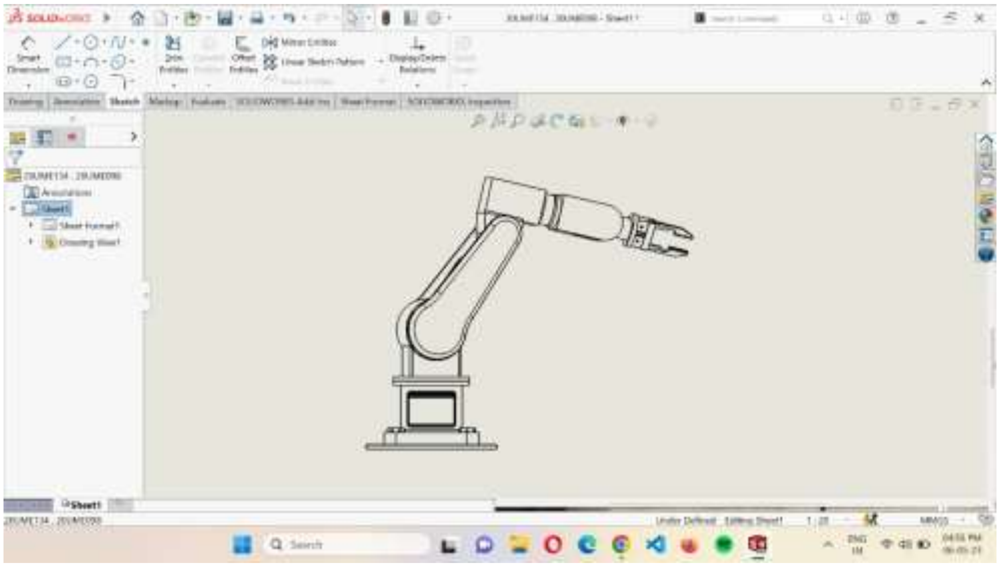


Fig. 1. design of the robotic arm

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 1 Specification of Model

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 theaxes
Material	Aluminum 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 attachedto 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 robotic armdesign consists of several portions as shown in Fig. 2.

