ME 306 Project

Stanford Robotic Arm

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INTRODUCTION AND DESIGNING OF THE ROBOTIC ARM

Robotic arms, like the Stanford arm, are revolutionizing automation across industries. These complex machines mimic human arms, boasting impressive precision and flexibility. They've become irreplaceable tools, surpassing human capabilities in repetitive, hazardous, or highly precise tasks.

The Stanford arm exemplifies this evolution. Its six degrees of freedom, akin to a human arm's movement, allow for a vast range of motions. This versatility makes it suitable for numerous applications. Imagine a tireless worker in a car factory, flawlessly welding intricate parts. Or a delicate assistant in a surgical suite, maneuvering instruments with unmatched precision. These are just glimpses of the potential held by robotic arms.

The future of automation is intricately linked to the continued development of these remarkable machines. Advancements in materials science promise lighter, stronger arms, expanding their capabilities. Integration of sensors will enable real-time feedback, allowing robots to adapt and react to their environment. Machine learning paves the way for robots that can learn and improve, further enhancing their efficiency and adaptability.

Design Components-

Base: The robotic arm's base provides stability and support, serving as the starting point for its movements. In the case of the Stanford robot, the base incorporates the first degree of freedom, allowing rotation around the vertical axis.

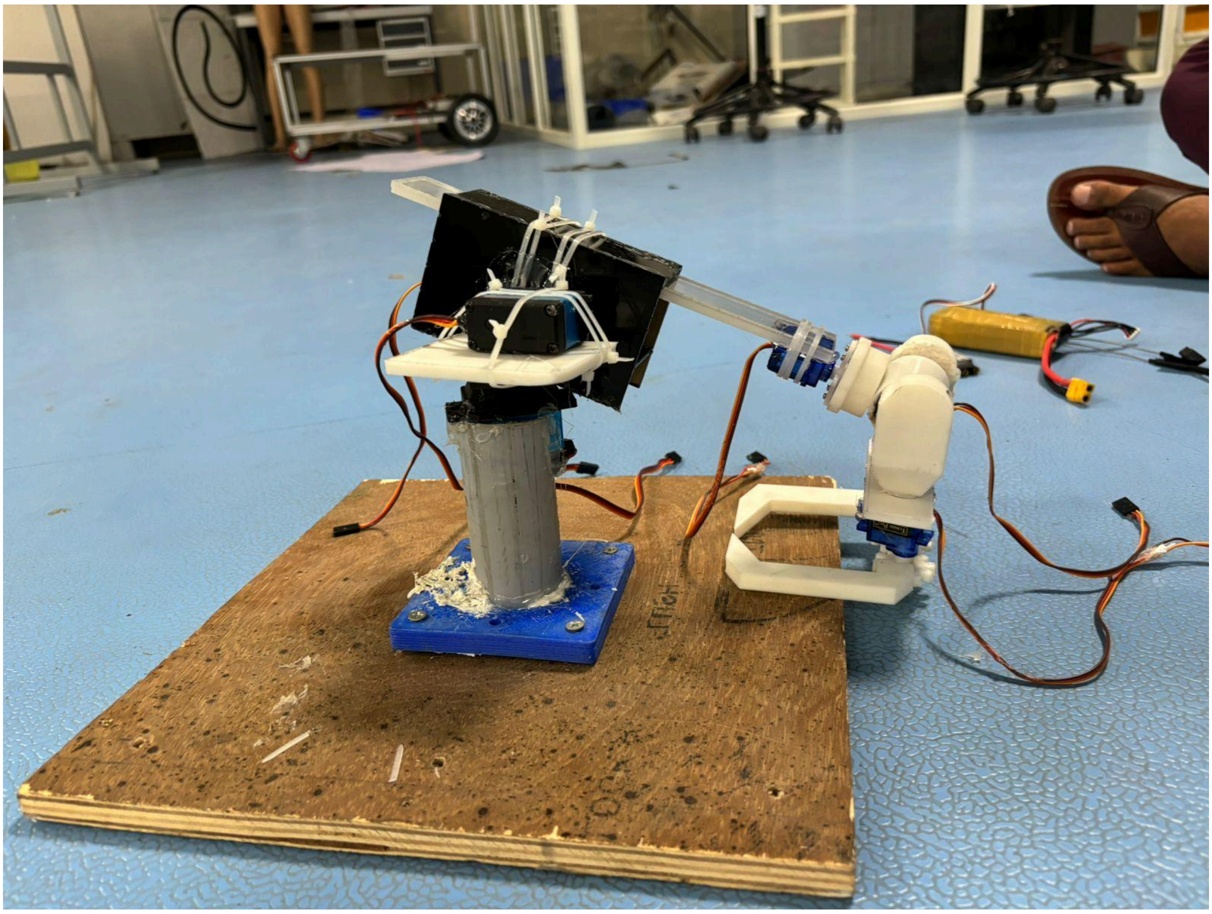
Shoulder Joint (Yaw): The first joint, akin to the shoulder joint in the human body, enables the arm to move horizontally from side to side, providing the second degree of freedom.

