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DESIGN AND ANALYSIS OF ROBOTIC ARM FOR EFFICIENT PICK AND PLACE OPERATIONS

[1]P Rajesh, [2] Naveen Kumar,[3] K Ganesh,

[1]PG Student, Dept. Of Mechanical Engineering, Kuppam Engineering college, AP, India
[2]Associate Professor, Dept. Of Mechanical Engineering, Kuppam Engineering college, AP, India
[3]Associate Professor & HOD, Dept. Of Mechanical Engineering, Kuppam Engineering college, AP, India

Abstract: This paper presents says that every year many workers are injured, become ill or are killed because of exposure to harmful chemical substances. These incidents cause human suffering, loss of production and high medical cost. This robotic arm aims to give assistance and guidance to employers and workers to promote a safe and healthy work environment and prevent injuries. And also repetitive tasks and high accuracy have become the two contradictory needs of any industrial process. By introducing autonomous robotic applications, simple repetitive tasks can be accomplished keeping the demands of the accuracy and speed in mind. This report presents an approach mechanical system design concept and fabrication of three degrees of freedom jointed arm robot with locally available materials, which should perform industrial task such as pick and-placement of waste chemically hazardous material. The special feature of this robotic arm is that it can rotate on its base around 360° and a gripper system. This robotic arm has forward backward motion and rotation on the base. These function and the movement of the arm is controlled by a lab view program via servo & DC motors, PC, motor drive IC, Arduino and an Wi-Fi control module. Mechanical gripper has been built as end effector and is capable of grasping diverse objects, even under external disturbances, within own workspace of the arm possible. Control of the robotic arm assembly has been achieved successfully using two DC motors and four servo motors. By controlling these six motors the robot can achieve a total of five degrees of freedom. The Arduino implements the position control on the motors. The project shows that the program allows the Arduino to automatically adjust their commands to be appropriate for the arm dynamics and the task. The design aims to provide fine manipulation in performing industrial tasks, while still maintaining the simplicity of design, miniaturization, and lightness are also achieved

Index Terms **-** robotics, industrial automation, hazardous material handling, servo motors, DC motors, Arduino control, LabVIEW programming, and workplace safety.

I. Introduction

The last two decades have witnessed a significant advance in the field of robots applications. Many more applications are expected to appear in space exploration, battlefields and in various activities of daily life in the coming years. Now-a-days various chemically hazardous materials are produced in factories which are very much dangerous for human body. Our project is to build a robotic arm model which can discharge these hazardous materials without any touch of human body. Robot is a mechanical device that performs automated tasks and movement according to either pre-defined program or a set of general guidelines and direct human supervision. These tasks either replace or enhance human work such as in manufacturing construction or manipulation of heavy and hazardous materials. To pursue a challenging career in a design environment that utilizes our skills and knowledge to best suit organizational growth. Man is progressive and the Engineers are the pioneers to the progress. The objective of being an engineer is to achieve the capability of performing laborious jobs with ease using certain mechanisms. With the advancement of modern technology manual labor is more & more replaced and reduced by the use of technological excellence Jointed Arm robots are suitable for a wide variety of industrial tasks, ranging from welding to assembly. A jointed arm robot has some rotational axes connecting rigid links and a base. It is sometime called an anthropomorphic arm because it closely resembles a human arm. It usually stands on a base on which it can rotate, while it can articulate at the "shoulder" joint, which is just above the base. The robot can also rotate about its "elbow" and "wrist" joints. These names match those of the corresponding human parts. The "hand" of a robot is known as gripper, an end effector, an actuator, or end-of-arm tooling. It consists of the driven mechanical devices attached to the end of the manipulator, by which objects can be grasped or acted upon. The robot may require a different type and design of hand for each different object to grasp or each different tool to build. In some cases, the hand itself acts as the tool. Clearly, designing grippers properly is a key task in robotics.

