KINEMATIC AND STRUCTURAL ANALYSIS OF SCARA ROBOT

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Content Table:

Abstract:

In this report I have done the analysis of the kinematics and structural behaviour of robots which is crucial in their design and development. This study focuses on the kinematic and structural analysis of a SCARA (Selective Compliance Assembly Robot Arm) robot using two different software tools: Roboanalyzer and ANSYS.

The kinematic analysis of the SCARA robot is performed using Roboanalyzer, which is a specialized software tool for robotic analysis. The software enables the user to create a virtual model of the robot, including its joints and links, and simulate its motion to analyse its kinematic behaviour. The results of the analysis provide important information such as the range of motion of the robot, the velocity and acceleration of its end effector, and also the inverse kinematics solution.

In addition to kinematic analysis, the structural behaviour of the SCARA robot is analysed using ANSYS, a widely used finite element analysis software. The software allows the user to simulate the robot's mechanical response under different loads and boundary conditions, enabling the prediction of stresses, deformations, and other critical parameters. The analysis results can be used to optimize the robot's design, improve its performance, and ensure its safety.

The results of the kinematic and structural analyses are essential for the successful design and implementation of SCARA robots. The analysis enables the identification of potential design flaws and helps to optimize the robot's performance. The study demonstrates the effectiveness of using specialized software tools to analyze the kinematic and structural behavior of robots.

Objectives:

The objective of this report is to provide an overview of two important software tools used in robotics engineering, namely RoboAnalyzer(for kinematic analysis) and ANSYS Workbench software(for structural analysis), and their application in the analysis of a SCARA robot.

The report begins with an introduction to robotics and the SCARA robot, explaining its basic structure, working principle, and applications. Then, it describes the importance of kinematics and structural analysis in the design and development of robots and provides an overview of the SCARA robot/manipulator arm.

The first part of the report focuses on RoboAnalyzer software, which is used for the kinematic analysis of robots. It describes the various features of the software and its interface, followed by a step-by-step guide on how to use it to analyze the kinematics of a SCARA robot.

The second part of the report focuses on ANSYS Workbench software, which is used for structural analysis. It explains the various features of the software and how it can be used to analyze the structural behavior of the SCARA robot, identifies if the robot can handle stress in realtime using metal density and property testing like aluminium body.

Introduction:

Robotic systems have become an essential part of modern-day industries due to their ability to perform a wide range of complex tasks with precision and accuracy. Robotic systems are used in various industries such as automotive, aerospace, medical, and manufacturing. Among different types of robots, SCARA (Selective Compliance Assembly Robot Arm) is widely used in the industry due to its excellent performance in assembly and pick-and-place operations.

The kinematic analysis of a SCARA robot is essential to understand its motion and performance characteristics. Kinematic analysis is the study of motion without considering the forces that cause the motion. It involves determining the position, velocity, and acceleration of each part of the robot. The kinematic analysis helps in understanding the robot's workspace, its ability to reach a specific location, and its speed and accuracy in performing the task.

To perform kinematic analysis, software tools such as RoboAnalyzer are used. RoboAnalyzer is a software tool that helps in the kinematic analysis of robotic systems. It is a user-friendly software tool that enables the user to perform various analyses such as inverse and forward kinematics, velocity analysis, and acceleration analysis. It provides visualizations of the robot's motion and trajectory, which helps in understanding the robot's behavior.

Structural analysis of a robot is another critical aspect that helps in understanding its mechanical behavior. Structural analysis involves determining the stresses and deformations in the robot's components under various loading conditions. The structural analysis is essential to ensure that the robot's design is safe and reliable.

ANSYS is a software tool used for structural analysis of mechanical systems. It provides a comprehensive set of tools for analyzing the structural behavior of mechanical systems. It enables the user to perform various analyses such as linear and nonlinear static, dynamic, and thermal analyses. ANSYS provides visualizations of stresses and deformations, which helps in understanding the mechanical behavior of the robot.

In this report, we will perform kinematic and structural analyses of a SCARA robot using RoboAnalyzer and ANSYS software tools. The kinematic analysis will help in understanding the robot's motion characteristics, while the structural analysis will help in understanding the mechanical behavior of the robot. The report will be structured as follows:

In the literature review, we will discuss the existing literature on the kinematic and structural analysis of SCARA robots. In the methodology section, we will discuss the experimental setup, the kinematic and structural analysis procedures, and the software tools used. In the results and analysis section, we will present the results obtained from the kinematic and structural analyses and discuss the implications of the results. Finally, in the conclusion and future work section, we will summarize the findings of the report and discuss possible areas for future research.

Literature Review:

SCARA robots have been studied extensively in the literature. Researchers have investigated their design, control, and applications. For example, in their study, Andrieux et al. (2018) designed a SCARA robot for an educational project. The robot was designed to perform various tasks such as pick-and-place, sorting, and assembly. The authors used a kinematic analysis to optimize the robot's workspace, and the results showed that the robot could reach all the desired positions.

In another study, Hu et al. (2018) designed a SCARA robot for a 3D printing application. The authors used a structural analysis to evaluate the robot's rigidity and found that the robot's stiffness was sufficient for the application.

Several researchers have also investigated the control of SCARA robots. For example, Zhang et al. (2017) proposed a hybrid force-position control algorithm for a SCARA robot. The algorithm used force and position sensors to achieve high precision and stability in the robot's motion.

Other researchers have investigated the application of SCARA robots in various industries. For example, Wang et al. (2019) studied the application of SCARA robots in the food industry. The authors designed a SCARA robot for sorting and packaging fruits and vegetables. The results showed that the robot was efficient and accurate, making it suitable for use in the food industry

In conclusion, SCARA robots are versatile and have many potential applications. The literature review has shown that researchers have investigated the design, control, and application of SCARA robots. In this report, we will perform a structural and kinematic analysis of a SCARA robot to evaluate its performance.

Methodology:

(i)Kinematic analysis(RoboAnalyzer)

Build the robot model: The first step is to build the robot model in the RoboAnalyzer software. This involves defining the number of links, joints, and their dimensions, as well as the end-effector and its properties. In the case of a SCARA robot, the model typically consists of four revolute joints and a prismatic joint.

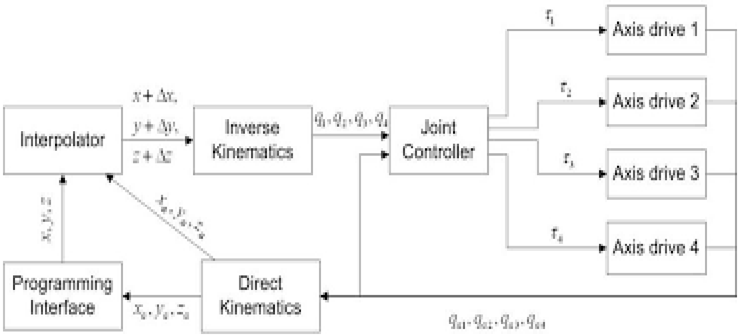
Define the joint parameters: The next step is to define the joint parameters, such as the joint angles and lengths, using the input values from the robot specification sheet. These parameters are used to calculate the position and orientation of the robot's end-effector.

Verify the model: Once the robot model and joint parameters have been defined, the next step is to verify the model by running a simulation. This involves testing the robot's motion to ensure that it moves as expected and that the joint angles and end-effector position and orientation are accurate.

Perform kinematic analysis: With the model verified, the next step is to perform the kinematic analysis. This involves calculating the forward kinematics, which determines the position and orientation of the robot's end-effector relative to the base coordinates, given the joint angles. Additionally, the inverse kinematics can be calculated to determine the joint angles required to achieve a desired end-effector position and orientation.

Analyze the results: Once the kinematic analysis has been performed, the results can be analyzed to assess the robot's performance. This may involve evaluating the robot's reach, workspace, and accuracy.

Optimize the robot design: Based on the results of the kinematic analysis, the robot design can be optimized to improve its performance. For example, the link lengths or joint angles may be adjusted to improve the robot's reach or accuracy.



(ii)structural analysis(Ansys software)

The structural analysis of a SCARA robot using ANSYS software involves several steps to determine the robot's performance and reliability under various loading conditions. The following methodology outlines the steps involved in conducting a structural analysis of a SCARA robot using ANSYS software.

Step 1: Model Creation

The first step in conducting a structural analysis of a SCARA robot using ANSYS software is to create a 3D model of the robot in ANSYS. The model should be created to the exact specifications of the robot, including its dimensions, materials, and any other relevant parameters.

Step 2: Meshing

Once the model has been created, the next step is to mesh it. Meshing involves dividing the model into small, finite-sized elements, which are then analyzed by ANSYS. The size and quality of the mesh will affect the accuracy of the results, so it is important to ensure that the mesh is of sufficient quality.

Step 3: Material Properties

After meshing, the next step is to assign material properties to the different parts of the robot. These properties include density, elasticity, and thermal expansion coefficients. The properties are usually obtained from the manufacturer's specifications or through testing.

Step 4: Loading Conditions

The next step is to define the loading conditions that the robot will be subjected to. These can include forces, moments, and pressure loads. The loading conditions should be based on the robot's intended use and operating environment.

Step 5: Boundary Conditions

The boundary conditions refer to the constraints applied to the model, which simulate the robot's mounting or attachment points. The boundary conditions are also used to simulate the robot's fixed and moving components.

Step 6: Analysis

Once all the necessary inputs have been defined, the next step is to perform the analysis using ANSYS software. ANSYS solves the finite element equations based on the material properties, loading conditions, and boundary conditions to generate the stress and strain distributions in the robot.

Step 7: Results and Verification

Finally, the results are analyzed and compared against the robot's design specifications to ensure that it meets the required performance criteria. If the results do not meet the required criteria, modifications may need to be made to the robot's design to improve its performance.