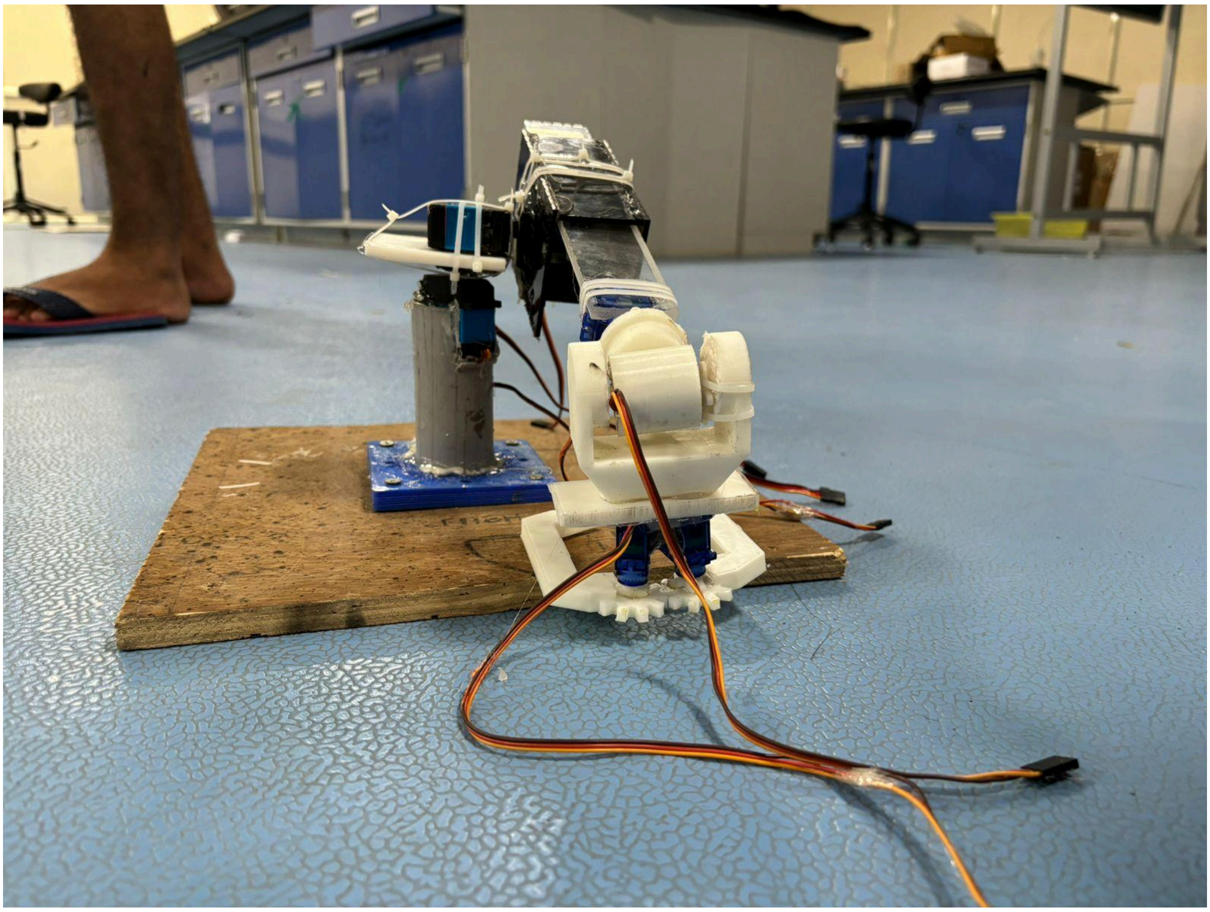
Elbow Joint (Pitch): Analogous to the human elbow joint, this component facilitates vertical movement, granting the third degree of freedom.

