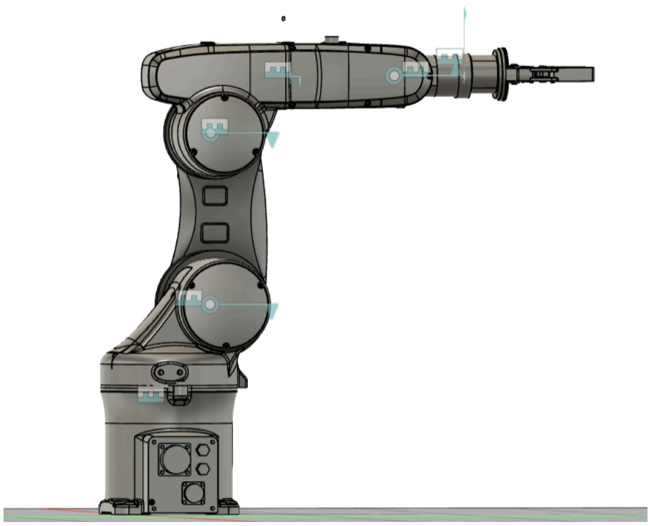
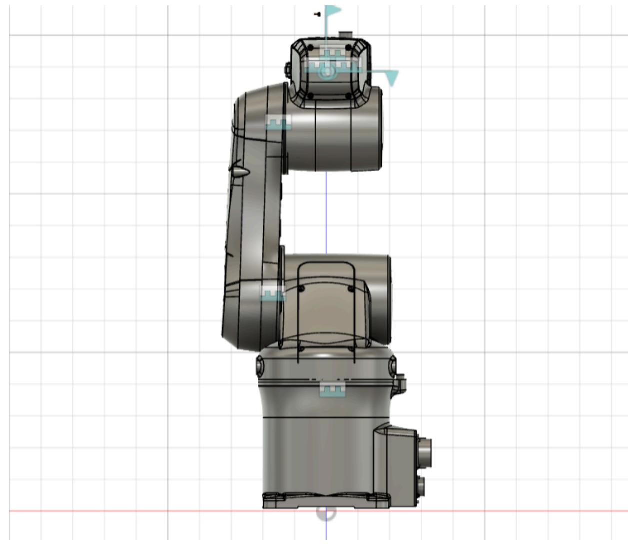
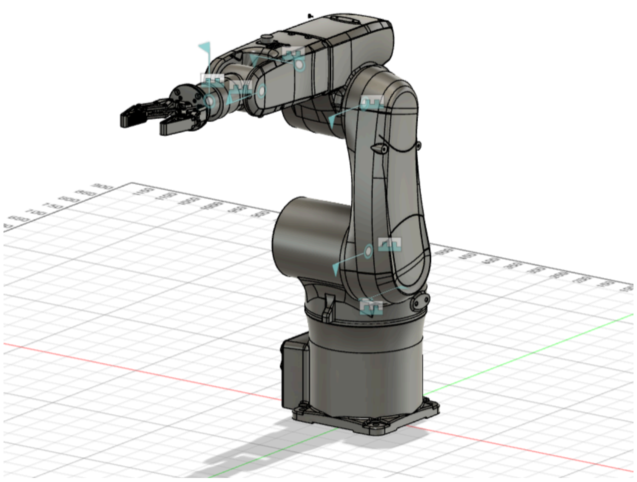
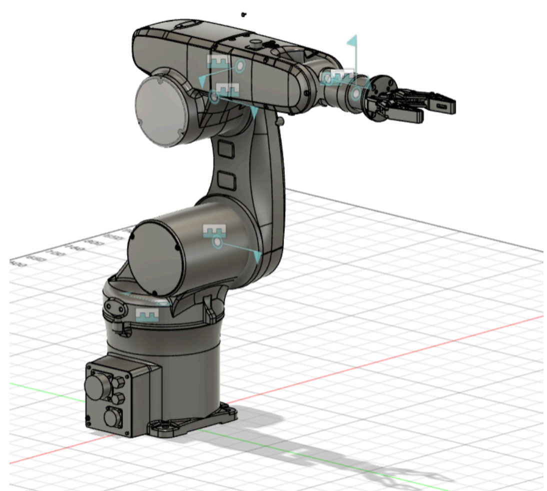
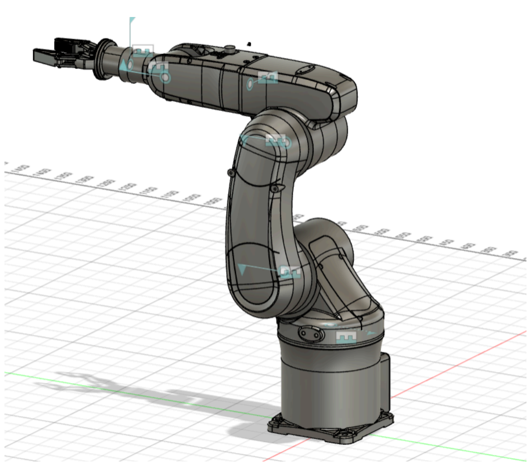
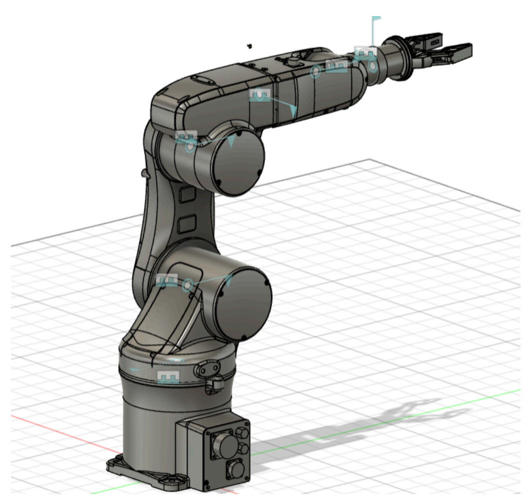
ME 306 PROJECT REPORT