II. LITERATURE REVIEW

The various works are carried out in stress analysis, Modal analysis of Robotic arm. Among which few are categorized and discussed below

In this paper, they have used 4 servo motors to make joints of the robotic arm and the movement will be controlled with the help of potentiometer. The controller used is Arduino UNO. The analogue input signals of the Arduino's are given to the Potentiometer. The arm has been built by the Cardboard and individual parts are attached to the respective servo motors. The arm is specifically created to pick and place light weight objects. So low torque servos, with a rotation of 0 to 180 degrees have been used. Programming is done using Arduino 1.6.10. Thus the paper basically focuses on creating a robotic arm with non-useful materials and its application on small purposes**. [1]**

The objective of this finding is to make a manipulator which can sort objects on basis of color using specific motors and photodiode sensors programmed with a Arduino Mega series microcontroller. The light photodiode sensor can identify RGB colors. In this system the output of Arduino Mega 2560 is displayed on a LCD screen which is an indication of the observed color. The first step of object moving process is by distinguishing the RGB color. The gripper of robotic arm will move to pick objects based on color, depending on the color input given by the light photodiode sensor. Arduino Mega 2560 is a microcontroller that uses ATmega2560 which is installed in robotic arm having 54 digital i/o ports segregated into different types. In this paper a color sensor testing is also carried out ,having a target to determine the ability of Photodiode sensor for distinguishing of color .The resultant voltage from photodiode will be sent to ADC to process and show result on the LCD screen provided.**[2]**

In this research paper the authors successfully built 4 degrees of freedom robotic arm using soft computing. They have formulated ways for controlled movement of robotic arm and planning of trajectory with the help of Genetic Algorithms (GAs) and fuzzy logic (FL). As optimal movement is critical for efficient autonomous robots. This architecture is used to limit the issues related to the motion , friction and the settling time of different components in robotic arm. Genetic optimization is used to find the finest joint angles for this four d-o-f robotic system. This type of optimization replaces the long process of trial and error in search of better combination of joint angles, which are valid as per inverse kinematics for robotic arm movement. These logic models (Fuzzy logic) have been developed for the joint movement, friction and least settling time attributes as the fuzzy logic input.**[3]**

Variety of tasks can be performed by a robotic arm when we do some changes in it , i.e changing the number of links, it can be made self- adaptable , this aspects of a robotic arm is discussed by the author in this paper. The paper represents a basic robotic solution to fulfill different applications with the help of it. The Design consists of two panels which have there individual wiring with it, thus as per the application required the panels are arranged and servo motors are connected to perform the task.**[4]**

The paper represents the author using accelerometers to collect information. The controller used is Arduino Atmega328. Human arm motion, a finger are located by flex, gyro sensors and signals are sent to Arduino ATmega328 which in turn controls the servo motors and makes the movement of the arm possible. The programming of the Arduino was done with the help of embedded C language. The Flex and Gyro Sensors were placed near the fingers. Whenever the change is detected, the information by both the sensors is processed by the controller. The Future Scope of this paper includes using 5 Flex Sensors near the fingers and more Gyro for the ease of operation.**[5]**

III. Objective of the Work

The objective of this study is to design and analyze a robotic arm system tailored specifically for efficient pick-and-place operations in industrial settings. The primary goals of this work include:

1. **Mechanical Design Optimization:** To develop a robust mechanical design for the robotic arm that maximizes efficiency, accuracy, and reliability in pick-and-place tasks. This involves selecting appropriate materials, optimizing linkages and joints, and ensuring adequate payload capacity and workspace coverage.
2. **Kinematic and Dynamic Analysis:** To analyze the kinematic and dynamic characteristics of the robotic arm to determine its motion capabilities, workspace reachability, and response to external forces. This includes modeling the arm's motion using forward and inverse kinematics, as well as conducting dynamic simulations to evaluate its performance under various operating conditions.
3. **Control System Development:** To design and implement control algorithms and strategies that enable precise and coordinated movement of the robotic arm during pick-and-place operations. This involves developing real-time control algorithms, trajectory planning methods, and sensor integration techniques to ensure accurate positioning and manipulation of objects.
4. **End-Effector Design Optimization:** To design and optimize the end-effector, or gripper, of the robotic arm to enhance its grasping capabilities, adaptability to different objects, and overall efficiency in pick-and-place tasks. This includes selecting appropriate gripper types, optimizing grip force and dexterity, and integrating sensors for object detection and feedback.
5. **Performance Evaluation and Optimization:** To evaluate the performance of the robotic arm system through comprehensive testing and analysis. This involves assessing factors such as cycle time, throughput, energy consumption, and reliability in pick-and-place operations. Additionally, optimization techniques will be employed to further improve system efficiency and performance metrics.
6. **Validation and Verification:** To validate the design and analysis results through experimental testing and validation in a controlled laboratory environment. This includes conducting physical prototype testing, comparing experimental results with simulation predictions, and verifying the functionality and effectiveness of the robotic arm system for pick-and-place operations.

Overall, the objective of this work is to contribute to the advancement of robotic technology for industrial automation by designing and analyzing a highly efficient and reliable robotic arm system tailored specifically for pick-and-place operations

IV. METHODOLOGY, PROPOSED SYSTEM, OBJECTIVES, PROBLEM IDENTIFICATION AND DESIGN PROPERTIES

A. METHODOLOGY

1. Design Phase:

Determine the required degrees of freedom for the robotic arm to perform pick and place tasks efficiently. consider the reach, payload capacity, and precision needed for the application. design the robotic arm components to ensure compatibility with the rover and wheels.

2. Fabrication Techniques

Utilize 3D printing technology for fabricating precise components of the robotic arm, ensuring accuracy and cost-effectiveness. Fabricate parts such as links, grippers, and supporting structures using appropriate materials like acrylic or metal.

3. Assembly Process:

Assemble the base of the robotic arm by attaching servo motors and necessary components. Connect the different segments of the robotic arm to create a multi-degree-of-freedom structure capable of picking and placing objects. Integrate the gripper mechanism with servo motors for precise gripping functionality

4. Integration with Rover

Connect the fabricated robotic arm to a rover platform equipped with Omni wheels for mobility Ensure proper alignment and stability between the robotic arm and the rover to facilitate seamless movement during pick and place operations.

B. PROPOSED SYSTEM

1. **Integrate Mechatronic Principles**: By combining mechanical, electrical, and computer engineering disciplines, the system integrates mechatronic principles to address industrial challenges.
2. **Optimize Production Processes**: Its primary goal is to optimize production processes within the industrial sector, enhancing overall efficiency.
3. **Enhance Efficiency**: Through mechatronics, the system enhances the efficiency of traditional robotic arms by refining mechanical design, optimizing electrical components, and enhancing computer control mechanisms.
4. **Overcome Limitations**: It addresses the limitations of traditional robotic arms by offering improved adaptability, precision, and versatility in various industrial applications.
5. **Provide Innovative Solutions**: The system offers innovative solutions for pick and place operations, promising higher accuracy, faster cycle times, and improved reliability in manufacturing processes.

C.OBJECTIVES

- Develop a mechatronic robotic arm system capable of precise and accurate movements.
- Implement advanced control algorithms to enhance motion planning and trajectory tracking.
- Improve the arm's flexibility and adaptability to various industrial tasks.
- Integrate safety features to ensure reliable human-robot collaboration.
- Enhance the arm's performance through the use of cutting-edge technologies and materials.
- Reduce overall system costs and maintenance requirements.