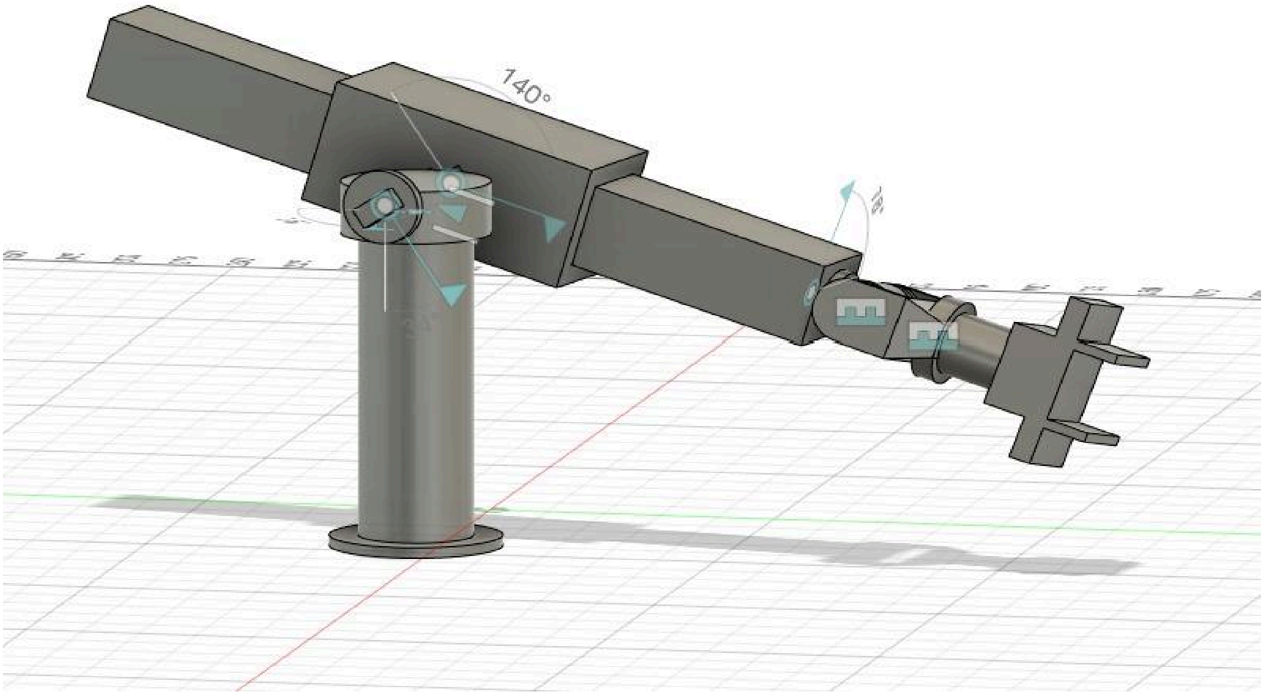
Wrist Pitch (Roll): The wrist pitch allows rotational movement of the end effector, akin to the rolling motion of the human wrist, constituting the fourth degree of freedom.

Wrist Yaw: This joint enables the end effector to rotate horizontally, providing the fifth degree of freedom.

Wrist Roll: The final joint allows the end effector to roll vertically, completing the six degrees of freedom and providing unparalleled flexibility in orientation.







We created a 3D model of the Stanford robot arm in Fusion 360.

MOTOR DESCRIPTION-

There are two types of motors used first is the servo motor with 180 degree rotation and the other is servo motor with 360 degree rotation.

1) Servo motor with 180 degree rotation-

The servo motor in the Stanford robot arm facilitates precise movement within a 180-degree range. It operates based on a closed-loop control system, where feedback mechanisms ensure accurate positioning. This motor features a compact design, allowing seamless integration into the arm structure. Its high torque output enables the arm to manipulate objects with efficiency and reliability. Utilising advanced control algorithms, the servo motor ensures smooth and consistent motion, crucial for various robotic applications. With its robust construction and precise control capabilities, this servo motor plays a pivotal role in enabling the

Stanford robot arm to perform intricate tasks with precision and agility.