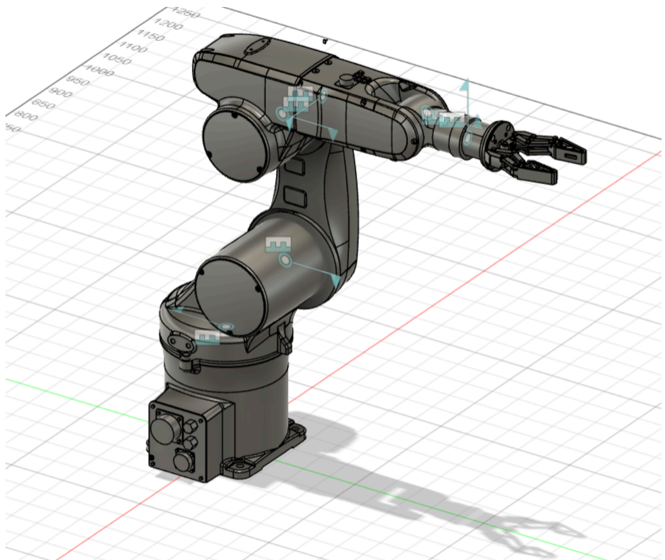
Topic: ADEPT-6 DESIGN ANALYSIS

Project Report Submitted By Group 8:

Name of the Group Member	Roll Number
Devashish Mihir Thakkar	210003077
Saran Teja	210003052
Vempati Rishi	210003083
Banoth Vennela	210005013
Raghavi Venkata	210003043
Sai Abhinav	210003041
Kondapally Dhanush	210003042
Ranjith Naik	210003062
Savara Jeevana	210003068
Stacy Harold	200003077
Anshuman Gaurav	200003013

OUR CAD DESIGN IMAGES:



INDEX

Sr. No	Topic
1	Introduction
2	Project Background
3	Methodology (CAD Modeling)
4	Design and Dimensions
5	Linkages and Joints
6	Stress analysis with payload (x2) with area converted
7	Kinematic Diagram & Hand Calculations
8	Results and Discussions

1. Introduction

In today's rapidly evolving technological landscape, the intersection of design and fabrication plays a pivotal role in shaping the future of robotics. As the demand for versatile and efficient robots continues to grow, it becomes imperative to dive into the intricate nuances of both design principles and fabrication techniques.

The Adept-6 tabletop-sized robot plays a pivotal role in industrial automation, research and development, educational robotics, and small-scale manufacturing processes.

This design analysis report aims to evaluate the structural integrity of the robot.

Here are some pics showing real time Adept-6 mode in work:

2. Project Background

By conducting structural analysis, we seek to gain insights into its mechanical behavior under different loading conditions and assess its dynamic response to external forces.

Description:

The Adept-6 is a high-performance industrial robotic arm designed for precision handling and assembly tasks.

The Robotic Arm boasts a versatile range of motions, including**:**

- Base rotation**:** Provides 360-degree horizontal movement for expansive workspace coverage & fluid maneuverability.
- Shoulder bend**:** Enables vertical movement of the arm for reaching various heights & helps in precise positioning.
- Elbow bend**:** Allows for additional dynamic reach and maneuverability within the workspace
- Wrist pitch**:** Facilitates precise tilting of the gripper for accurate part placement (flexibility in orientation)
- Wrist roll**:** Offers rotational control of the gripper at the end of the arm, allowing for fine manipulation of objects.

Adept-6 is equipped with a robust gripper capable of handling objects weighing up to a specified limit (exact payload capacity may vary depending on the specific Adept-6 model).

The robot gripper typically uses sensors like proximity sensors or force/torque sensors to detect object presence or contact. The margin within which it can detect object presence depends on the specific sensors used and their sensitivity settings.