These are the methodology I consider for this report

KINEMATIC ANALYSIS:

Software used:

RoboAnalyzer software downloaded version

DH PARAMETERS:

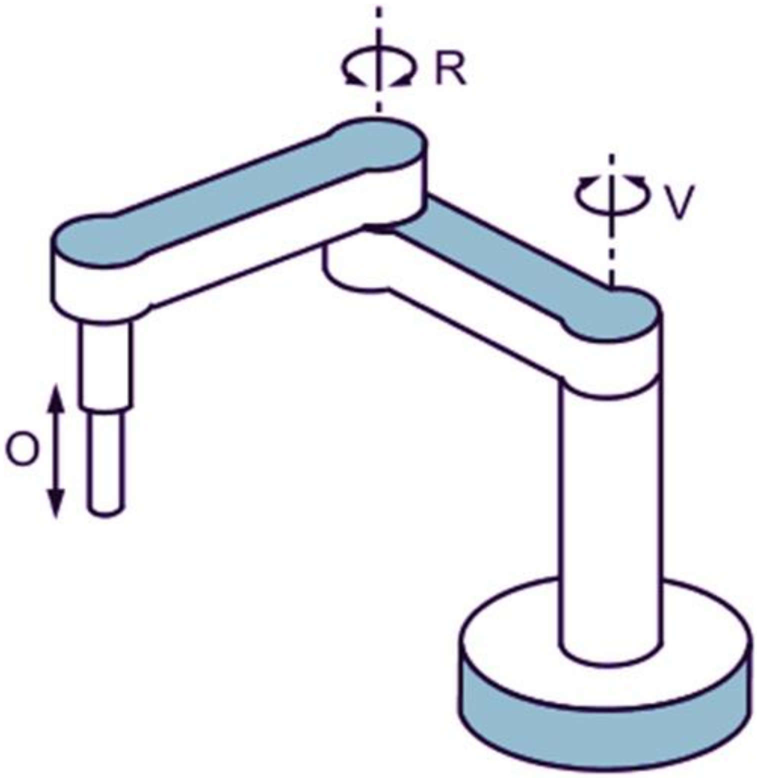
What is DH and why do we need it?

DH parameters, also known as Denavit-Hartenberg parameters, are a set of parameters that are commonly used to describe the kinematics of robotic manipulator arms. The parameters describe the position and orientation of each joint of the manipulator with respect to the previous joint.

The DH parameters consist of four values for each joint: the length of the joint, the twist angle between the previous joint and the current joint, the offset distance between the previous joint and the current joint along the common normal, and the angle between the coordinate systems of the previous joint and the current joint.

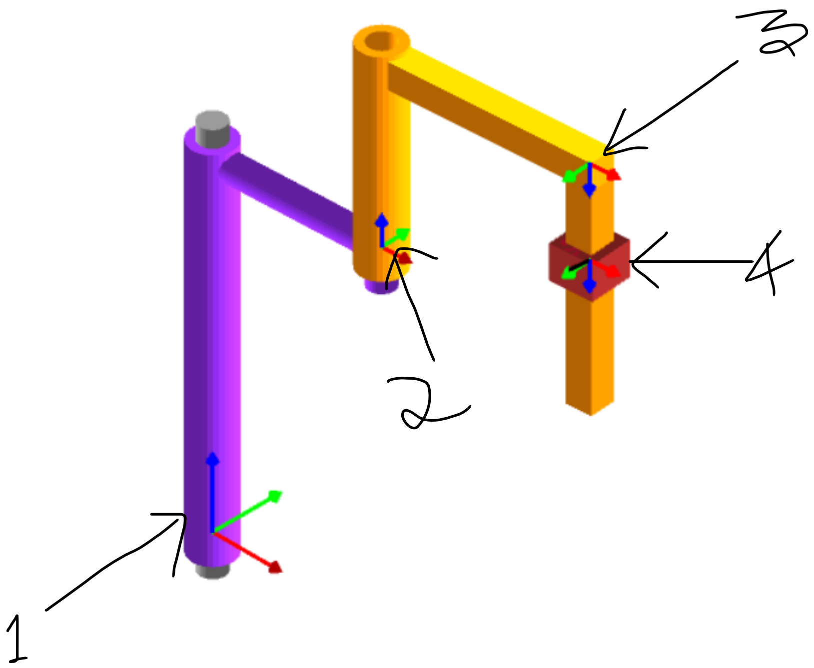
DH parameters are used to derive the transformation matrix between two adjacent joints in a robotic manipulator arm, which is used to calculate the position and orientation of the end effector of the arm. This is essential for controlling the movement of the robotic arm and ensuring that it moves accurately and precisely.

In summary, DH parameters are used to describe the kinematics of robotic manipulator arms and are necessary for calculating the position and orientation of the end effector of the arm.



DH of SCARA Robot:

i	d_i	θi	a_i	α_i
1	0	θ_1	L_1	0
2	0	θ_2	L_2	0
3	d_3	0	0	0
4	d_4	θ_4	0	0

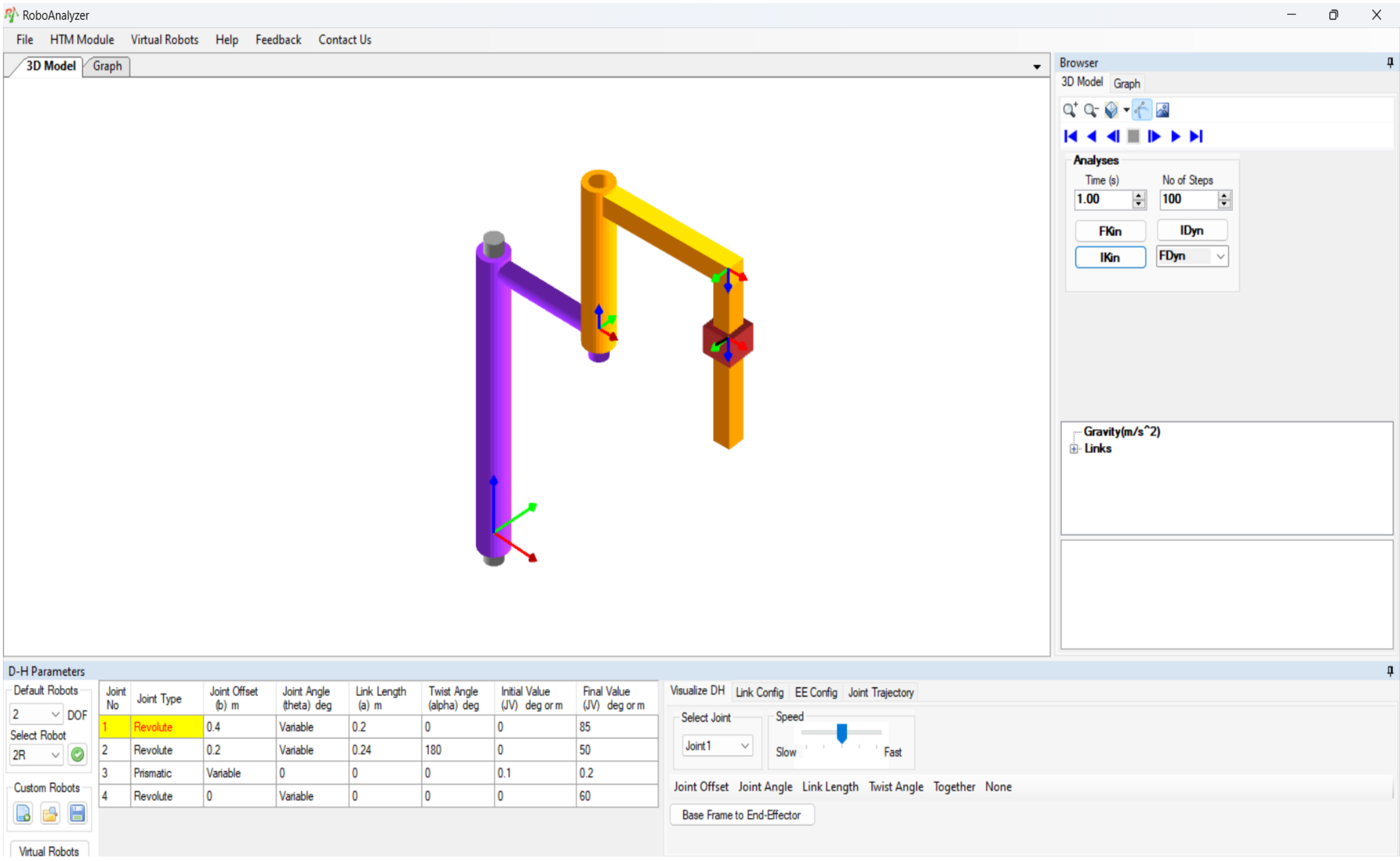


1-Base frame

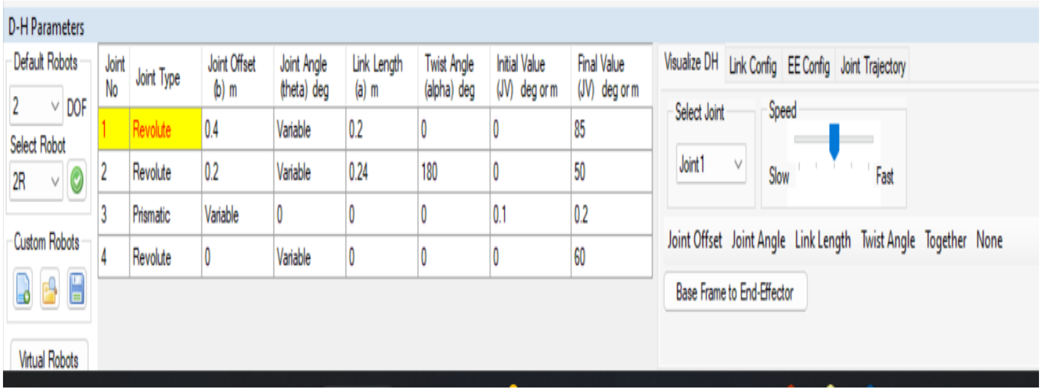
2-link2 frame

3-link3 frame

4-link4 frame

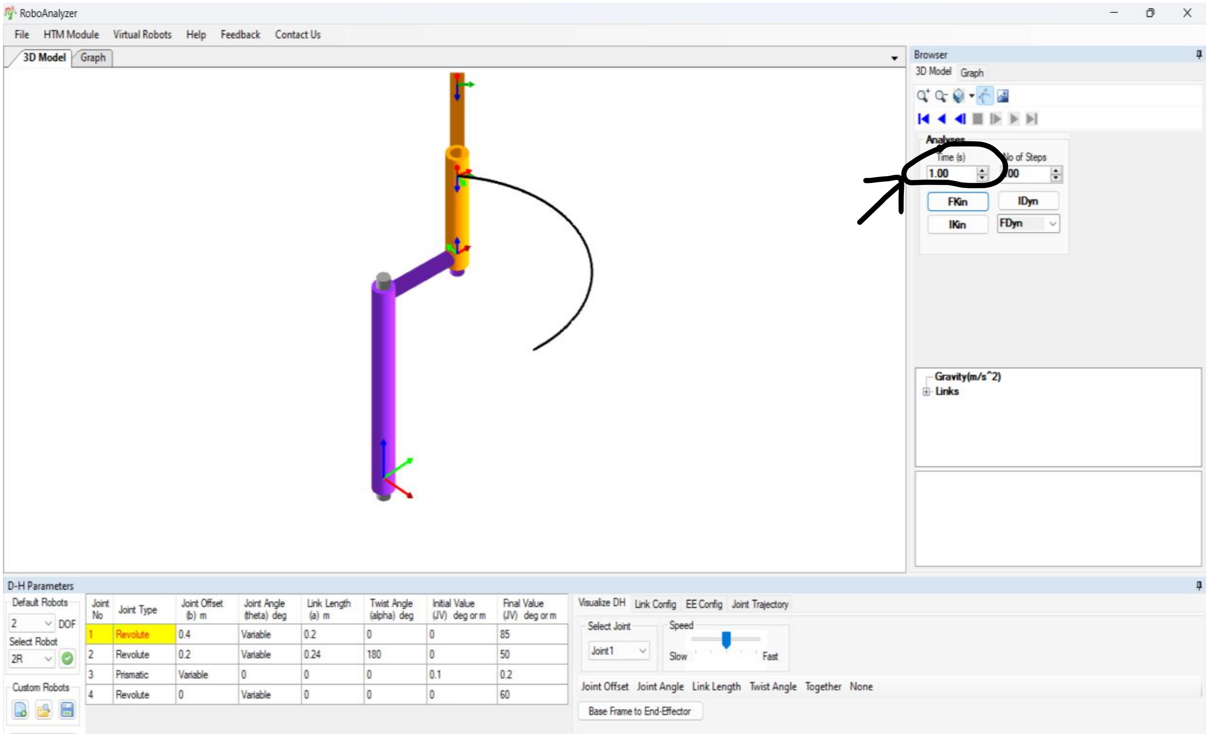


Joint No	Joint Type	Joint Offset (b) m	Joint Angle (theta) deg	Link Length (a) m	Twist Angle (alpha) deg	Initial Value (JV) deg or m	Final Value (JV) deg or m
1	Revolute	0.4	Variable	0.2	0	0	85
2	Revolute	0.2	Variable	0.24	180	0	50
3	Prismatic	Variable	0	0	0	0.1	0.2
4	Revolute	0	Variable	0	0	0	60



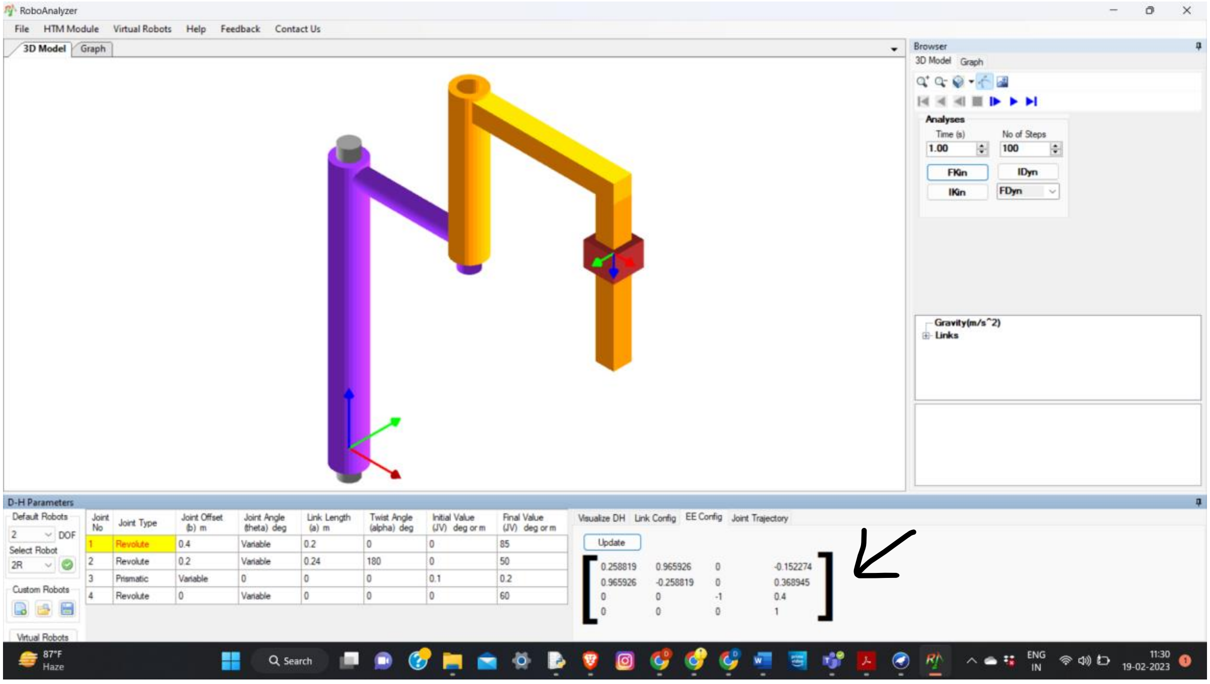
Forward kin

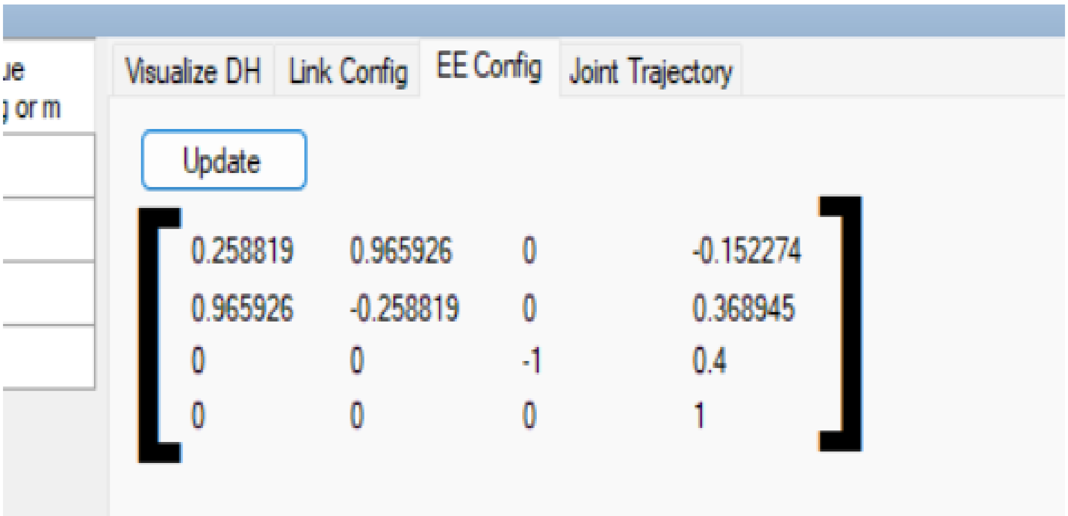
Press play icon to demonstate



See DH table

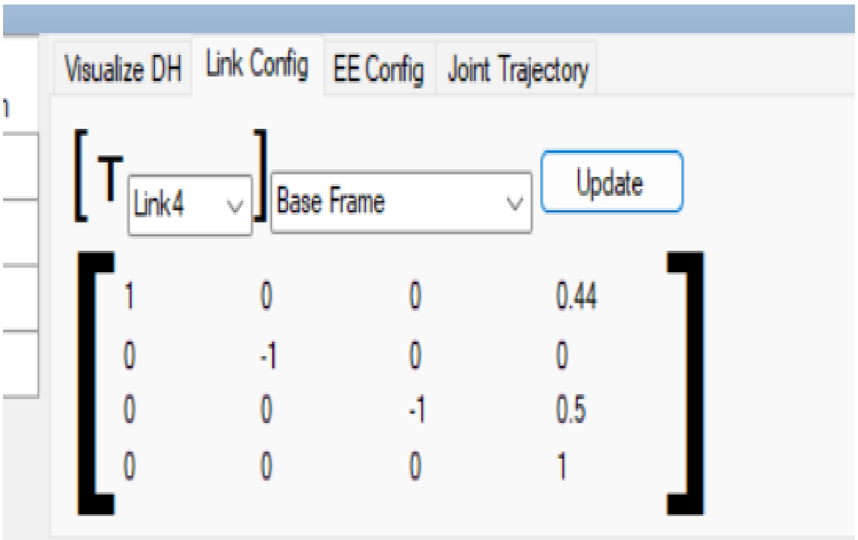
(in EE CONFIG)



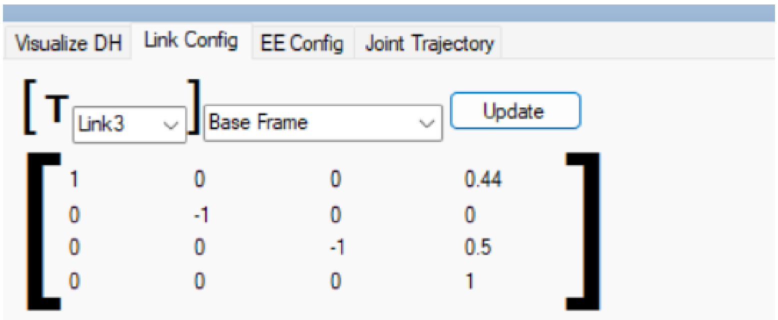


DH table for Link 4 to base Link frame:

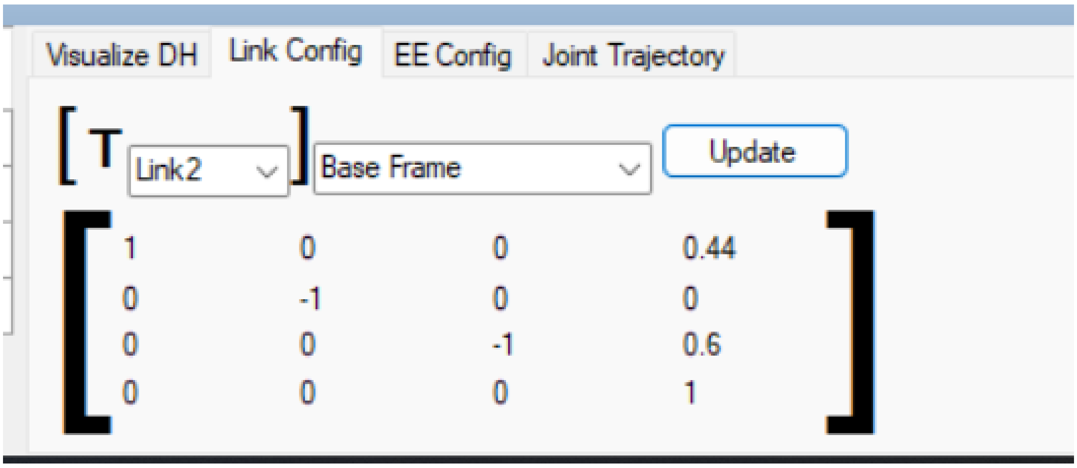
(under link Config)



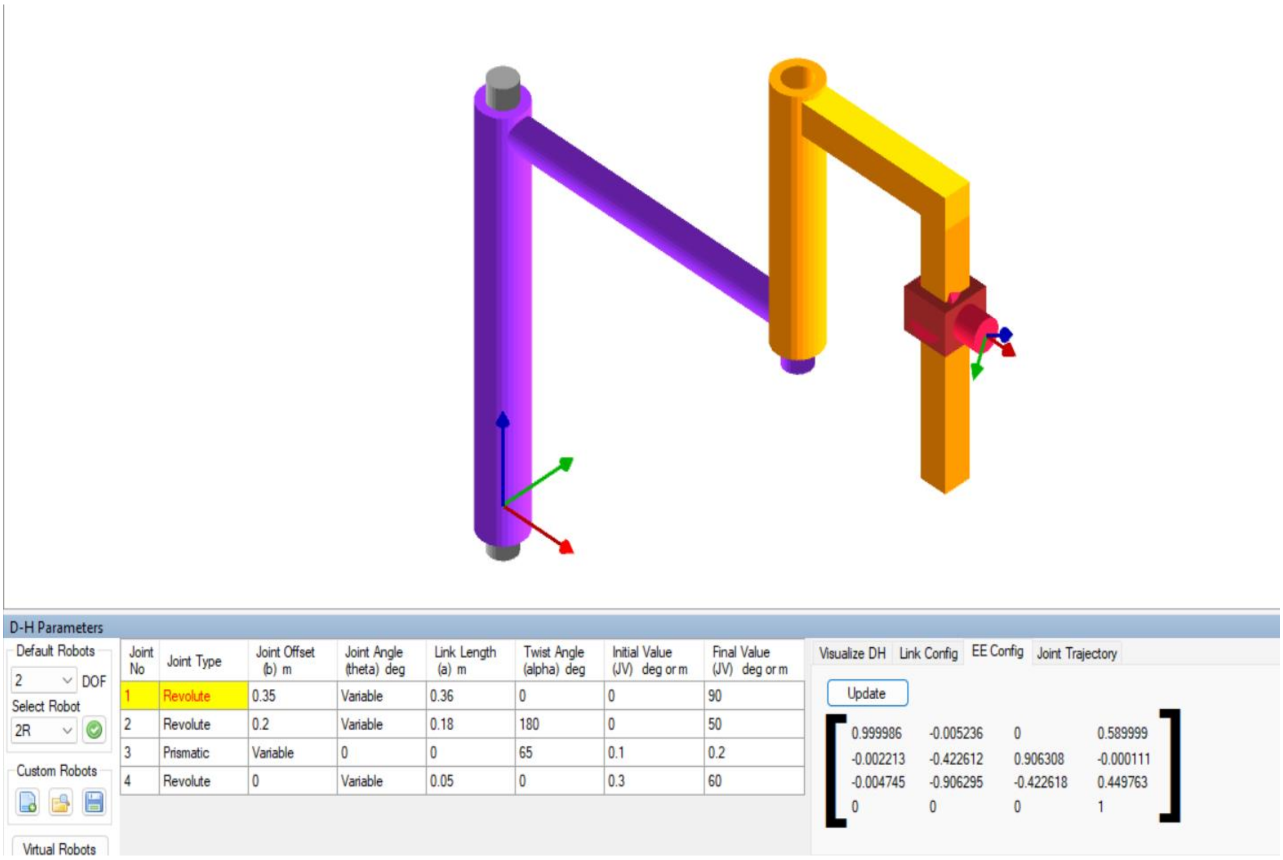
DH table for link 3 to base frame:



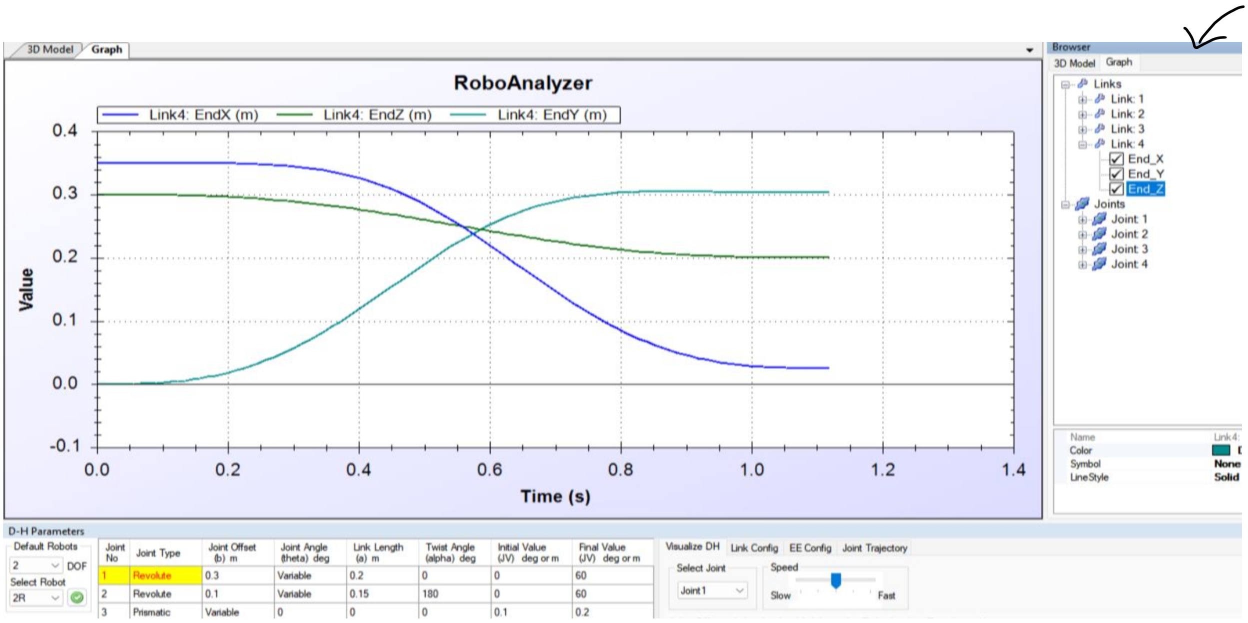
DH table for link 2 to base:



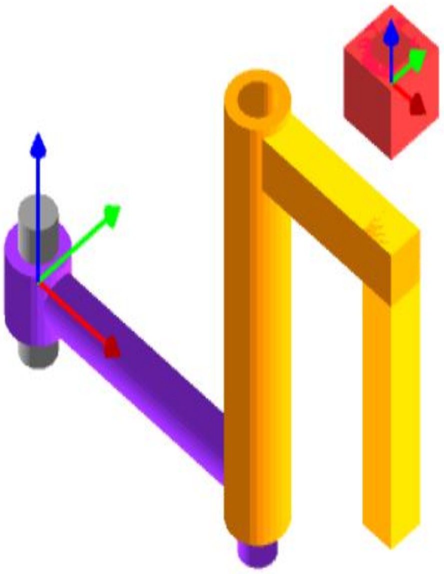
LET us DH parameters:



GRAPH:



Another configuration:



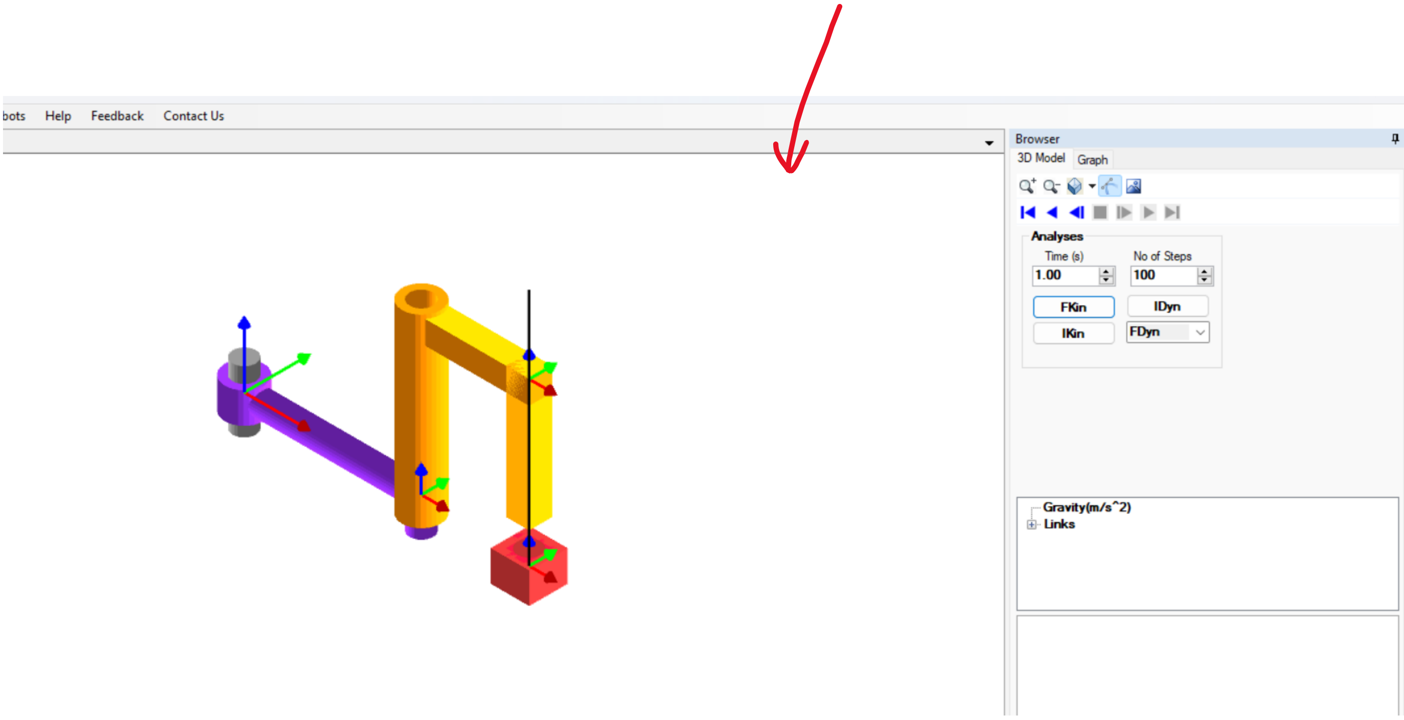
Joint No	Joint Type	Joint Offset (b) m	Joint Angle (theta) deg	Link Length (a) m	Twist Angle (alpha) deg	Initial Value (JV) deg or m	Final Value (JV) deg or m
1	Revolute	0	Variable	0.23	0	0	0
2	Revolute	0.2	Variable	0.14	0	0	0
3	Prismatic	Variable	0	0	0	0.1	-0.21
4	Revolute	0	Variable	0	0	0.2	0

Visualize DH | Link Config | EE Config | Joint Trajectory

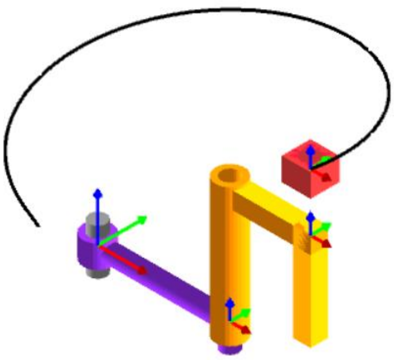
Update

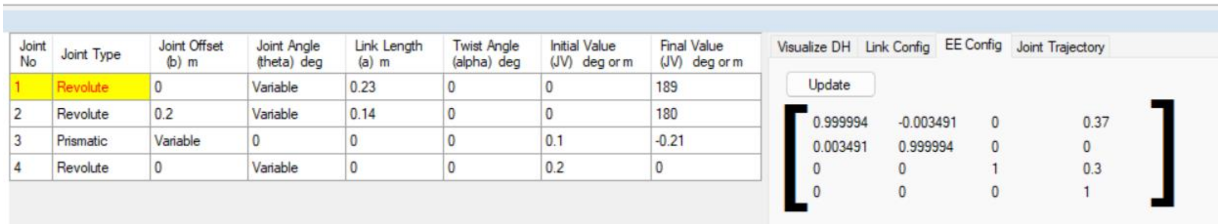
$$\begin{bmatrix} 0.999994 & -0.003491 & 0 & 0.37 \\ 0.003491 & 0.999994 & 0 & 0 \\ 0 & 0 & 1 & 0.3 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Simulation:



TO cover a spiral path:



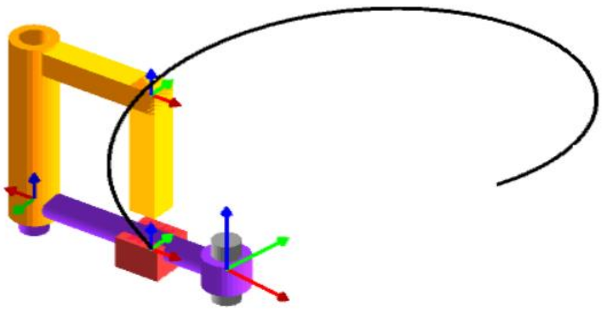


Joint No	Joint Type	Joint Offset (b) m	Joint Angle (theta) deg	Link Length (a) m	Twist Angle (alpha) deg	Initial Value (JV) deg or m	Final Value (JV) deg or m
1	Revolute	0	Variable	0.23	0	0	189
2	Revolute	0.2	Variable	0.14	0	0	180
3	Prismatic	Variable	0	0	0	0.1	-0.21
4	Revolute	0	Variable	0	0	0.2	0

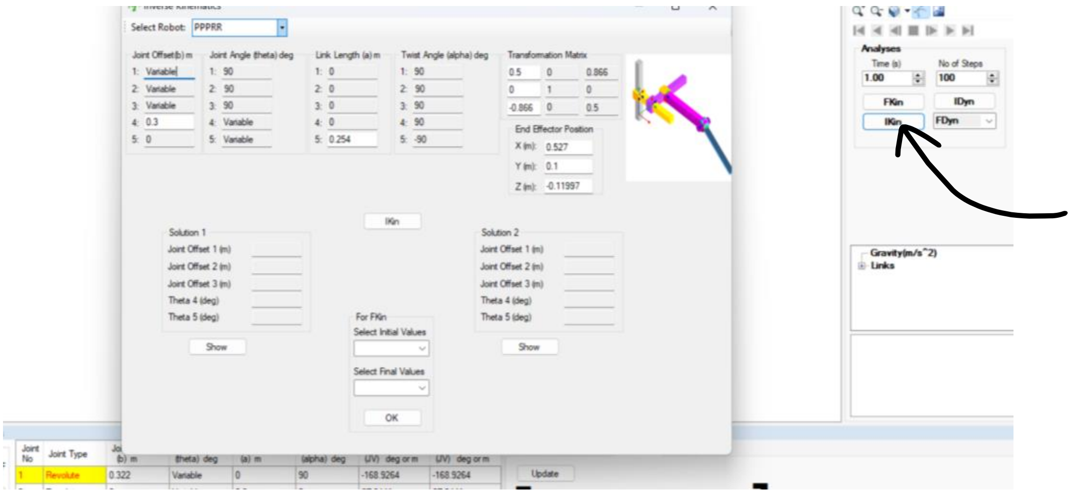
Visualize DH | Link Config | EE Config | Joint Trajectory

Update

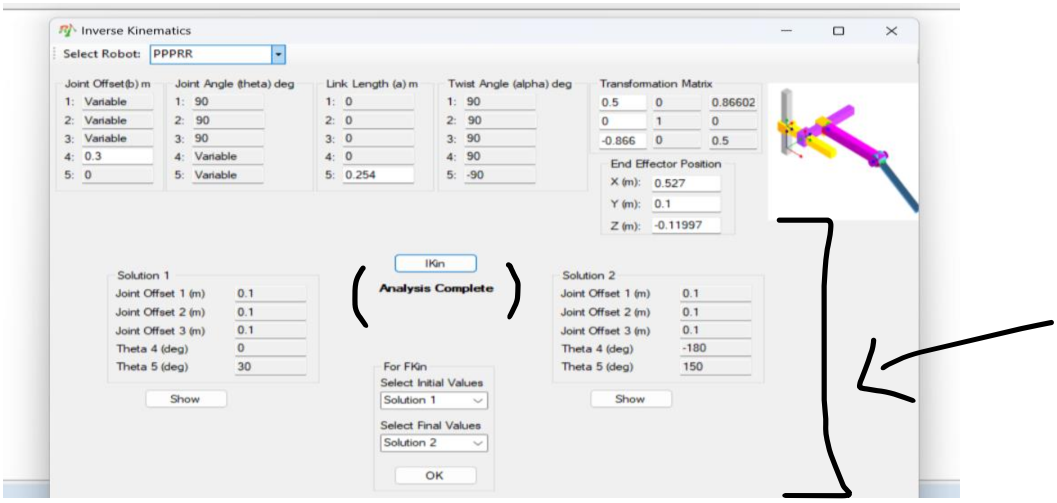
$$\begin{bmatrix} 0.999994 & -0.003491 & 0 & 0.37 \\ 0.003491 & 0.999994 & 0 & 0 \\ 0 & 0 & 1 & 0.3 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$



INVERSE KINEMATICS:



Now get the 2 solutions,



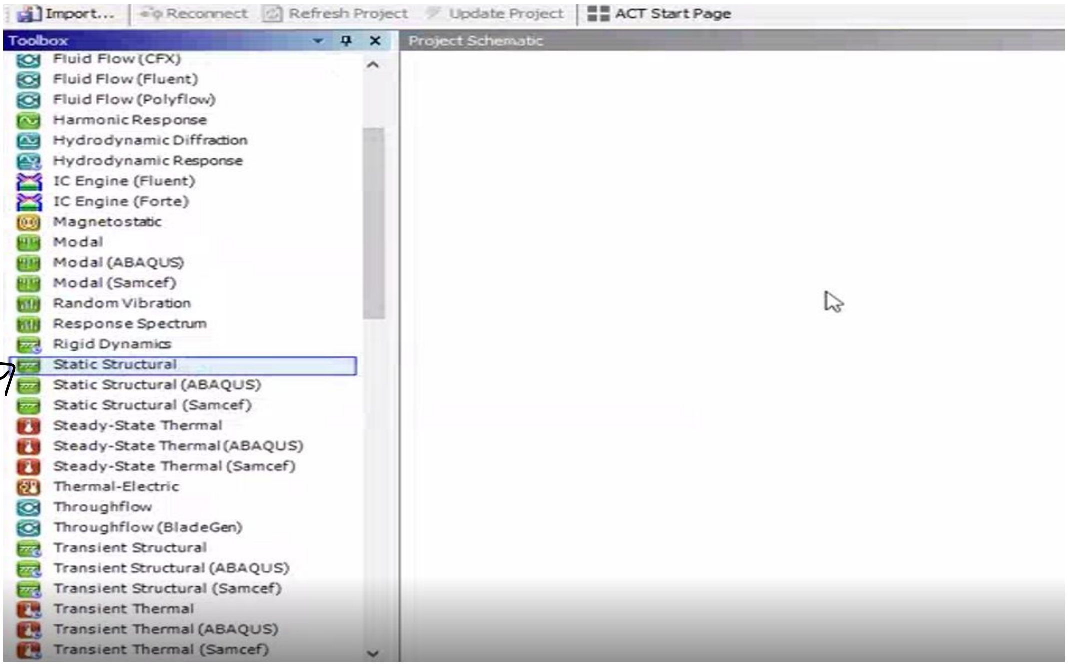
STRUCTURAL ANALYSIS:

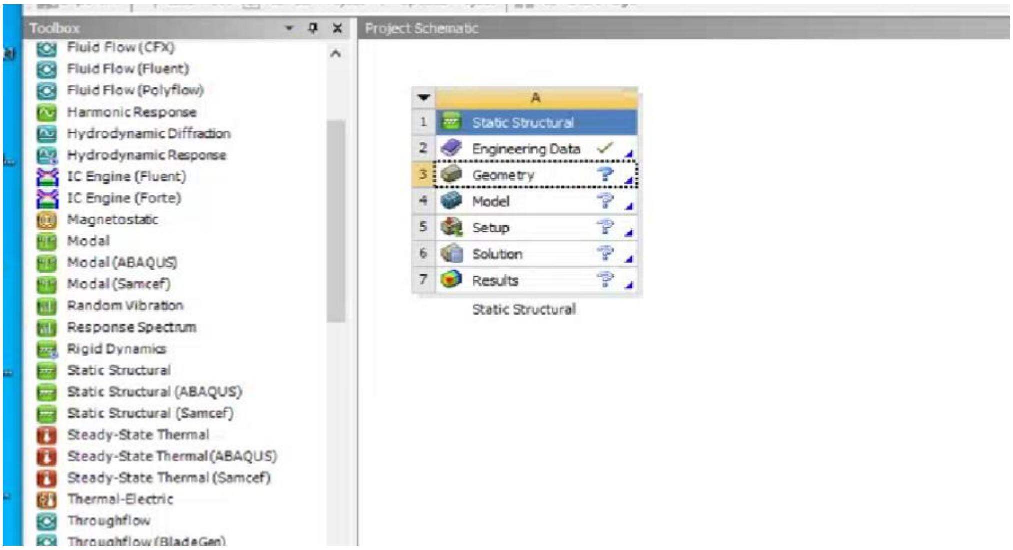
SOFTWARE:

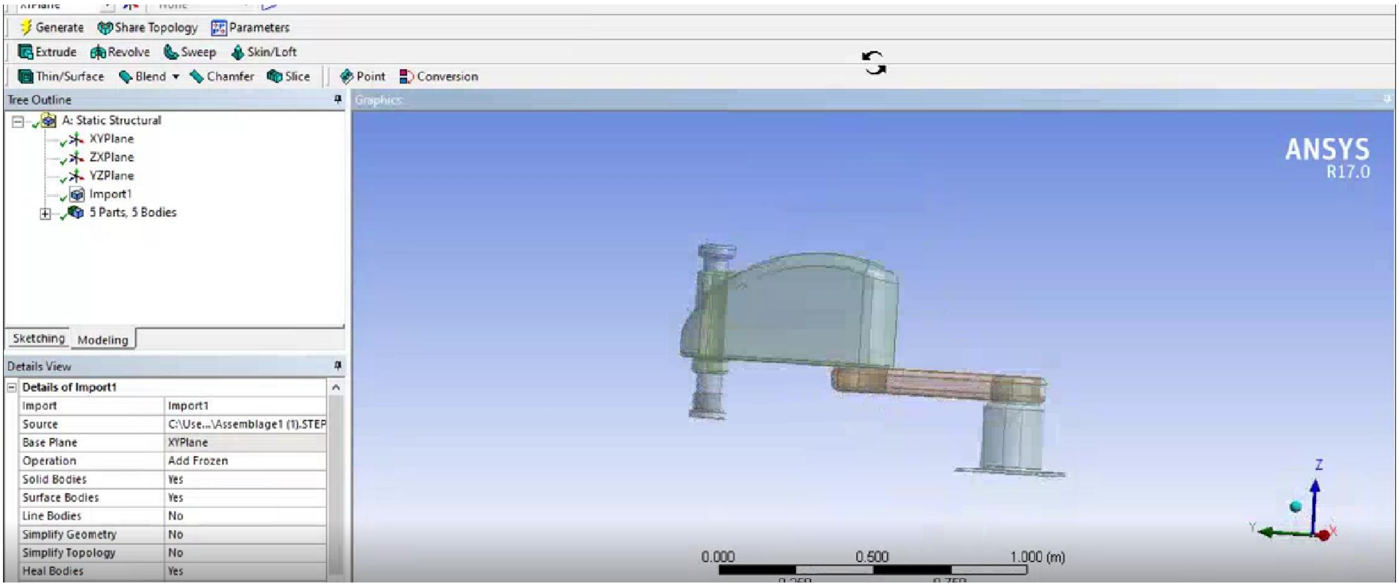
Ansys workbench 17.0

We need scara cad model in .STEP format which we can download it from GRABCAD website