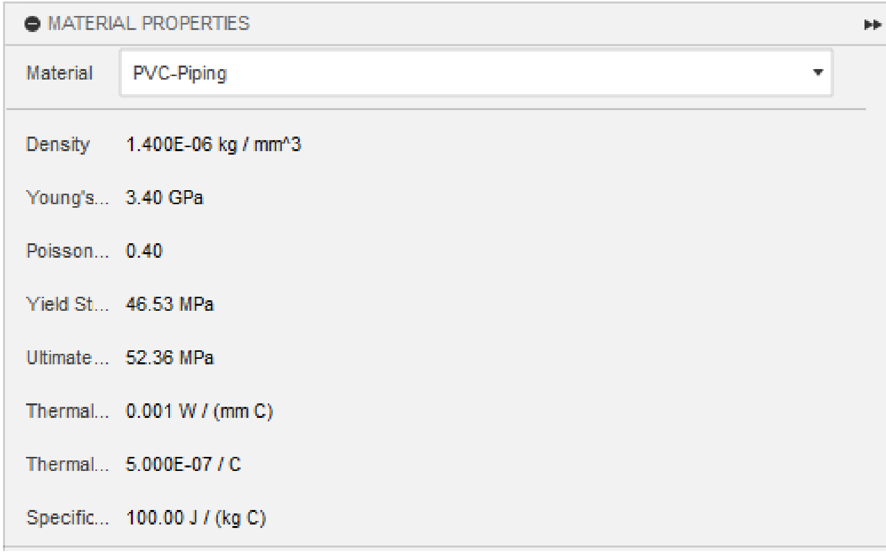
2) Servo motor with 360 degree rotation-

The servo motor designed for 360-degree rotation in the Stanford robot arm boasts versatility and precision. Equipped with advanced gearing mechanisms, it enables seamless and continuous motion across its entire range. This motor is engineered with high-resolution encoders for accurate positioning feedback, ensuring precise control over its movements. Its compact form factor allows for efficient integration within the arm structure without compromising performance. Operating within a closed-loop control system, the servo motor delivers consistent and reliable performance, essential for complex robotic tasks. With its robust construction and agile manoeuvrability, this servo motor empowers the Stanford robot arm to handle diverse applications requiring full-range rotation with utmost accuracy and efficiency.

STRESS ANALYSIS

Design Parameters

For stress analysis to maintain uniformity we have used PVC-piping which has the following properties-



MATERIAL PROPERTIES

Material	PVC-Piping
Density	1.400E-06 kg / mm^3
Young's...	3.40 GPa
Poisson...	0.40
Yield St...	46.53 MPa
Ultimate...	52.36 MPa
Thermal...	0.001 W / (mm C)
Thermal...	5.000E-07 / C
Specific...	100.00 J / (kg C)

In application we have used sunboard,aluminium,PVC-pipes and peek for construction of the stanford arm robot.