Proximity sensors, for example, can detect objects within a certain range, often measured in millimeters to centimeters, depending on the sensor's specifications. Force/torque sensors can detect contact forces and thus object presence when the force exceeds a certain threshold.

Regardless, even if the gripper design may differ from other models, it offers similar grasping capabilities for various object shapes and sizes.

3. Methodology/ Approach

The design analysis was conducted using computer-aided design (CAD) Autodesk Fusion 360 software.

We have rebuilt the Adept-6 robot design, tailored to tabletop dimensions while retaining essential functionality and aesthetics of the original design.

So form our opinion and perform design calculations for the robot model the following phases were completed:

1. Reference Gathering: We collected available visual references regarding the gripper's structure, dimensions, and overall appearance.

2. Modeling Approach: Leveraging Fusion 360's robust modeling tools for the basic geometric shapes that comprise the gripper robot, including the standard base, arm segments, and grippers.

3. Dimensional Scaling: To adapt the design to a tabletop size, the base diameter was adjusted to **120** mm & maintaining proportional relationships at **0.6**x scale factor throughout the design.

4. Assembly and Validation: Once individual components were modeled, they were assembled to create the complete gripper robot assembly and the design was continuously validated to ensure accuracy.

4. Design with Dimensions

Here's a brief outlook on how we designed the Adept-6 model for our project:

Pre-Design Considerations:

Before diving into Fusion 360, it was crucial to gather information about the Adept-6. So we tried to collect relevant detail on the following aspects:

- Specifications**:** Determining dimensions, weight, payload capacity, and joint range of motion (referring to user manuals, datasheets, & online resources. There were not many available but we tried our best & garnered whatever we could.).
- Material Selection**:** Common materials for robot links include aluminum, steel, or composites. Here we selected the material PLA (Polylactic Acid)
- Functionality**:** Understanding the intended purpose of the robot and the tasks it will perform.

Design Procedure:

1. **Sketching Individual Components:**

    - Starting by sketching the 2D profiles of each link (standard base, arm segments) in Fusion 360.
    - Using dimensions obtained from specifications to ensure accuracy.
    - Creating separate sketches for each unique component.

2. **3D Modeling:**

    - We then extruded the 2D sketches to create 3D solid models of each link.
    - Referring youtube videos we tried to use features like fillets and chamfers to add details and improve manufacturability.
    - Then we added servo motors. SG90 model is used since this model is good enough for a robotic arm of small scale. A total of 6 motors are used to achieve 6 DOF of motion. This motor can help us to achieve a rotation of 180° with precise control. The body of the servo motor is attached to links with a rigid joint and the gear which rotates is attached to links with a revolute joint with minimum angle as 0 deg and maximum angle as 180 deg.

3. **Assembly Modeling:**

    - We then assembled the individual link models using joints to create the complete Adept-6 robot model.
    - Ensured proper alignment and movement between links.

4. **Design Verification and Refinement:**

    - Using Fusion 360's simulation tools we checked for potential interferences during movement.
    - Tried to analyze the model's range of motion comparing it with references available.
    - Reiterated the design few times for aligning simulation results

The Output:

The final result was a functional, digital 3D model of the Adept-6 robot within Fusion 360. This model represented the actual robot's geometry, joints, and overall assembly accurately.

Contribution of key parts to overall functioning:

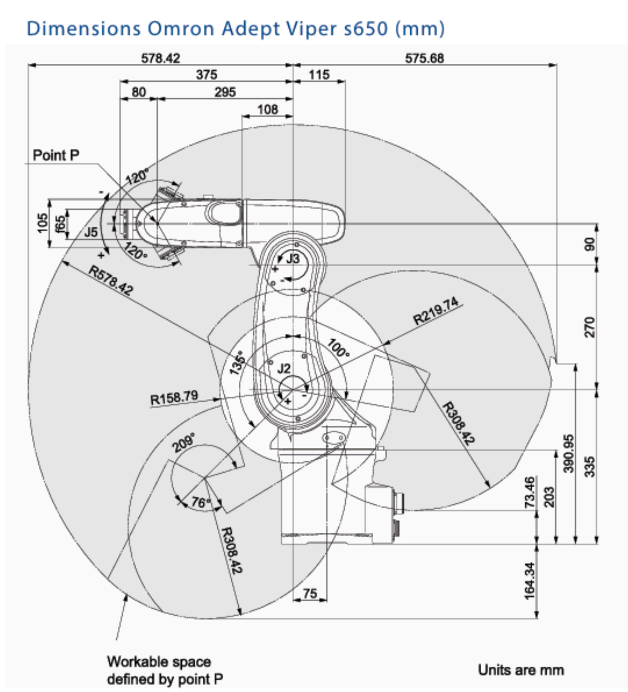
- Links**:** The rigid links form the skeleton of the robot, transmitting forces and motion between joints. Their shapes and sizes influence the robot's workspace and payload capacity.
- Joints**:** These allow controlled movement between links. The type and range of motion of each joint determine the robot's dexterity and flexibility.

