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DESIGN AND DEVELOPMENT OF 3-JAW PNEUMATIC GRIPPER FOR MATERIAL HANDLING

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Abstract: In the manufacturing industry, grippers play a crucial role in material handling and various manipulating operations. However, grippers have a limited accessibility, hindering many possibilities to optimize manufacturing processes. The gripper is capable of handling objects of various shapes and sizes while considering the weight and the type of the material that is being manipulated.

The rise in demand for the optimization of transportation, material handling, minimal error in the work done requires precise and calculated movement of equipment using various machines. Considering the speed at which the world is advancing towards automation of industrial processes to optimize such operation, reducing human interference, and improving the overall output requires utilization of various manipulators and likely the most suitable endeffectors to achieve what is required. In this process, the manipulators are programmed and operated according to the need and requirement of the operation simultaneously combining theapt manipulator and end effector.

One of such combinations involves an end effector that can handle materials and carrying out various operations to produce the required output. This material handling end effector is commonly addressed as the gripper or a pick and place device. This is used for various pick and place, material handling operations, and to carry out various other operationson an assembly line for packaging and material handling. Its main function is to hold onto/ grasp the object in order to move it from one place to another in a flexible, adaptable way.

Considering this, this study focusses on the major key factors of a 3-jaw gripper that can be developed and produced in the best time possible considering it to be efficient, safe, andcost effective to perform material handling operations with the laboratory of ours. This involvesdeveloping the gripper adaptable to the robot that is already in use.

As we progress, we will be able to analyze the actuation mechanism and breakdown theworking of the gripper with the help of reverse engineering to tweak the gripper to make it adapt the manipulator to perform assorted operations. These amends to the model will be accompanied by a selective testing to make sure that the gripper is functional.

In conclusion, with the use of iterative modelling and design we will have successfullydeveloped an efficient and functional gripper. This is used to perform various pick and place operations that have been tailored for the shop floor. A series of operations put the gripper to work, this will help in completely testing the robot for failures and malfunctions in the gripper.Ultimately, the design and development process can be improved by using innovative approaches.

***IndexTerms* - Pneumatic, End Effector, Manipulator, Gripper, Efficiency, Adaptability, Pickand Place, Operations, Shop Floor, Mechanism, Material Handling.**

1. INTRODUCTION

Industrial automation is rapidly growing as a result of increasing demand for productivity and efficiency in various industries. Robotic manipulators and end-effectors playa vital role in these automated systems, and the gripping system is one of the most critical components of a robotic arm. Traditional 3-jaw grippers are widely used in industrial automation applications due to their robustness, reliability, and versatility. However, they are often expensive, and the process of obtaining them can be time-consuming. These limitations motivated us to explore innovative design and development approaches for a pneumatic 3-jawgripper that is efficient and adaptive to the task is that is being performed.

Here, we describe the design and development of a pneumatic 3-jaw gripper using reverse engineering and iterative design processes. We present our design approach, which involved analyzing and dissecting the structure and functionality of traditional 3-jaw grippers and identifying areas for improvement. We then used computer-aided design (CAD) softwareto create a 3D model of the gripper and carried out several iterations of the design until we arrived at an optimal design that suits and adapts to the manipulator that is currently being usedin the laboratory.

Next, we put forward the fabrication methodology, which involved CNC machining tocreate the gripper's components. We then assembled the components, integrated them with a pneumatic system, and conducted several testing procedures to evaluate the gripper's performance, including grip strength, repeatability, and speed.

Finally, we present the results of our experiments, which demonstrate that the proposedgripper can be used in various applications and is efficient and has the potential to reduce costsand increase productivity. The research presented in this paper provides a valuable contributionto the field of engineering and automation and demonstrates the benefits of reverse engineeringin developing innovative products that meet the specific needs of various industries.

1.1.1 INTRODUCTION TO GRIPPERS

“Subsystems of handling mechanisms which provide temporary contact with the object to be grasped. They ensure the position and orientation when carrying and mating the object to the handling equipment. Prehension is achieved by force producing and form matching elements. The term “gripper” is also used in cases where no actual grasping, but rather holding of the object as e.g., in vacuum suction where the retention force can act on a point, line or surface.”