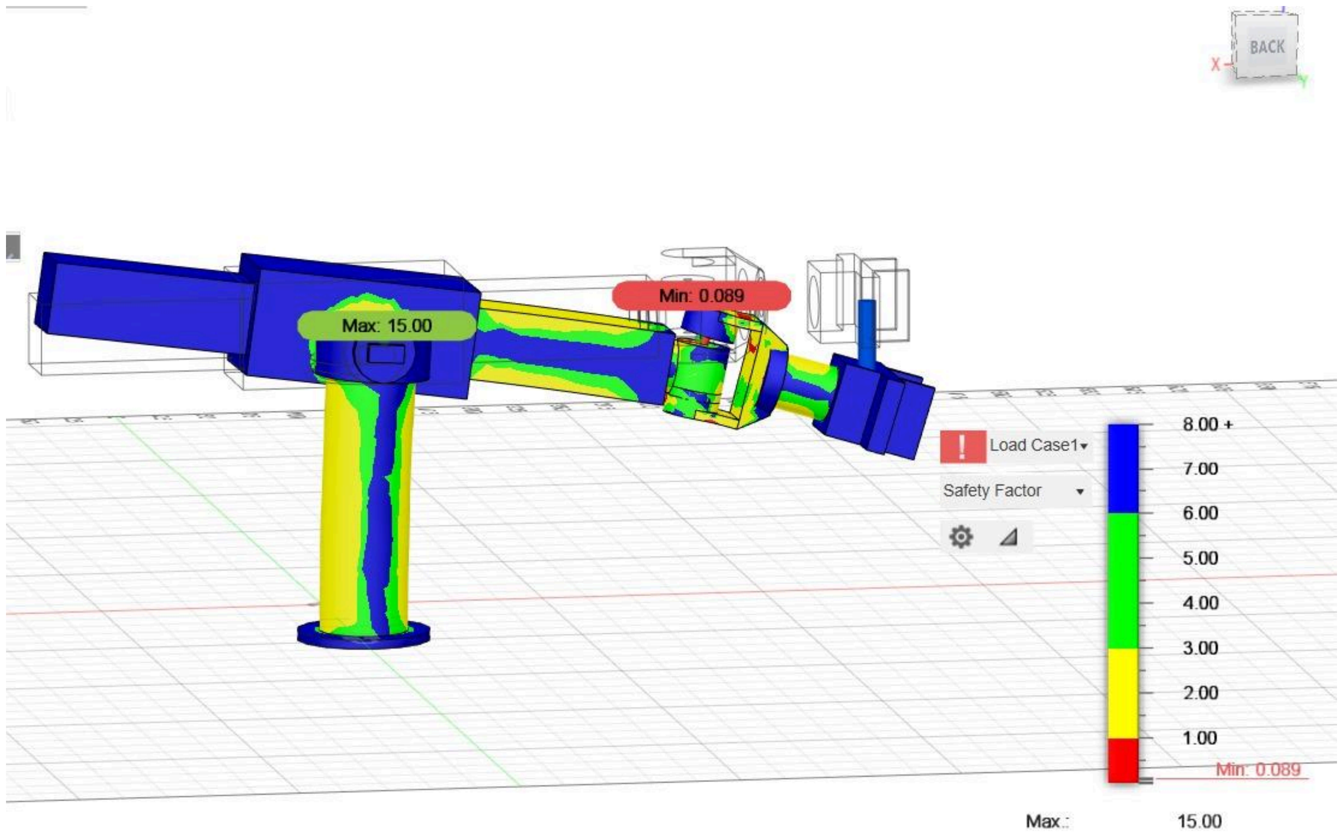
Stress analysis on the Stanford robotic arm involves evaluating the structural integrity and performance under various loads and conditions. We have used Fusion 360 to assess how the arm withstands forces during operation, ensuring optimal functionality and durability for its intended tasks. This analysis is crucial for enhancing the arm's reliability and for calculation of its factor of safety.

Analysis of complete structure

After analysing the complete structure under load conditions of 20N in the negative Z axis, we came to the following conclusions.

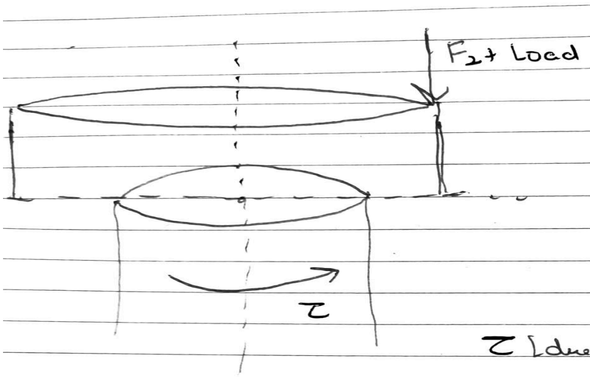
1. The robotic arm can bear upto 20 N load with a minimum safety factor of 0.089(indicated by the red region) at the joint between the arm and the gripper.
2. The maximum factor of safety is 15 as indicated by the blue regions.
3. Deflection of the robotic arm from its original position can also be observed.

We can identify areas of stress concentration in the robotic arm.
One is the joint between the arm and the gripper. Another one is the base cylinder supporting the arm.
Insights in their stress concentrations present opportunities for design optimization or structural modifications to improve overall performance and reliability under varying operational scenarios.