D. DESIGN OF A ROBOTIC ARM

1. Design objective

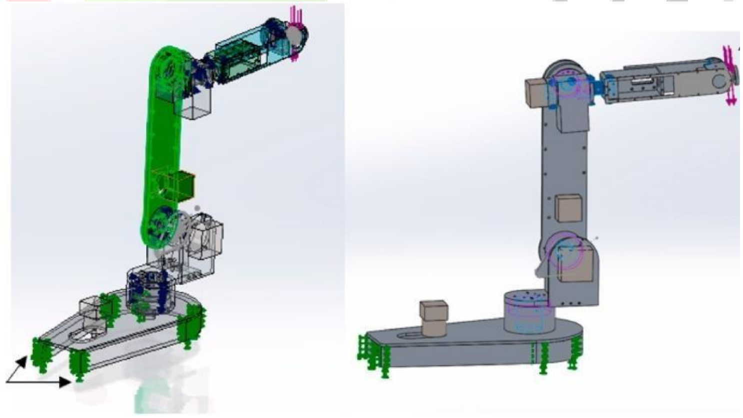


Figure 1 Design of a Robotic and Arm

- xi, yi, zi are coordinates of each joint.
- di is the offset from along zi-1 to the common normal.
- θi is angle about zi-1, from old x axis to new x axis.
- ai is the length of common normal.
- αi is angle about common normal, from old z axis to new z axis.

2. KINEMATIC ANALYSIS

Table 1: kinematic parameters of the robot.

Joints	θ_i	d_i	a_i	α_i
1	θ_1	d_1	a_1	-90^0
2	θ_2	0	a_2	0
3	θ_3	0	0	90^0
4	θ_4	d_4	0	90^0
5	θ_5	d_5	0	90^0
6	θ_6	d_6	0	0

Based on the proposed construction, Table 1 displays the DH parameters of the robot arm.Using the parameters from Table 1, the following forward kinematic equation can be generated to determine the transformation matrix of the connecting rod:

simulated moldboard.