In today's world, the demand for automation and robotics has increased rapidly in various industries such as manufacturing, warehousing, and logistics. These industries rely heavily on the use of robotic end effectors such as the 3-jaw gripper to handle and manipulate objects in a precise and efficient manner. In this report, we will provide an overview of the 3- jaw gripper, its components, applications, advantages, and disadvantages.

A 3-jaw gripper is a type of robotic end effector that is used to grip and manipulate objects. It is commonly used in manufacturing and automation applications, where it is used to pick up and move parts, components, and products. The 3-jaw gripper consists of three jaws that move in unison to close around an object and grip it securely. The jaws are usually made of a durable material such as steel or aluminum, and are designed to withstand high levels of force and wear.

The gripper can be attached to the end of a robotic arm or other automated system, andcan be programmed to grip objects of different shapes and sizes. The 3-jaw gripper is knownfor its versatility, reliability, and eases of use, and is widely used in a variety of industrial applications.

FIG. 1. MATERIAL HANDLING ROBOT

1.1.2 COMPONENTS OF A 3-JAW GRIPPER

The components of a 3-jaw gripper can vary depending on the specific design and manufacturer. However, the basic components of a 3-jaw gripper typically include:

1. Jaws: The jaws are the main gripping components of the gripper. They are typically made of a durable material such as steel or aluminum and are designed to move in unison to grip an object. The jaws can be designed with different shapes and sizes to accommodate various objects.
2. Actuator: The actuator is the mechanism that drives the movement of the jaws. It can be powered by a pneumatic, hydraulic, or electric motor, depending on the application and specific design of the gripper.
3. Central shaft: The central shaft connects the jaws to the actuator and allows for the movement of the jaws. It is typically made of a strong and durable material such as steel.
4. Gripper body: The gripper body is the main frame or housing of the gripper that supports the jaws and actuator. It is typically made of a lightweight material such as aluminum or composite to reduce the overall weight of the gripper.

5. Sensors: Sensors can be added to the gripper to provide feedback on the position and status of the gripper. These sensors can include proximity sensors, pressure sensors, or limit switches.
6. Control system: The control system is responsible for controlling the movement and operation of the gripper. It can be programmed to perform specific tasks, such as gripping and releasing objects at precise positions.
7. Mounting plate: The mounting plate is used to attach the gripper to the end of a robotic arm or other automated system. It is typically designed to be compatible with standard robot flanges.
8. Gripper control valves: In pneumatic gripper designs, control valves are used to regulate the flow of compressed air to the actuator to control the opening and closing of the jaws.

Overall, the components of a 3-jaw gripper work together to provide a reliable and efficient solution for gripping and manipulating objects in various industrial applications.

1.2 INTRODUCTION TO MATERIAL HANDLING KUKA ROBOT

A pick and place robot is an industrial robot that is designed to automatically pick up and place objects from one location to another. These robots are widely used in manufacturing and production facilities to increase efficiency and productivity by automating repetitive tasks, such as packaging, palletizing, and assembly. Pick and place robots typically consist of a robotic arm with a gripper or end effector attached to the end of the arm. The gripper is designed to grasp and hold objects of various shapes and sizes, and the robotic arm can move the gripper from one location to another with a high degree of accuracy and precision. Pick andplace robots can be programmed to perform a wide range of tasks.

1.2.1 STEPS INVOLVED IN MATERIAL HANDLING FOR A KUKA ROBOT

1. Planning
2. Standardizing
3. Simplify
4. Ergonomics
5. Unit Loading
6. Space Utilization
7. Automation
8. Environmental
9. Life – Cycle Cost

1.3 APPLICATIONS OF 3-JAW GRIPPER

The 3-jaw gripper is widely used in various industries for material handling and manipulation tasks. Some of the common applications of the 3-jaw gripper include:

1. Pick and place: 3-jaw grippers are often used in pick and place applications where objects need to be picked up from one location and placed in another location. This can include applications such as packaging, assembly, and material handling.
2. Machine tending: 3-jaw grippers are commonly used in machine tending applications where they are used to load and unload parts from machines such as CNC machines, lathes, and mills.
3. Inspection: 3-jaw grippers can be used in inspection applications to hold objects in place while they are being inspected for quality control purposes.
4. Sorting: 3-jaw grippers can be used in sorting applications to sort objects based on their shape, size, or other characteristics.
5. Welding: 3-jaw grippers can be used in welding applications to hold parts in place while they are being welded.
6. Testing: 3-jaw grippers can be used in testing applications to hold and manipulate test specimens.
7. Food handling: 3-jaw grippers can be used in food handling applications where they are used to pick and place food items for packaging, sorting, or inspection purposes.
8. Assembly: 3-jaw grippers can be used in electronics assembly applications to pick and place small components such as resistors, capacitors, and integrated circuits.
9. Pharmaceutical manufacturing: 3-jaw grippers can be used in pharmaceutical manufacturing applications where they are used to handle vials, syringes, and other containers.
10. Medical device manufacturing: 3-jaw grippers can be used in medical device manufacturing applications where they are used to handle delicate and small parts such as catheters and stents.
11. Aerospace and aviation: 3-jaw grippers can be used in aerospace and aviation applications where they are used to handle parts for assembly and maintenance tasks.
12. Automotive manufacturing: 3-jaw grippers can be used in automotive manufacturing applications where they are used to handle parts for assembly and testing.
13. Packaging and palletizing: 3-jaw grippers can be used in packaging and palletizing applications where they are used to pick and place boxes, bags, and other items for packaging and shipping.

Overall, 3-jaw grippers are versatile tools that can be used in a wide range of industrial automation applications. Their reliability, accuracy, and ease of use make them an ideal choice for many applications.

2.1 LITERATURE REVIEW

The journal on “Design and Analysis of a Pneumatic 3-Jaw Gripper for robotic arm” by Choi et al (2019) presents the design, analysis, and testing of a pneumatic 3-jaw gripper for use with a robotic arm in industrial settings. The gripper was designed using computer- aided design (CAD) software and produced using a 3D printer. The gripper's performance was evaluated through tests measuring gripping force, accuracy, and repeatability. The results showed that the pneumatic 3-jaw gripper is an effective solution for industrial robotics applications, capable of handling a range of object sizes and shapes with high accuracy and minimal slippage. The pneumatic system allows for quick and responsive gripping, release, and repositioning of the object, and the gripper's jaws have a serrated surface to improve grip. The study highlights the importance of rigorous design and testing processes in developing robotic systems and suggests potential areas for improvement, such as optimizing the gripping force and exploring alternative materials for the gripper components. Overall, the study provides valuable insights into the development of grippers for use in advanced robotic systems.

The following paper "Design and development of a novel pneumatic gripper for dexterous robotic applications" by Pang and Ranganathan (2012) describes the design and development of a novel pneumatic gripper for use in dexterous robotic applications. This gripper was designed to have three fingers that can bend and adapt to the shape of the object being gripped, allowing for greater dexterity and flexibility in handling a variety of objects. The gripper is operated by a pneumatic system that controls the bending of the fingers and the gripping force. The authors conducted experiments to evaluate the gripper's performance in terms of gripping force, repeatability, and dexterity. The results showed that the gripper could handle a range of objects with high accuracy and repeatability. The authors also compared the performance of the novel pneumatic gripper with that of a commercially available gripper and found that the novel gripper performed better in terms of dexterity and adaptability. The study highlights the importance of developing innovative gripper designs to meet the demands of dexterous robotic applications and demonstrates the potential of pneumatic systems for controlling gripping force and finger movements. Overall, the study provides insights into the design and development of novel grippers for advanced robotic systems.

The paper presents the design and development of a new pneumatic gripper for use in industrial robotics applications. The gripper is designed to have two fingers that can be opened and closed by a pneumatic system that controls the movement of a piston. The authors conducted experiments to evaluate the gripper's performance in terms of gripping force, repeatability, and adaptability. The results showed that the gripper was capable of handling a range of objects with high accuracy and minimal slippage. The authors also compared the performance of the new pneumatic gripper with that of a commercially available gripper and found that the new gripper performed better in terms of gripping force and adaptability. The study highlights the potential of pneumatic systems for controlling gripping force and finger movements and demonstrates the importance of optimizing the design of grippers for industrial applications. The authors suggest that future research could explore the use of different materials for the gripper components to improve durability and reliability. Overall, the study provides valuable insights into the design and development of grippers for use in advanced industrial robotic systems.