Why Fusion 360?

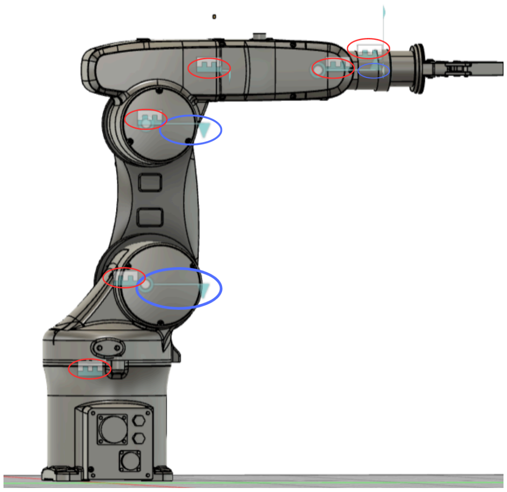
We considered Fusion 360 for the entire course of the project as a single design and simulation software based on the following factors:

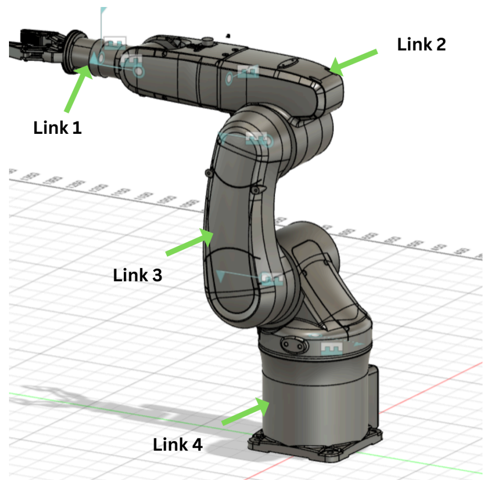
- Ease of Use**:** Fusion 360 offered a user-friendly interface with intuitive tools for sketching, modeling, and assembly. Moreover we had a good expertise learning it over the past 2 years which made it apparent to be inclined for it.
- Simulation Tools**:** Built-in simulation features enabled all the analysis that conformed to project requirements.
- Cloud-Based Collaboration**:** Allows for easy sharing and collaboration on the design with others.

Here's the schematic of the original Omron Adept Viper 6 model we referred during the design:



5. Linkages and Joints





Joints in the model:

In robot models, joints, sometimes called axes, are the fundamental building blocks of movement. They act as the connection points between the rigid segments, known as links, that make up the robot's body or arm. These joints allow for controlled relative motion between the connected links.

They are the workhorses of robot movement. They enable robots to perform various actions by allowing the links to rotate or slide relative to each other. This controlled movement allows robots to:

- Reach specific locations in their workspace.
- Manipulate objects with precision.
- Change their orientation to perform tasks from different angles.

In our Adept-6 model, we have two type of joints. Revolute joint and Rigid Joint. In the first figure above the blue circles represent revolute joints and the red circles represent rigid joints

Revolute Joints:

Revolute joints, also known as rotary joints or hinge joints, enable rotational motion around a single axis. These joints allow parts of the model to rotate relative to each other, mimicking the movement of human joints such as elbows, knees, and wrists. In our Adept-6 model, revolute joints are typically employed at points where rotation is necessary to articulate the robot's arm segments or end effector.

Key Features and Functions:

- Rotational Movement: Revolute joints facilitate rotational movement, allowing the robot arm to bend or pivot at specific angles.
- Axis of Rotation: Each revolute joint has a defined axis of rotation, which determines the direction in which the attached components can rotate.
- Controlled Motion: By actuating the revolute joints using servo motors or other actuators, precise control over the robot's movements can be achieved, enabling tasks such as reaching, grasping, and manipulating objects.

Applications in the Adept-6 Model:

- Articulation of Arm Segments: Revolute joints enable the arm segments of the Adept-6 robot to bend and extend, providing flexibility in reaching various positions within its workspace.
- End Effector Orientation: They allow for the orientation of the end effector (e.g., gripper or tool) to be adjusted, facilitating precise manipulation and interaction with objects.

Rigid Joints:

Rigid joints are fixed connections between components that do not allow for relative motion. These joints provide structural stability and rigidity to the robot's framework, ensuring that it maintains its shape and alignment during operation. In our Adept-6 model, rigid joints are utilized to connect segments of the robot's arm or base securely, minimizing unwanted movement or flexing.

Key Features and Functions:

- Structural Integrity: Rigid joints create strong connections between components, preventing excessive movement or deformation that could compromise the robot's stability or accuracy.

- Load Distribution: By distributing mechanical loads evenly across the robot's structure, thry help to minimize stress concentrations and potential points of failure.
- Alignment Maintenance: They maintain the relative orientation of connected components, ensuring that the robot remains properly aligned and operates as intended.