E. ANALYSIS OF ROBOTIC ARM

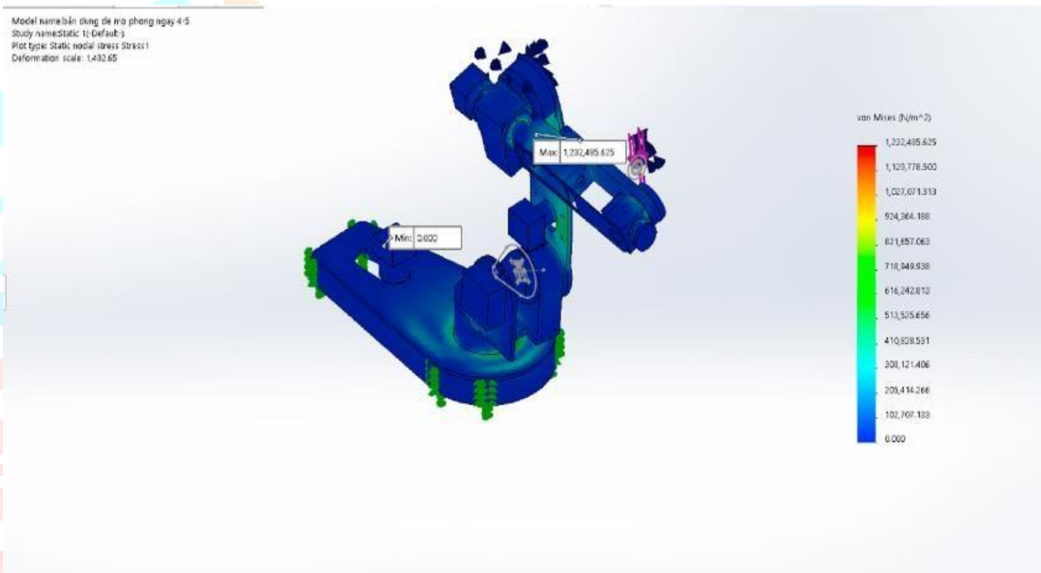


FIG 2 Stress simulation results

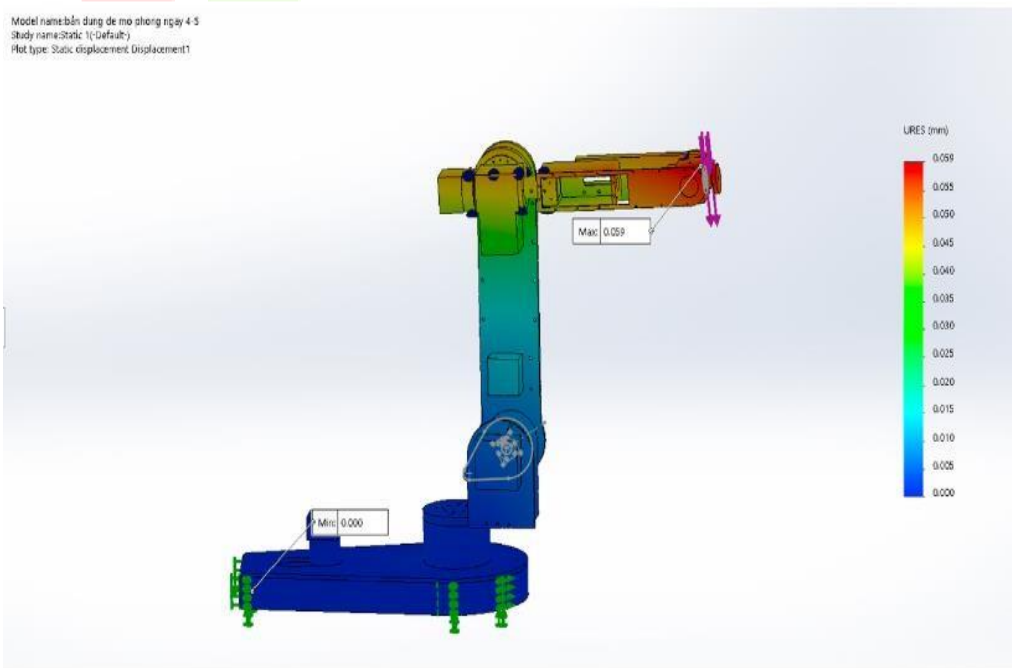
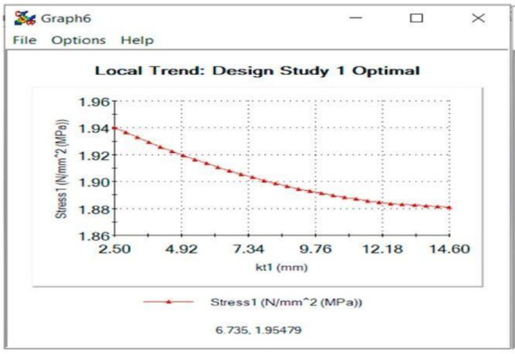


FIG 3 Displacement simulation results

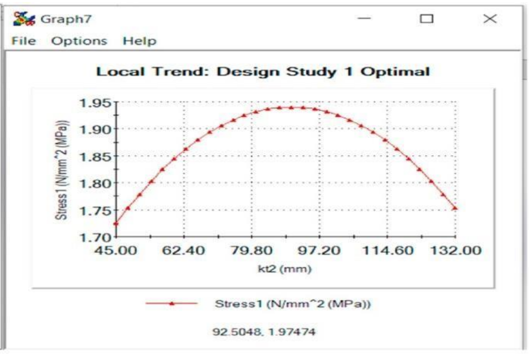
The direction and position of the wrist are represented with respect to the external fixed coordinate system ((world coordinate system O0). We have to solve the above problem for the unknowns θ1, …., θ6. The sixth structure rotation joints with the last 3 joints intersect with the solution method as follows: The position of the wrist center is determined through the tool position (The given tool position - relative to the coordinate system θ0) and the direction of the Tool pointing (Z6).) Because the position of the center of the wrist depends on the first 3 joint variables.