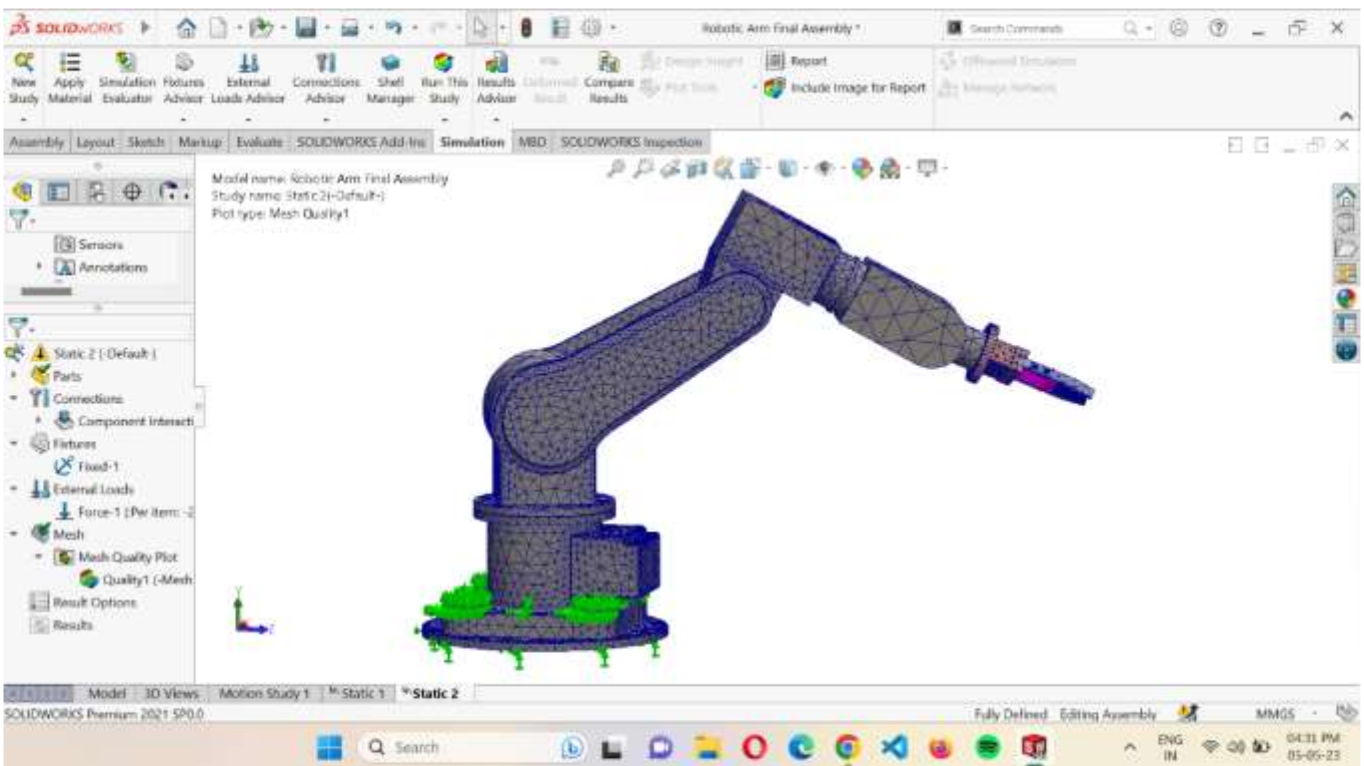


Fig. 2

IV. THE SOLIDWORKS MODEL AND ANALYSIS

A. Modelling of Robotic Arm in SOLIDWORKS

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 by SolidWorks

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

V. 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.

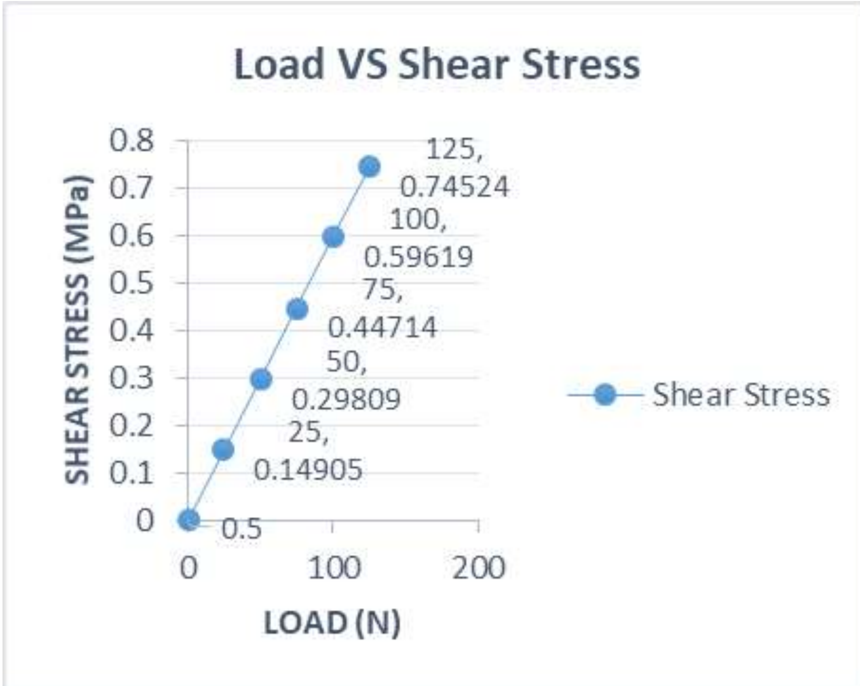
Table 2. Data of total deformation and maximum SS onsix dissimilar weight conditions

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

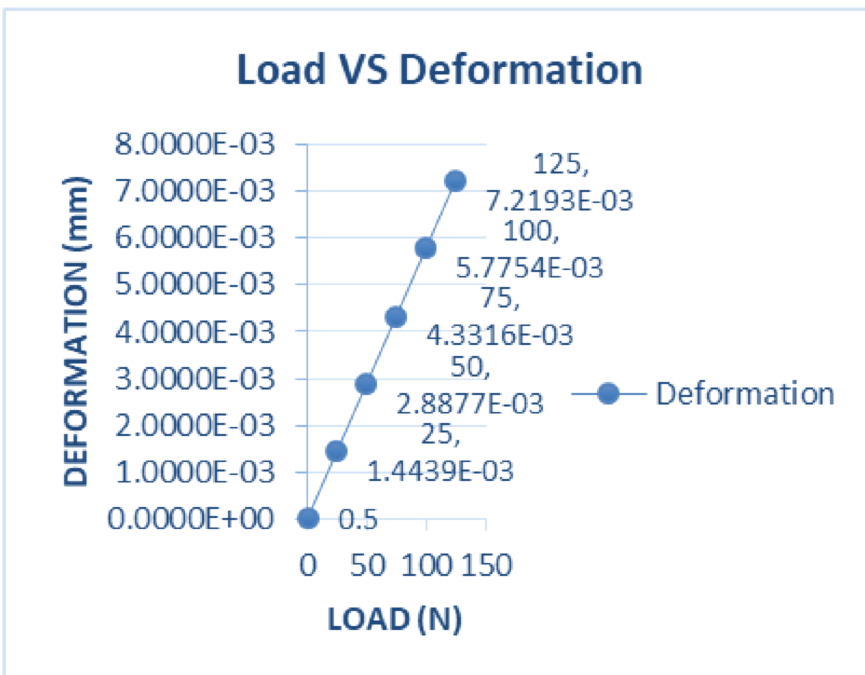
The analysis of total deformation and stress of the model provides the basic information regarding life span, destruction and screw-up of the design. The SS for 6 dissimilar nozzle weights is presented in Fig. 3.

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 tothe nozzle. Left half of the figure contains dialog box and gives the required data. The dark blue color shows the leastdata, the light blue color shows the lesser data, the yellow color 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-axisand is appeared in Fig. 5. From the chart, it is very clear that asthe weight expands the SS increments consistently. Furthermore, for the weight of 125 N, it is the largest data of 0.74524 MPa is acquired.