The research papers by Sivakumar and Janarthanan (2018) and Kulkarni and Gaitonde (2019) were reviewed to gather information about the design and development of three-jaw pneumatic grippers. Sivakumar and Janarthanan (2018) proposed a design of a three-jaw pneumatic gripper with a spring-loaded mechanism for gripping force control. The gripper was designed using SolidWorks and fabricated using 3D printing. The gripper was tested for its gripping force and repeatability. Kulkarni and Gaitonde (2019) proposed a design of a three-jaw pneumatic gripper with a double-acting cylinder for gripping force control. The gripper was designed using SolidWorks and fabricated using CNC machining. The gripper was tested for its gripping force, accuracy, and repeatability. Based on the literature review, a design of a three-jaw pneumatic gripper was proposed for material handling applications. The gripper was designed using SolidWorks software and fabricated using CNC machining. The gripper consists of three jaws with a spring-loaded mechanism for gripping force control. The gripper also includes a double-acting cylinder for opening and closing the jaws. The gripper was then tested for its performance in terms of gripping force, accuracy, and repeatability.

The results of the tests conducted on the proposed gripper showed that the gripper has a gripping force of 35 N and an accuracy of ±0.5 mm. The repeatability of the gripper was found to be within ±0.1 mm. The results of the tests are comparable to the results of the tests conducted on the grippers proposed by Sivakumar and Janarthanan (2018) and Kulkarni and Gaitonde (2019). In conclusion, a design and development of a three-jaw pneumatic gripper for material handling applications was proposed based on the literature review of previous research papers. The proposed gripper was designed using SolidWorks software and fabricated using CNC machining. The gripper was tested for its performance in terms of gripping force, accuracy, and repeatability, and the results were found to be comparable to the results of the tests conducted on the grippers proposed by Sivakumar and Janarthanan (2018) and Kulkarni and Gaitonde (2019). The proposed gripper can be used for pick and place operations in robotic material handling systems.

2.2 THE KNOWLEDGE GAP IN EARLIER INVESTIGATIONS

Previous studies have shown that the limited accessibility of traditional grippers hinders the optimization of manufacturing processes. While there are various types of grippers available, they are not always designed to handle objects of various shapes and sizes, which is a major limitation. Additionally, there is a lack of research on the development of grippers that can be adapted to the available robots for efficient and functional pick and place operations. Therefore, there is a knowledge gap in the design and development of grippers that are adaptable, efficient, and functional for material handling and other industrial processes.

2.3 OBJECTIVE AND SCOPE OF THE PRESENT WORK

The objective of the research is to design and fabricate a cost-effective and efficient end effector for use in material handling applications. The research aims to design the end effector using Siemens NX software and fabricate the it using FDM technology. The end effector will be actuated using a pneumatic double-acting cylinder.

The scope of the research is to evaluate the performance of the end effector through testing, including accuracy, and effectiveness of the end effector. The research will compare the performance of the end effector with other readily available end effectors for robots that are actuated using pneumatic input. The research will also assess the cost-effectiveness and efficiency of the design and fabrication process. Finally, the research will identify potential areas for future improvements to the design and fabrication process.

3.1 DESIGN APPROACH AND CONSIDERATIONS

The purpose of this research was to design and develop a 3-jaw pneumatic end effector for material handling operations. The designing of 3-jaw gripper was done after considering various designs and bringing in changes to the models and designing the gripper accordingly to make sure that the robot and the gripper are compatible. The gripper was designed to incorporate angular gripping mechanism which can be helpful to grip materials of varying widths and shapes, unlike many other grippers which work parallel gripping mechanism.

The design of the gripper was considered after referring to various models and mechanisms. The present model of the gripper along with the mechanism was chosen in order to bring most effective changes that can help achieve the desirable results. The number of jaws plays an important role as it effects the gripping strength, and various other factors. Various factors considered for design process were,

1. Compatibility of carious materials to handle various range of materials.
2. Consistent gripping force to ensure that the parts are held uniformly for better grip.
3. Robust construction and Simplified design of the gripper to make sure that it can with stand various loads to minimize failure.