V. RESULT AND DISCUSSION

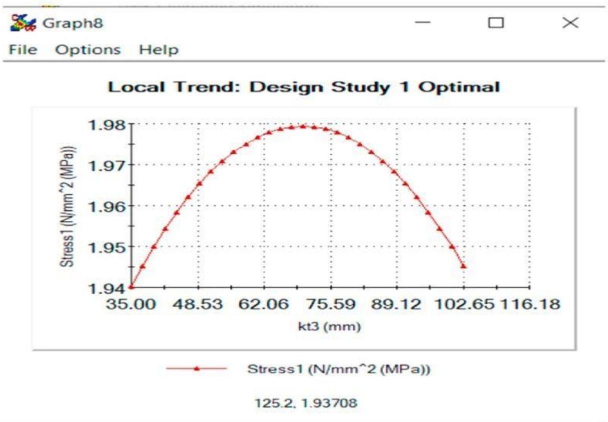
STRESS



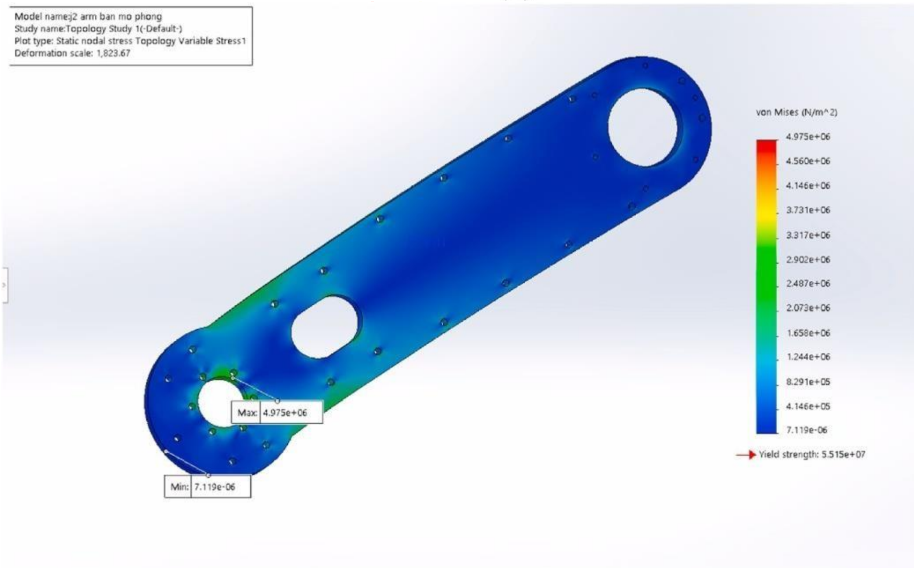
(a)



(b)



(c)



The optimization structure

Strain

The results of the deformation simulation allow us to determine the location of the greatest deformation. The vibration caused by other stages cannot be avoided during the load-bearing process and the movement of the entire model, despite the fact that the largest deformation occurs in the non-bearing portion. The upper portion is comprised of plastic (detail of the shell), so it is easily deformed by external forces