(a)



(b)

Fig. 5. Graphical representation

(a) Load vs Shear stress (b) Load vs Deformation

VI. USES AND APPLICATION OF ROBOTS

Robots have a wide variety of use cases that make them the ideal technology for the future. Soon, we will see robots almost everywhere. We'll see them in hospitals, hotels and even on roads.

1) Robotics in Manufacturing

The manufacturing industry is probably the oldest and most well-known user of robots. These robots and co-bots (bots that work alongside humans) work to efficiently test and assemble products, like cars and industrial equipment. It's estimated that there are more than three million industrial robots in use right now.

2) Logistics Robots

logistics companies employ robots in warehouses, and even on the road, to help maximize time efficiency.

3) Robots for Home

Robots can be seen all over our homes, helping with chores, reminding us of our schedules and even entertaining our kids.

4) Travel Robots

Is there anything more science fiction-like than autonomous vehicles? These self-driving cars are no longer just imagination. Companies like Tesla, Ford, and BMW are all working on the next wave of travel that will let us sit back, relax and enjoy the ride.

5) Healthcare Robotics

Examples of robots at work in healthcare are Toyota's healthcare assistants, which help people regain the ability to walk, and TUG.

VII. ADVANTAGES AND DISADVANTAGES

Advantages of Robot

1) Lower Cost
2) Improved Quality Assurance
3) Increased Productivity
4) Energy Efficient
5) Faster Operating Speeds
6) Heavy lifting for long durations of time

Disadvantages of Robot

1) Potential Job Losses
2) Initial Investment Costs
3) Hiring Skilled Staff
4) Expensive Maintenance
5) Availability of Space

VIII. SAFETY PRECAUTIONS

1. The workspace of robots that pose significant risk of minor or major injury (large and/or non-collaborative robots) shall have their workspace marked off with appropriate floor tape, safety barriers, and/or signage.
2. Robots that pose significant risk of major injury shall have indicator lights around the robot's workspace that activate when the robot's movement is permitted and/or is placed in autonomous mode.
3. Experiments that involve study personnel or humans subjects performing close-proximity interaction with a robot must have a safety plan describing how persons will be instructed to avoid collisions, pinch points, and other hazards on the robot. The plan should be kept on file with the Lab Manager John M. Hart.
4. Read the safety sections of the manufacturer's manual before operating a robot for the first time.
5. E-stops must be operational and within reach at all times when the robot is powered on.
6. When approaching a damaged or possibly stuck robot arm, first remove the power and be wearing proper protection equipment (safety glasses, shoes, attire, etc.)
7. Before robot operation:
    1. Check for signs of damage to the robots, observe if there are any fluid spills, broken wires, loose cables, etc.
    2. Dress properly and use appropriate safety equipment:
        1. Wear safety glasses and other suitable PPE
        2. Remove loose-fitting clothing (ties, scarves, extra-long or loose sleeves, etc.)
        3. Tie up long hair, etc.
    3. If uncertain of the safety of the operation to be undertaken, notify the IRL Lab Manager or other CSL faculty or staff and obtain guidance before proceeding.
    4. Use extra caution when performing motion experiments for the first time or if recovering from a collision. When running any new code, observe the robot carefully with a hand on the E-Stop (Emergency-Stop) button
8. During robot operation:
    1. Everyone in the vicinity of the robot must be mentally alert and paying attention (no headphones, etc.)
    2. Have a safety-buddy present when the robot is performing any autonomous function.
    3. E-Stop pushbuttons must always be within reach of any person working with the robot
    4. Before starting any robot movement, communicate with others loud and deliberately on the operation about to be executed, such as "Starting robot motion"
    5. For collaborative robots (ISO/TS 15066:2016), personnel can be within the robot's workspace while the robot is performing autonomous functions, but it is highly recommended to avoid entering the robot's workspace unless necessary.
    6. For non-collaborative robots, all personnel must be outside of the robot workspace while the robot is performing any autonomous function.
    7. Disable the robot after experimentation is complete.

IX. FUTURE OF ROBOTICS

There is no denying that Robotic technologies are all set to change the way things are done in the industries in which they are being implemented. Entrepreneurs are voicing a similar sentiment and are clearly optimistic about the use of Robotics in various industrial segments. Robotics is mainly capturing industries like manufacturing, pharmaceutical, FMCG, packaging and inspection. A bit of Robotics would also be seen in the healthcare sector primarily in the form of assistive and skill development technologies. The other promising sectors are defense and education. World had come across PC revolution and mobile revolution in the recent past now it is the time for inevitable robotics. Considering that the global players, like Google, FESTO and Tesla are investing in Robotics along with substantial increase in amateur robotic enthusiasts, Open source tools and platforms available for robotics, It is assured that significant development in this field will occur in another

5-10 years.

X. 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 SOLIDWORKS 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 SOLIDWORKS with mesh size of 0.05 are significantly decent whereanalysis 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 (SOLIDWORKS), the extreme data of the different aspects can be figured out which can cause to failure of the model design.

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