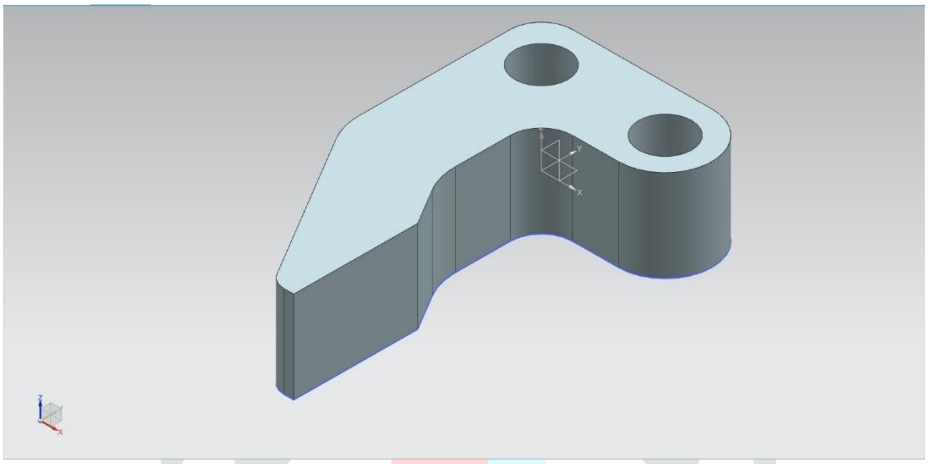


FIG. 2. Isometric View of Jaw

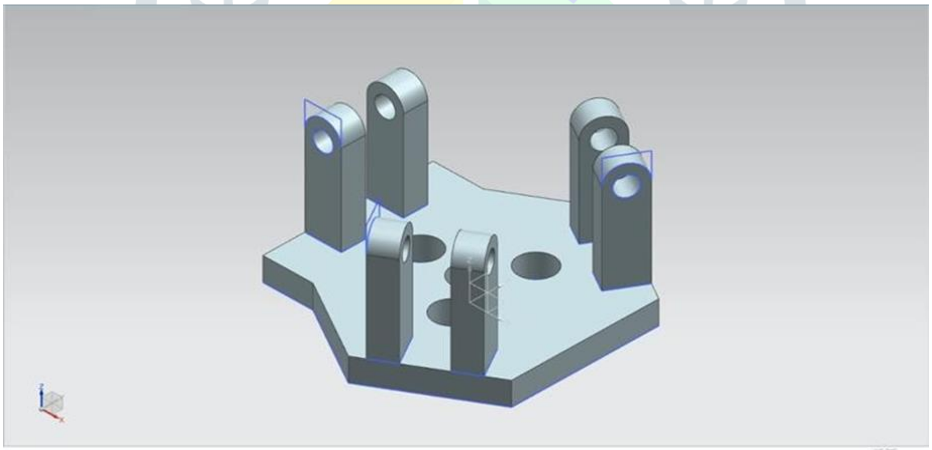


FIG. 3. Isometric View of Base Plate

3.2 CAD MODELLING AND SIMULATION

The CAD (Computer Aided Designing) for the 3-jaw gripper was carried out using Siemens NX software. It was used to design and make changes to all the components individually and to assemble the components into an assembly file. The parts that were modelled for the 3-jaw gripper were provided with enough clearances in accordance to the accuracy and precision of the FDM printer we were to use for the fabrication of the 3-jaw pneumatic gripper. The design of the gripper was completely assembled and constrained in NX to test the mechanism that was chosen.

The whole process of assembly and constraining for testing the mechanism worked out as it was used to simulate the motion of the gripper in NX using various simulation tools after defining the relations between the individual components. The simulation helped to determine the factors that can lead to failure of the gripper. This was followed up by various changes to the gripper and other dimensional changes.