Stress Analysis of Base Part-

As can be seen from the complete stress analysis of the robotic arm, the base part experiences the maximum stress.Therefore, we will examine the forces causing stress in this area.



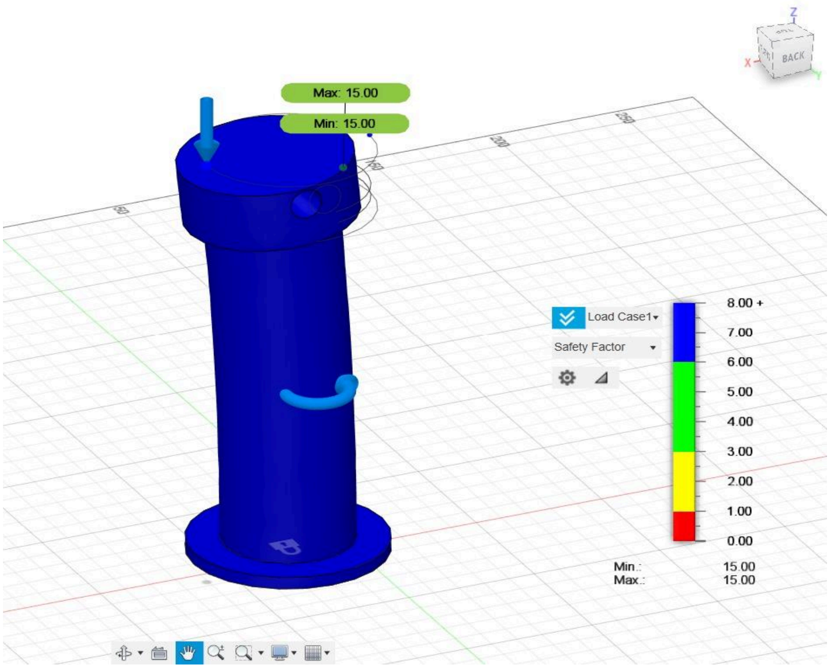
$F_2 = V e g$

$= [1173.89] \times 9.81$

$= 11.52\,N$

τ [due to Motor] $= 0.1569\,Nm$

Load $= 20N$

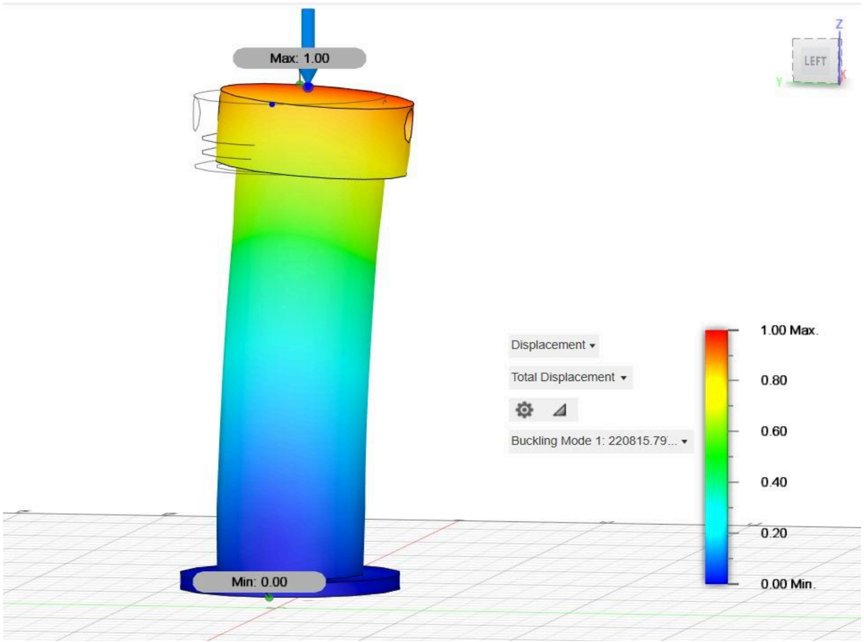


The arm attached to the base, along with the load on the gripper, creates a force that can cause bending and buckling in the base part.Additionally, the movement of the motor mounted on the base generates a torsional force.