Applications in the Adept-6 Model:

- Framework Construction: Rigid joints are used to assemble the structural framework of the Adept-6 robot, providing a sturdy and reliable support structure for mounting motors, actuators, and other components.
- Base and Arm Connections: They secure the connections between the base, arm segments, and end effector, maintaining the overall integrity of the robot's mechanical assembly.

Linkages in the model:

Linkages play a crucial role in the functionality and motion control of the Adept-6 robot model. They serve as mechanical connections between various components, facilitating the transmission of motion and force to achieve desired movements and tasks. In the second figure above, we can see 4 linkages at work in our model.

Few aspects of these linkages are discussed below.

1. Functionality:

Linkages act as articulated joints or connections between different segments or parts of the robot's structure. They enable controlled movement and articulation, allowing the robot to reach different positions and orientations within its workspace. Depending on the design and configuration, linkages may enable rotational motion, translational motion, or a combination of both, providing flexibility and adaptability in performing tasks.

2. Role in Motion Control:

These elements are essential for controlling the motion and trajectory of the robot model. They are actuated either by servo motors, pneumatic actuators, or other motion control mechanisms, translating input signals or commands into corresponding movements of the robot's joints and end-effector. By adjusting the angles or lengths of linkages, the robot can navigate its workspace, manipulate objects, and perform tasks with accuracy and efficiency.

3. Integration with Servo Motors:

Linkages are coupled with servo motors or other actuators to achieve controlled motion in our Adept-6 model. Servo motors drive the motion of specific joints or segments by rotating their shafts to desired positions, while linkages transmit this rotational motion to the connected components, enabling coordinated movement and manipulation. The interaction between linkages and servo motors allows for precise control over the robot's kinematics and behavior

4. Design Considerations:

When designing linkages, factors such as mechanical strength, rigidity, range of motion, and weight must be carefully considered. The selection of materials, geometry, and mechanism design plays a crucial role in optimizing the performance and reliability of the linkages, ensuring smooth operation and longevity of the robot model.

6. Stress analysis with payload (x2) with area converted

The purpose of stress analysis and simulation of a robot CAD design is to identify potential structural weaknesses, anticipate points of failure, and optimize the design for durability and performance. By subjecting the CAD model to virtual testing, engineers can assess how different loads, forces, and operating conditions affect the structural integrity of the robot, ensuring that it can withstand real-world stresses and operate safely and reliably.

The process we followed for the same is briefed as follows:

1. Pre-processing:

- 3D Model Acquisition**:** We first designed a 3D CAD model of the Adept-6 robot,.

- Material Properties**:** Then we defined the material properties for each link in the robot arm, such as Young's modulus, Poisson's ratio, and yield strength. The sources for information was research reports/material datasheets.
- Defining Loading Conditions**:** We then identified the forces and moments the robot will experience during operation. It involved considering the robot's payload capacity, range of motion etc.

2. Simulation Software Selection:

For simulation we sticked to the software Autocad Fusion 360 considering the ease of use and the expertise we had.

3. Model Setup:

- Normally one needs to import the design into a chosen software for simulation. It wasn't needed for our case as bothe the design and simulation softwares were the same. We just opened the design that was created in the simulation window.
- We then defined the joints in the model, specifying their type (revolute and rigid) and range of motion.
- It was followed by defining fixed constraints (faces or edges) on the model that represents how it will be attached or supported in real-world use. This simulates how the part is held in place.
- We assigned the material properties to each link in the model.
- Finally we applied the defined loading conditions (forces, motor torque etc) to the robot model at appropriate locations.
- We then broke down our model into a simplified network of small elements called a mesh. The mesh size affects the accuracy and computational time of the simulation. A finer mesh provides more accurate results but takes longer to solve.

4. Simulation Run:

- Running the simulation once everything is defined.
- The software will calculate the robot's motion, joint forces, the stresses, strains, and deformations the model experiences under the applied loads and constraints.throughout the simulated movement.

5. Post-processing and Analysis:

- Analyzed the key results from the simulation as follows.

  Factor of Safety (FOS): A ratio indicating how much stronger the material is compared to the calculated stresses. A lower FOS suggests a higher risk of failure.

Reaction Forces: The forces exerted on the constrained faces/edges due to the applied loads.

Strain: The deformation or change in shape of the model under load.

Displacement: The actual movement of specific points on the model due to the applied loads.

- We also visualized the stress distribution across the robot arm using color plots/scales.
- Identified areas with high stress concentrations, which could be potential failure points.
- Compare the maximum stress values to the material's yield strength to ensure they stay within safe limits.