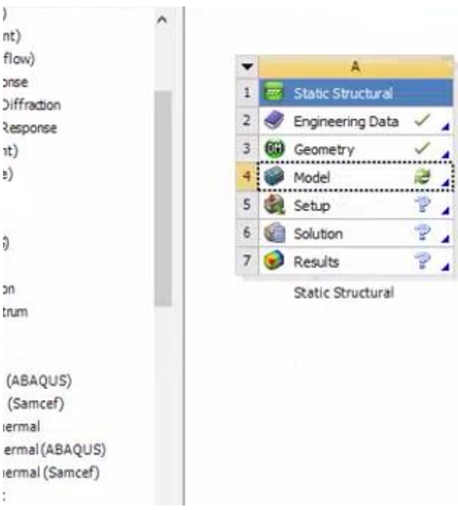
Now Open ANSYS workbench,

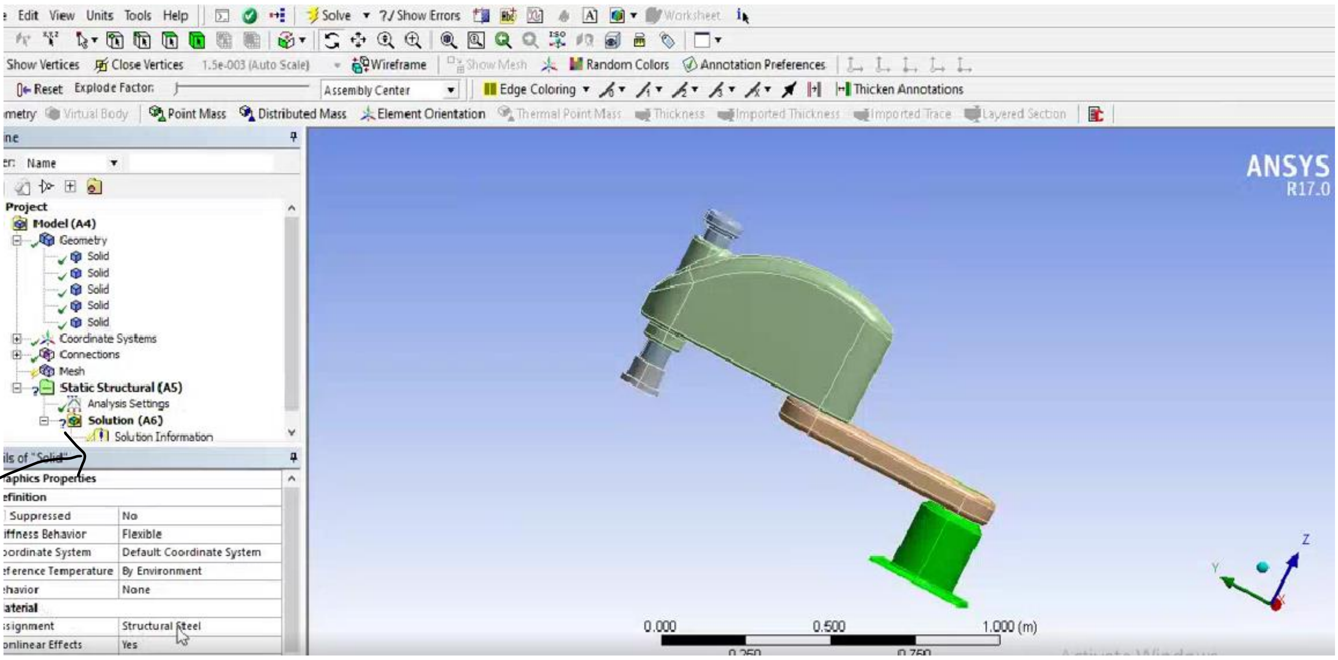




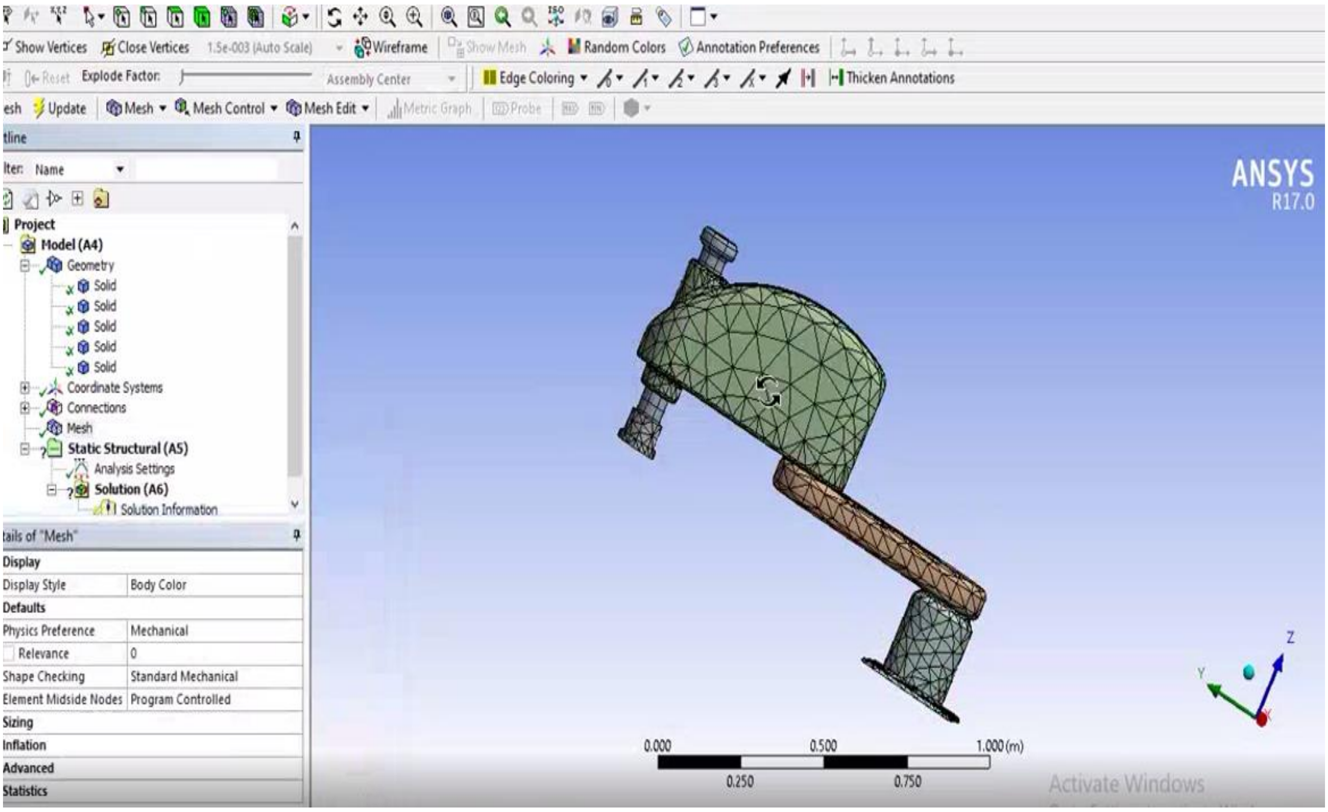


Now model(for analysis),

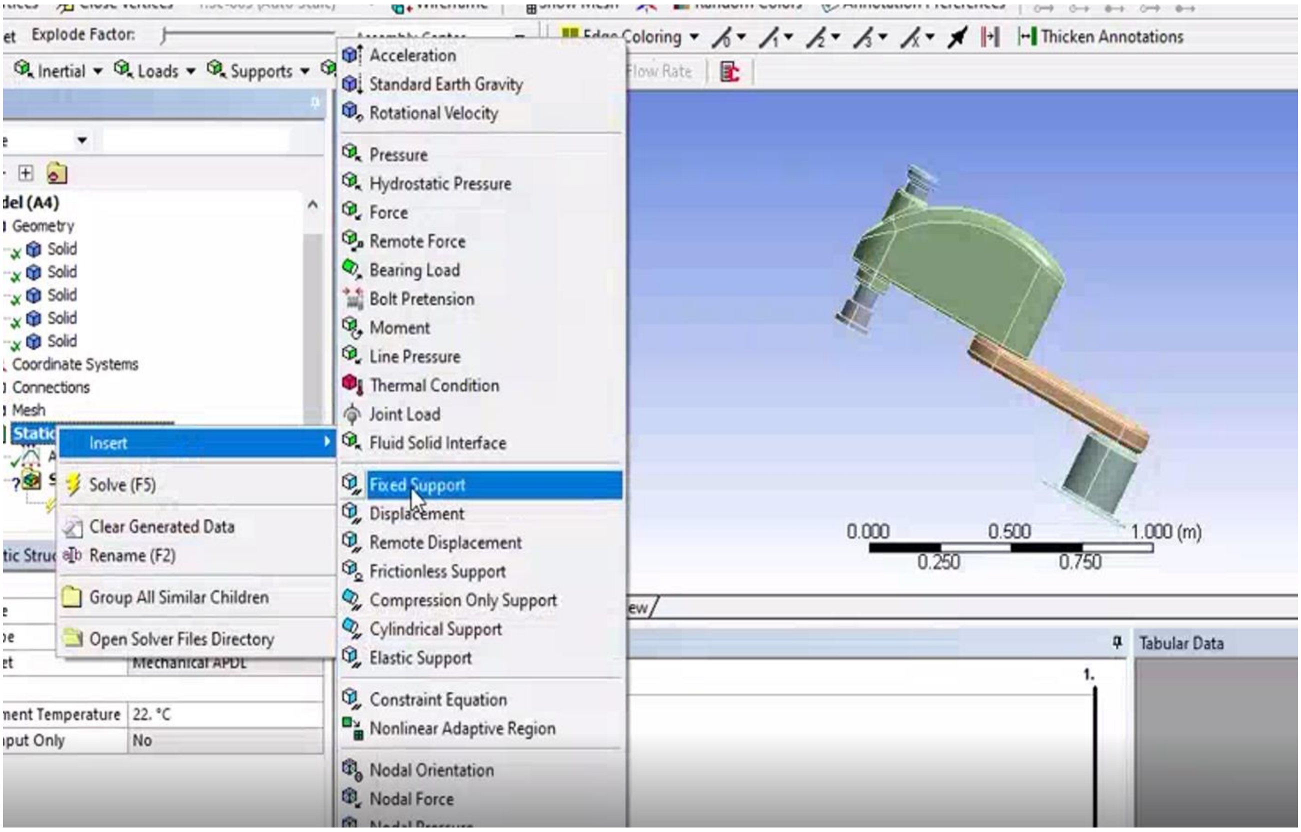


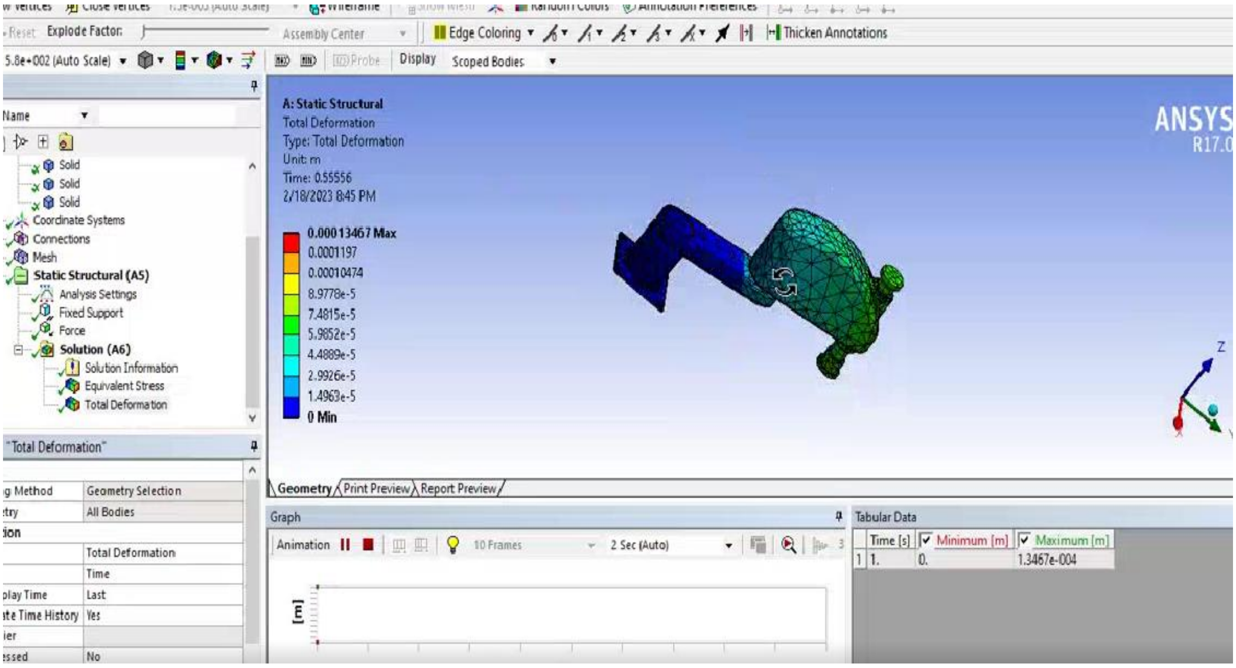


Mesh(means dividing the object into smaller parts);