During our individual stress analysis of the base part, we approximated the force due to weight of the arm and load to be 20N. Additionally, the torque produced by the motor was factored in.
We see that the part bends but does not fail.

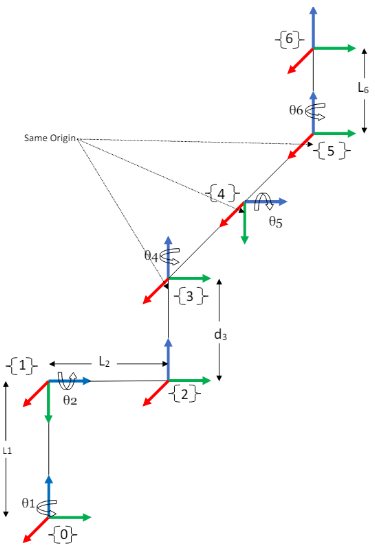
A robotic arm that buckles under its intended load can't perform tasks effectively. Buckling tests guarantee the arm operates within design limits, maintaining accuracy and precision.

After performing buckling tests we found the following results-
The graph shows the total displacement experienced by the structure as the load increased. The maximum displacement is around 1.



FORWARD KINEMATICS:

Forward kinematics for a Stanford arm involves determining the position and orientation of the gripper (end-effector) relative to the base of the arm. This is accomplished by sequentially applying geometric transformations from the base to the end-effector, taking into account the joint angles of the arm's revolute joints. Each joint angle contributes to the overall pose of the gripper, and the transformation matrices associated with each joint are multiplied together to obtain the final end-effector pose. By understanding forward kinematics, engineers can predict where the gripper will be located and how it will be oriented based on the joint angles of the Stanford arm. This knowledge is essential for tasks such as motion planning, trajectory generation, and obstacle avoidance. Forward kinematics provides valuable insight into the spatial relationship between the arm's joints and the end-effector, enabling precise control and manipulation in various robotic applications.



Joint	theta(θ)	d(Joint Offset in mm)	a(Link Length in mm)	Link Twist in degrees
Joint 1	θ1	50	0	-90
Joint 2	θ2	62.5	0	-90
Joint 3	-90	d3	0	0
Joint 4	θ4	0	0	-90
Joint 5	θ5	0	0	-90
Joint 6	θ6	160.25	0	0

The steps to implement Forward Kinematics involves :

1.Transformation Matrix

The transformation matrix is expressed as the function getTransformMatrix. It takes the DH parameters of a single joint as its input argument, and outputs the corresponding transformation matrix.

2.

Forward Kinematics

Forward kinematics then becomes a simple implementation of the getTransformMatrix above. By setting the link lengths constant, the end-tip position can be computed.

On implementing the code on Matlab we get the following results:
The homogenous matrix obtained on multiplying on the transformation matrix is

```
         0    0.4226    0.9063  207.9805
    0.7071   -0.6409    0.2988   41.9692
    0.7071    0.6409   -0.2988    2.0308
```

The last vector is the displacement vector which is the X,Y,Z coordinate of the gripper.
Hence the coordinates of the gripper:

```
X coordinate: 207.9805
Y coordinate: 41.9692
Z coordinate: 2.0308
```

FUTURE SCOPE:

The Stanford robotic arm presents a promising platform for future advancements in automation and manipulation. Here's how:

- **Enhanced Material and Design:** Utilising lighter, stronger materials can improve the arm's weight capacity while reducing stress on the base. Further design optimization can lead to a more efficient structure.

- **Sensor Integration:** Incorporating sensors like force and proximity sensors can enable real-time feedback on grip strength and object detection, allowing for more sophisticated grasping and manipulation tasks.

- **Machine Learning Integration:** Machine learning algorithms can be integrated to allow the arm to learn from its environment and adapt its movements for improved grasping success rates and obstacle avoidance.

- **Micromanipulation Capabilities:** By miniaturising the arm and integrating high-precision actuators, the Stanford arm can be adapted for delicate tasks in microsurgery or electronics assembly.

- **Collaborative Applications:** Equipping the arm with safety features and object recognition can pave the way for human-robot collaboration in tasks like assembly or shared workspace operations.

  These advancements can propel the Stanford robotic arm into various industries, from manufacturing and healthcare to scientific research and space exploration.