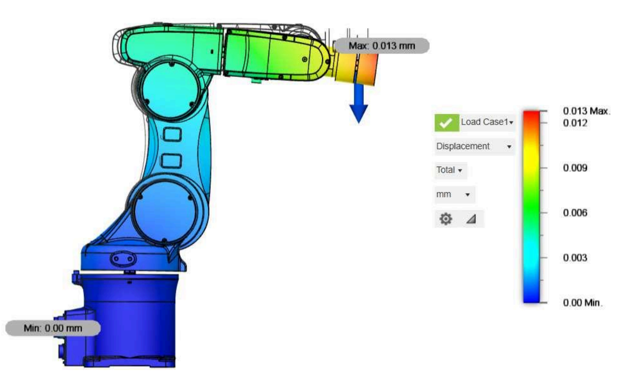
7. Kinematic Diagram & Hand Calculations - Attached

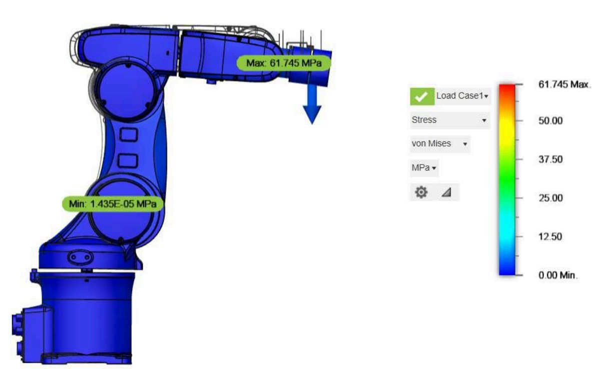
8. Results and Discussions based on Stress Analysis

The analysis is done with different forces applied to the end effector or gripper of the robotic arm with two different materials namely Structural Steel and Aluminum Alloy 356. The results of total deformation and total equivalent Stress is carried out for four different loading conditions i.e. 75N, 100N and 200N. If the value of maximum stress is greater than the yield stress that means the structure will fail.

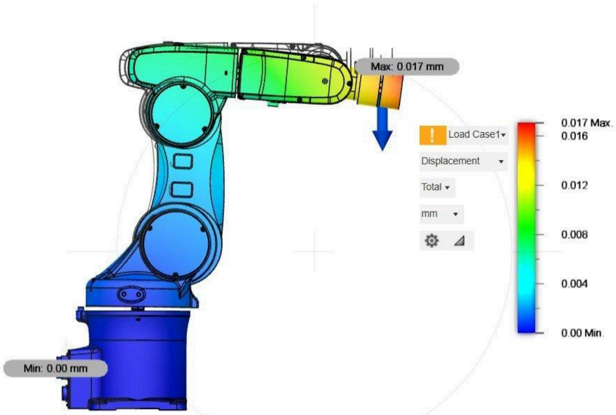
The simulation images are shown as follows:

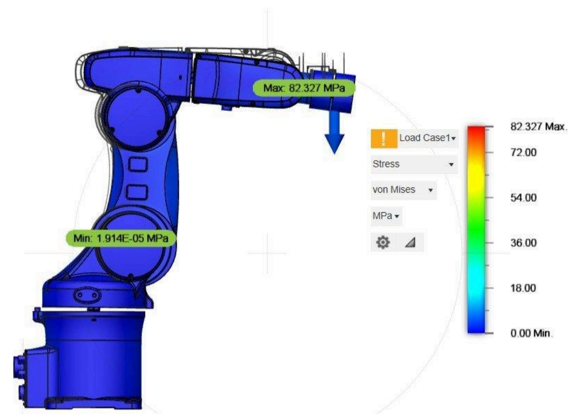
For 75N load, displacement & stress distribution



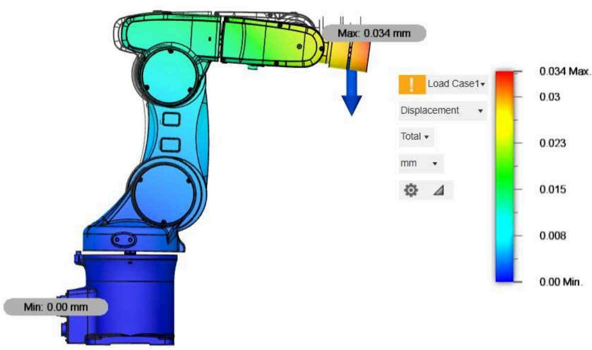


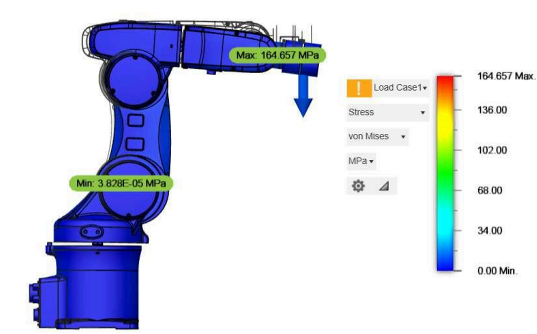
For 100N, displacement & stress distribution