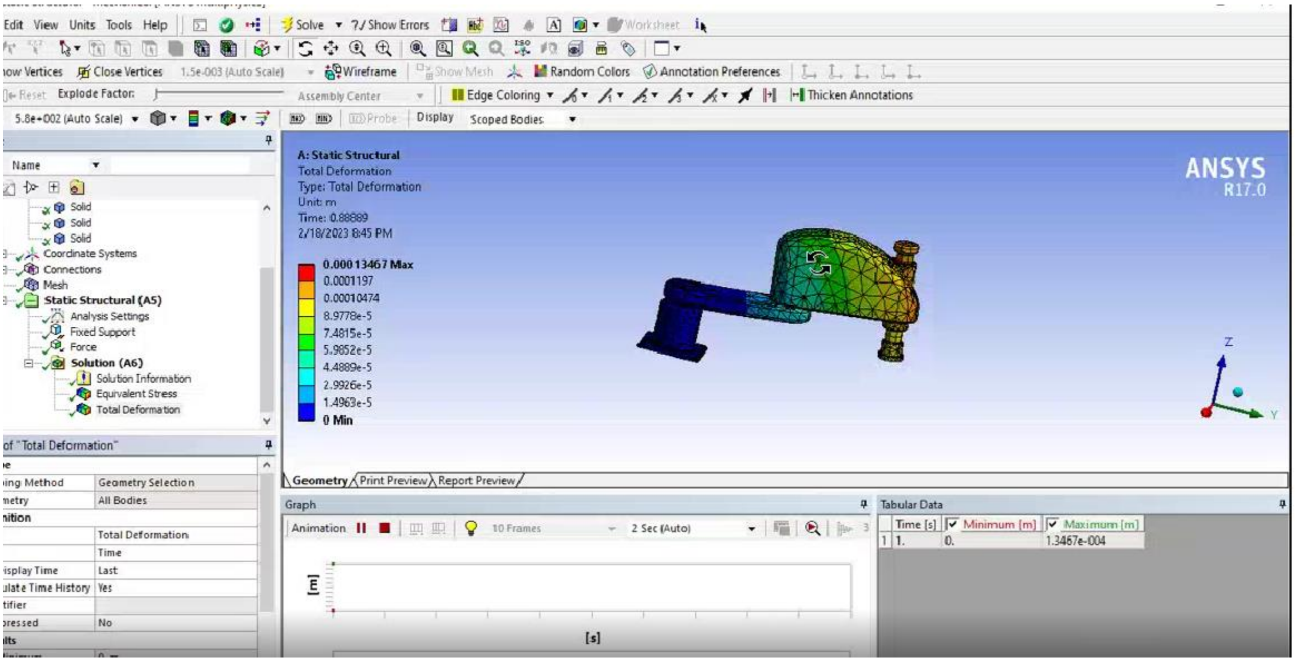


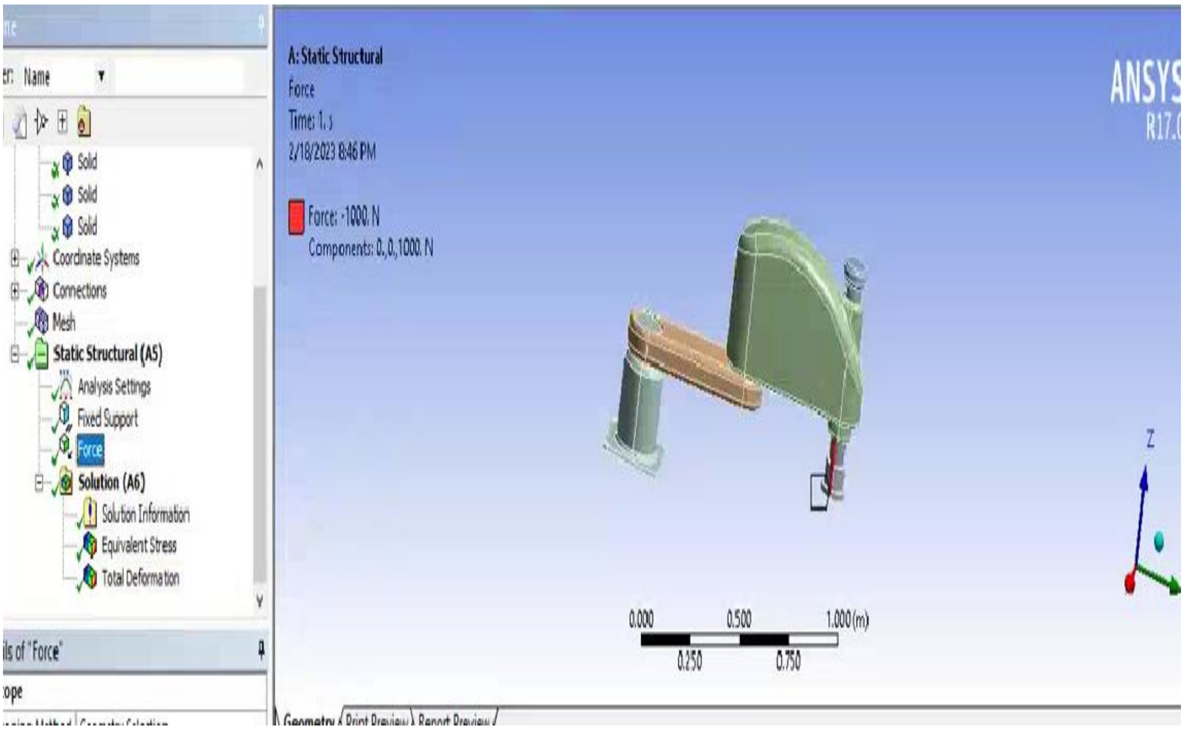
Apply the force and before it fix support,



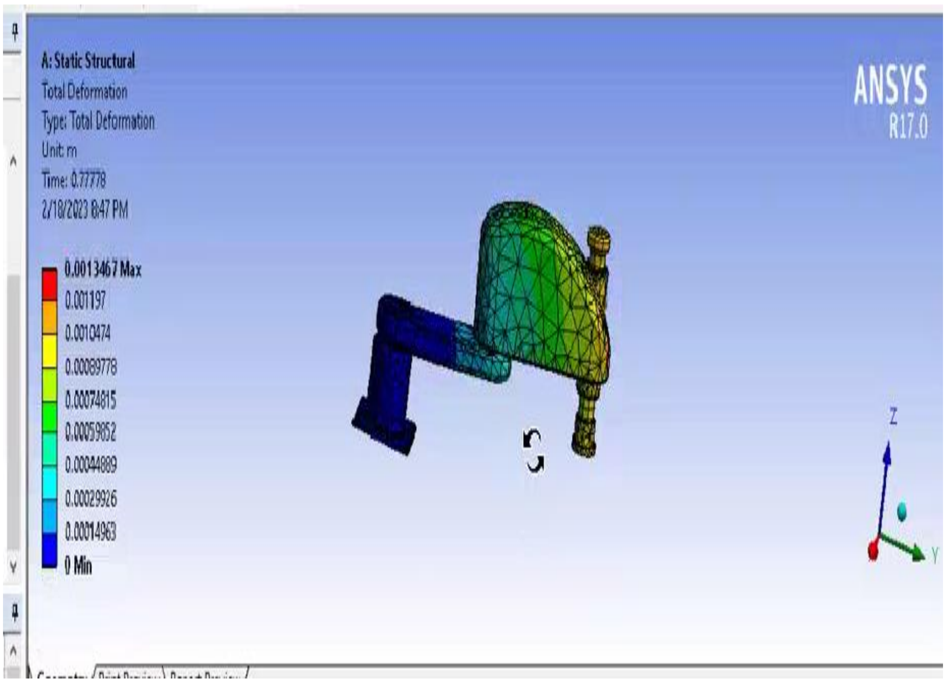


Stress and Deformation Test:





Let us try different parameters,



Conclusion:

In conclusion, the Kinematic and Structural analyses of the SCARA robot were carried out using RoboAnalyzer and Ansys software, respectively. The analysis of the SCARA robot was conducted to evaluate its performance and identify potential areas for improvement.

The Kinematic analysis of the SCARA robot was carried out using RoboAnalyzer software. The software helped in simulating the movement of the robot's arm and its end-effector. The results obtained from the Kinematic analysis showed that the robot's arm could move in all three dimensions with high precision and accuracy. The simulation also indicated that the robot could achieve its desired motion within its workspace. The Kinematic analysis results can be used to optimize the robot's movement parameters such as speed and acceleration to ensure that the robot can perform its tasks with high efficiency and accuracy.

In addition to Kinematic analysis, Structural analysis of the SCARA robot was conducted using Ansys software. The structural analysis was carried out to evaluate the mechanical strength of the robot's arm and identify any areas of weakness that may lead to failure. The results from the Structural analysis showed that the robot's arm was structurally stable and had the required strength to carry out its tasks without failure. The analysis also identified areas where the robot's arm could be strengthened to improve its overall performance.

The combined results of the Kinematic and Structural analysis of the SCARA robot provide insight into the robot's performance and its capability to perform its tasks effectively. The analysis results can be used to optimize the robot's movement parameters and identify areas where the robot can be improved for enhanced performance.

The RoboAnalyzer and Ansys software used for Kinematic and Structural analysis, respectively, proved to be effective tools for evaluating the SCARA robot's performance. The software helped in simulating the robot's motion and its mechanical properties, making it easier to identify any areas that may require improvement. The use of these software tools has enabled engineers and designers to analyze the performance of the SCARA robot accurately and identify areas where it can be improved for enhanced performance.

I have shown that the robot is capable of achieving its desired motion with high precision and accuracy. The Structural analysis also showed that the robot's arm is structurally stable and has the required strength to carry out its tasks without failure. These results are significant for the development of the SCARA robot and can be used to optimize its performance for enhanced efficiency and accuracy in its operations.

THE FUTURE SCOPE,

The future scope of kinematic and structural analysis of SCARA robots is vast and promising. As the field of robotics continues to advance, there is a growing need for more sophisticated and capable robots. The integration of SCARA robots with other technologies, such as artificial intelligence and machine learning, will enable these robots to perform more complex tasks with greater precision and accuracy.

In terms of kinematic analysis, future research can focus on optimizing the robot's motion planning and trajectory control algorithms, which will improve its performance and reduce its energy consumption. Additionally, the use of augmented reality and virtual reality can facilitate the training of operators to control and program SCARA robots.

Regarding structural analysis, future work can investigate the use of advanced materials and manufacturing techniques to reduce the weight of the robot and increase its strength and durability. Moreover, the incorporation of sensors and data analytics can enable predictive maintenance and early fault detection, improving the robot's reliability and reducing downtime. Overall, the future scope of kinematic and structural analysis of SCARA robots is promising, and it will continue to drive innovation in the field of robotics.

Thanks for reading