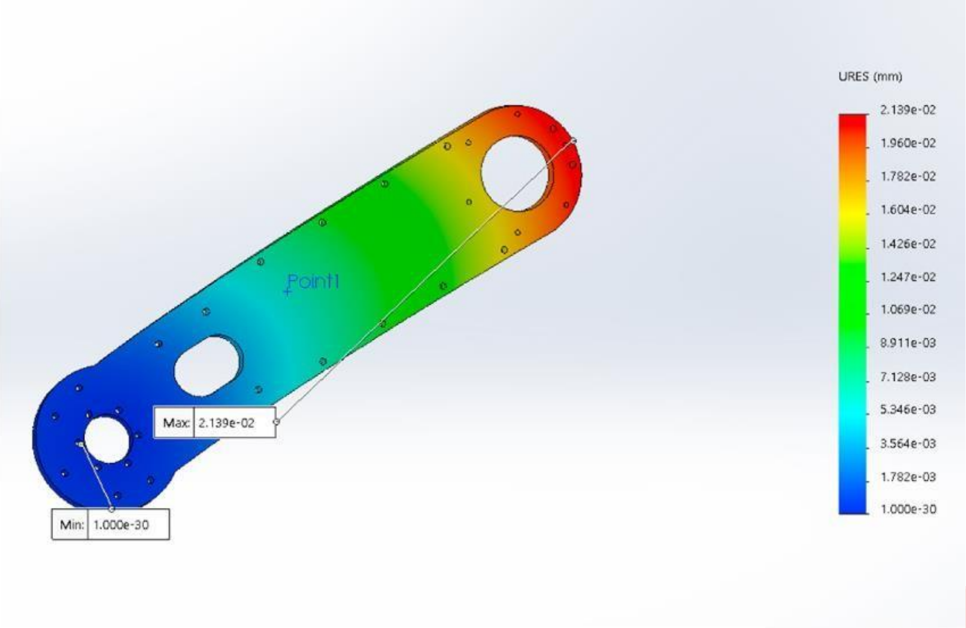


Fig: Displacement from new structure

According to the results of the component's static simulation, there are numerous huge redundant places. To solve this problem, we will employ the topology algorithm with the objective of minimizing the part's volume. The outcomes of the optimization problem for a variety of scenarios with starting constraints. Including the recommended column for the optimalstructure for the specifics.

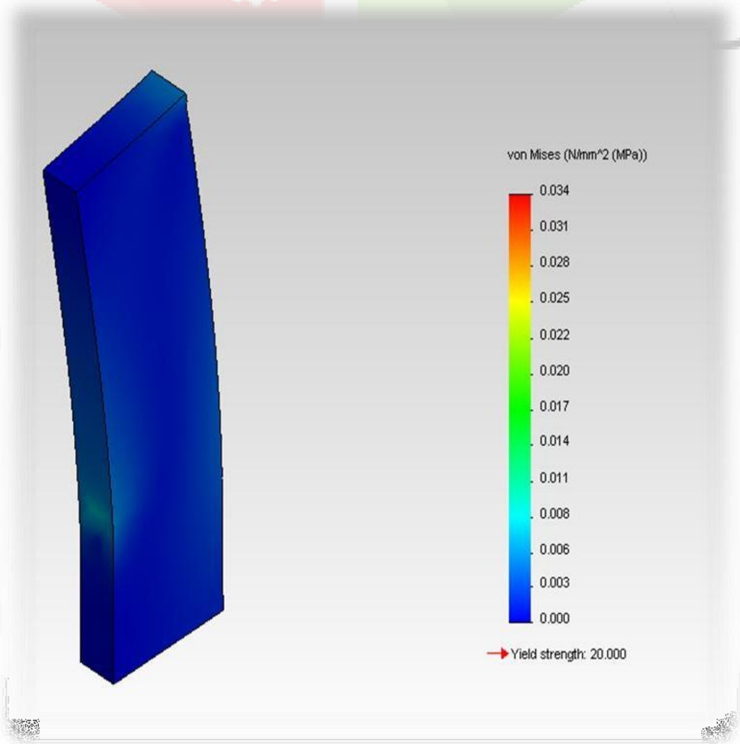


Figure : Dynamic element analysis of first arm showing stress.

TABLE

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 4	0.000870119 mm Node: 1458
Strain1	ESTRN: Equivalent Strain	1.53361e-009 Element: 3462	1.28672e-005 Element: 4139

VI. CONCLUSION

On the basis of result and discussion so far, the following features can be summarized:

- Robotic arm with low costing can be fabricated by locally available materials and instruments.
- A suitable mechanical, programming and control system is required to perform better manipulation with robotic arm.
- Robotic arm is capable to grip objects with various size, shape and load.
- A mechanical arm recreates many of the moments of the human arm having a full 360 degree circular motion.
- A Robotic arm can perform lot of tasks more essentially than human beings because they are so precise.
- A very strong multidiscipline team with good engineering base is necessary for the development of robot and robotics.
- It is expected that flexible automation and robotics technology in particular, will playan important part in the revolutionizing progress of technology.

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