For 200N load, displacement & stress distribution



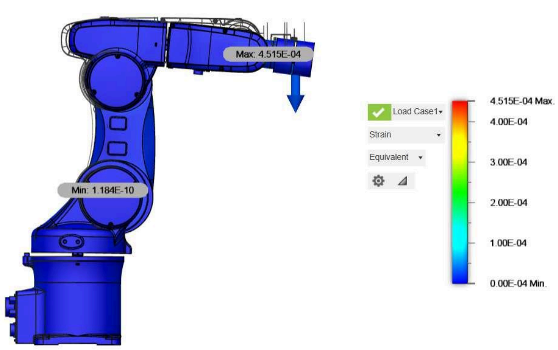


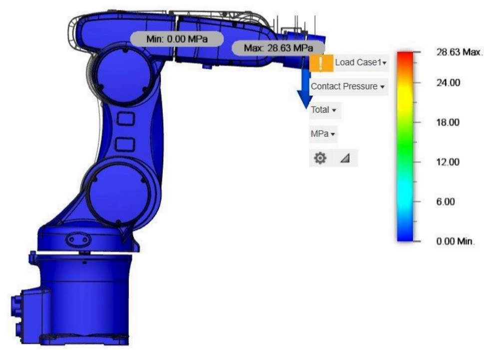
Here's the observation table for the extremum we get for each of the loads we used:

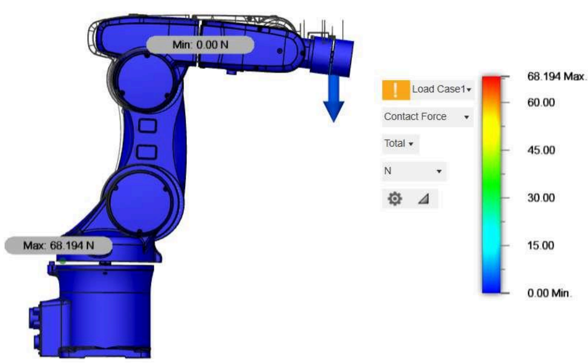
Force (N)	Max Equivalent Stress (MPa)	Max Deformation (mm)
75	61.745	0.013
100	82.327	0.017
200	164.657	0.034

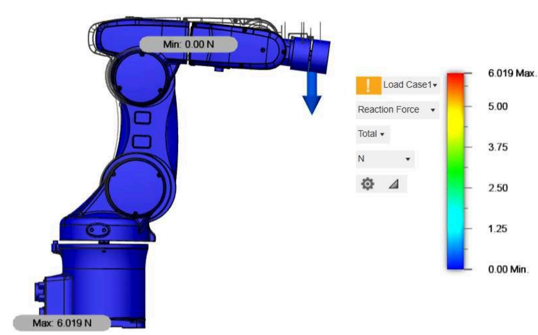
We can also see various other factors like reaction force, contact pressure, strain, contact force etc after the analysis.

Here are few pics showing it:









9. Conclusion

Design and Development of a versatile and low-cost Adept-6 model was possible due to systematic approach taken. A 3D CAD software, Fusion 360 was used to design an explained robot and the designed model is structurally analyzed with the same software.

This robot can be used in industries for various tasks such as packaging, assembly etc. The structural analysis has been successfully verified. It is observed that the model is meeting design requirements and is able to carry various payloads. This is suitable for hazardous areas in industries and will be helpful in increasing productivity. In the future, simulation can be carried out in the given workspace.

10. Materials Used & Our 3D Printed Model

We used PLA (Polylactic Acid) as our 3D printing material, a feasible option for this project.

Here are the material properties:

Density: 1.3 g/cm^3
Infill Density: 20%
Total Mass: 396.841 grams
Volume: 3.053 x 10^5 mm^3

To optimize the robot's weight for maneuverability while maintaining structural integrity, we limited the infill amount to 20%. This infill percentage provided a good compromise between strength and weight, meeting our rigidity requirements for the Adept 6's anticipated range of motion.

Initially, we thought to explore building the base or support arms with a combination of wood blocks and pipes for a potentially faster and more cost-effective approach. However, due to the inherent dimensional uncertainties associated with working with wood and the need for precise joint alignments crucial for the robot's functionality, we opted for the dimensional accuracy and control offered by 3D printing the entire robot structure.

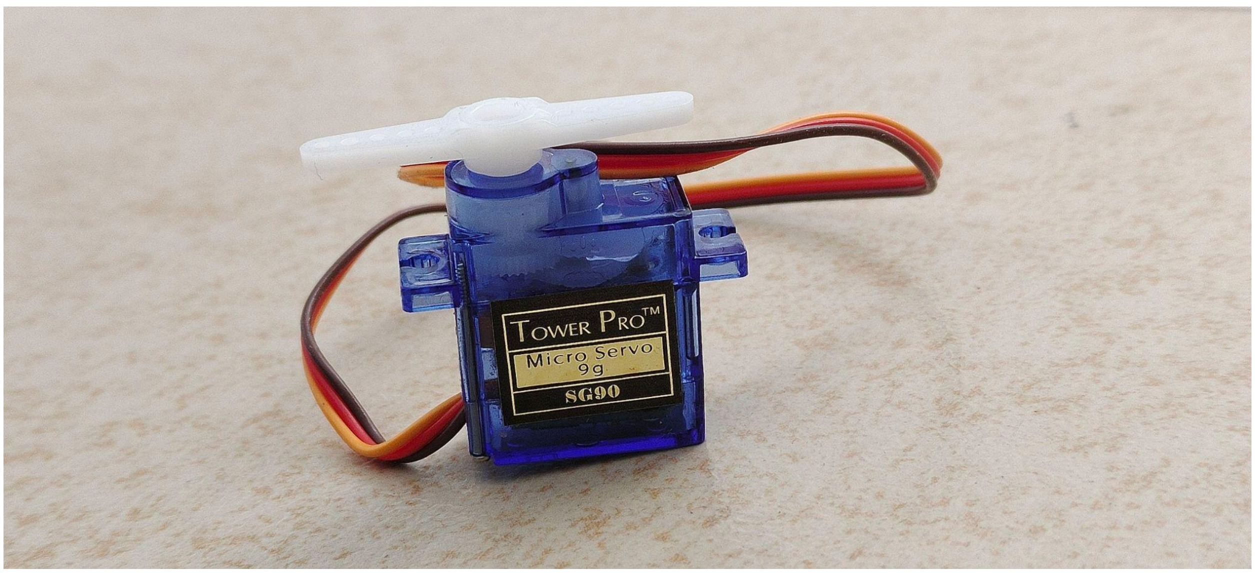
(Images of our 3D- printed model are attached)

11. Motor Description

We used 6 servo motors in our design model.

The servo motors in the robot arm facilitate precise movement within a 180-degree range. It operates based on a closed-loop control system, where feedback mechanisms ensure accurate positioning. These motors feature a compact design, allowing seamless integration into the arm structure. Its high torque output enables the arm to manipulate objects with efficiency and reliability. Using 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.

Here is the actual pic of the SG90 motor we used in our fabrication:



12. Future Scope & Applications

The future scope and applications of the Adept-6 robot model are diverse and promising, reflecting the increasing demand for automation and robotics across various industries. Here's some areas where we can see its potential:

- Manufacturing and Assembly: Adept-6 robots will continue to play a vital role in manufacturing and assembly lines. With advancements in AI and machine learning, these robots can adapt to changing production needs, perform complex assembly tasks with precision, and collaborate safely alongside human workers. This ensures higher efficiency, improved quality control, and quicker turnaround times in production processes.

- Packaging and Logistics: In the e-commerce era, there's a growing need for efficient packaging and logistics solutions. Adept-6 robots excel in handling, sorting, and packaging goods in warehouses and distribution centers. With their speed and accuracy, they streamline order fulfillment processes, reduce errors, and optimize inventory management, thereby enhancing overall supply chain efficiency.

- Material Handling and Warehousing: Adept-6 robots are well-suited for material handling tasks such as palletizing, depalletizing, and conveyor handling. In warehousing environments, they can autonomously navigate through dynamic environments, locate and transport items, and perform inventory management tasks. As the demand for automation in logistics grows, Adept-6 robots will become indispensable for optimizing warehouse operations.

- Electronics Manufacturing: The electronics industry requires precision and reliability in assembly processes, making Adept-6 robots an ideal choice for tasks like soldering, PCB handling, and component placement. With advancements in vision systems and sensor technology, these robots can detect defects, ensure accurate soldering joints, and improve overall product quality in electronics manufacturing facilities.

- Medical and Pharmaceutical Applications: Adept-6 robots hold immense potential in the medical and pharmaceutical sectors. They can assist in repetitive tasks such as pill dispensing, sample handling, and surgical instrument sterilization. Additionally, in laboratory settings, these robots can automate processes like pipetting, sample preparation, and assay development, leading to increased productivity and reproducibility in research and diagnostics.

- Food Industry: In the food industry, Adept-6 robots offer solutions for food processing, packaging, and quality inspection. They can handle delicate food items with care, ensure consistent portioning and packaging, and perform tasks such as sorting, grading, and labeling. With food safety regulations becoming increasingly stringent, Adept-6 robots help maintain hygiene standards and reduce contamination risks in food production facilities.

- Collaborative Robotics: As collaborative robots (cobots) gain traction, the Adept-6 model can be further developed to enhance its collaborative capabilities. By integrating advanced safety features and intuitive programming interfaces, these robots can work alongside human operators in shared workspaces, facilitating close collaboration and enhancing productivity in diverse industries.

Thank You.