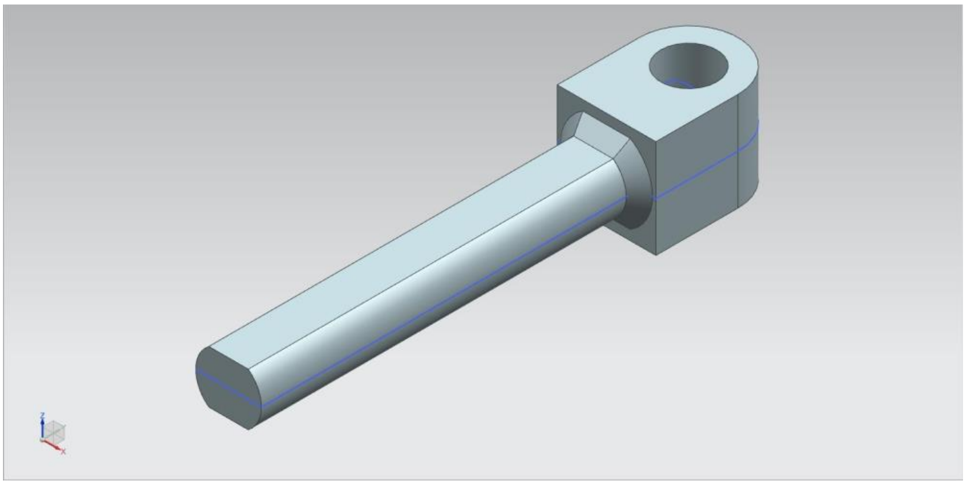


FIG. 4. Isometric View of Connecting Rod

Table 1: Details of the components of 3-Jaw Gripper

S. No.	**Name of the component**	**Count**	**Volume of the component/piece (mm^3)**	**Volume*Count (mm^3)**
1.	Connecting Rod	3	5646.96	16940.88
2.	Disc plate	1	11161.75	11161.75
3.	Base plate	1	109331.46	109331.46
4.	Jaw	3	15057.04	4517.12
5.	Connecting link	6	1871.64	11229.84
6.	Dowel pin	6	1679.44	10076.64
7.	Bush	3	908.86	2726.58
8.	Retaining pin	3	2482.09	7446.27

3.3 ANALYSIS OF THE 3-JAW PNEUMATIC GRIPPER

The Assembly part file of the 3-jaw pneumatic gripper was exported from Siemens NX into Initial Graphics Exchange Specification (.iges) format to perform structural analysis using ANSYS software. Structural analysis was performed on the 3- jaw gripper to make sure that the gripper was strong enough to withstand varying loads and stresses. This helps to determine stresses and strain levels in the individual components which helped to optimize the design for maximum performance and durability. The analysis helped to assess the safety of the mechanical systems and components, by identifying the potential failure modes and ensuring that the system is designed to prevent catastrophic failures.

As to choosing ANSYS for performing analysis, ANSYS is one of the best options for structural analysis due to its wide capabilities, accuracy, user-friendly interface, and industry-standard status in mechanical industry.

In conclusion to analysis, this helped to optimize the design and ensure that the End Effector can withstand the required loads and stresses. The results were also helpful to identify potential causes of further failures in the model and individual parts depending of various loading conditions.

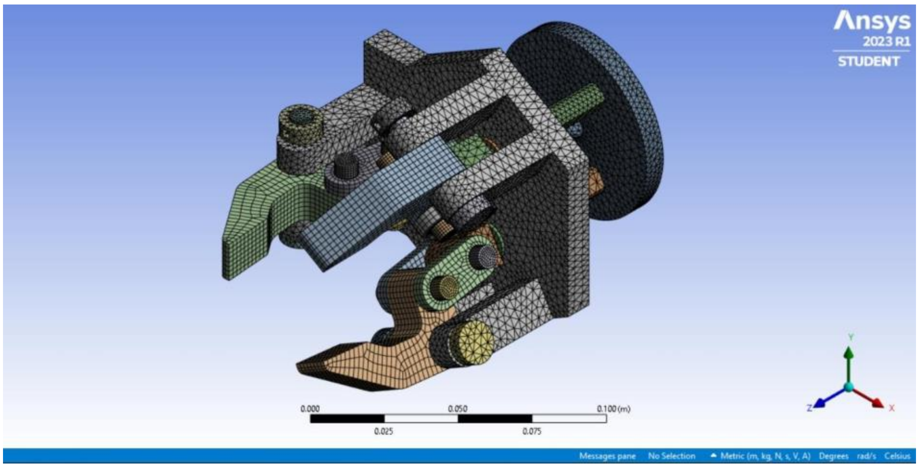
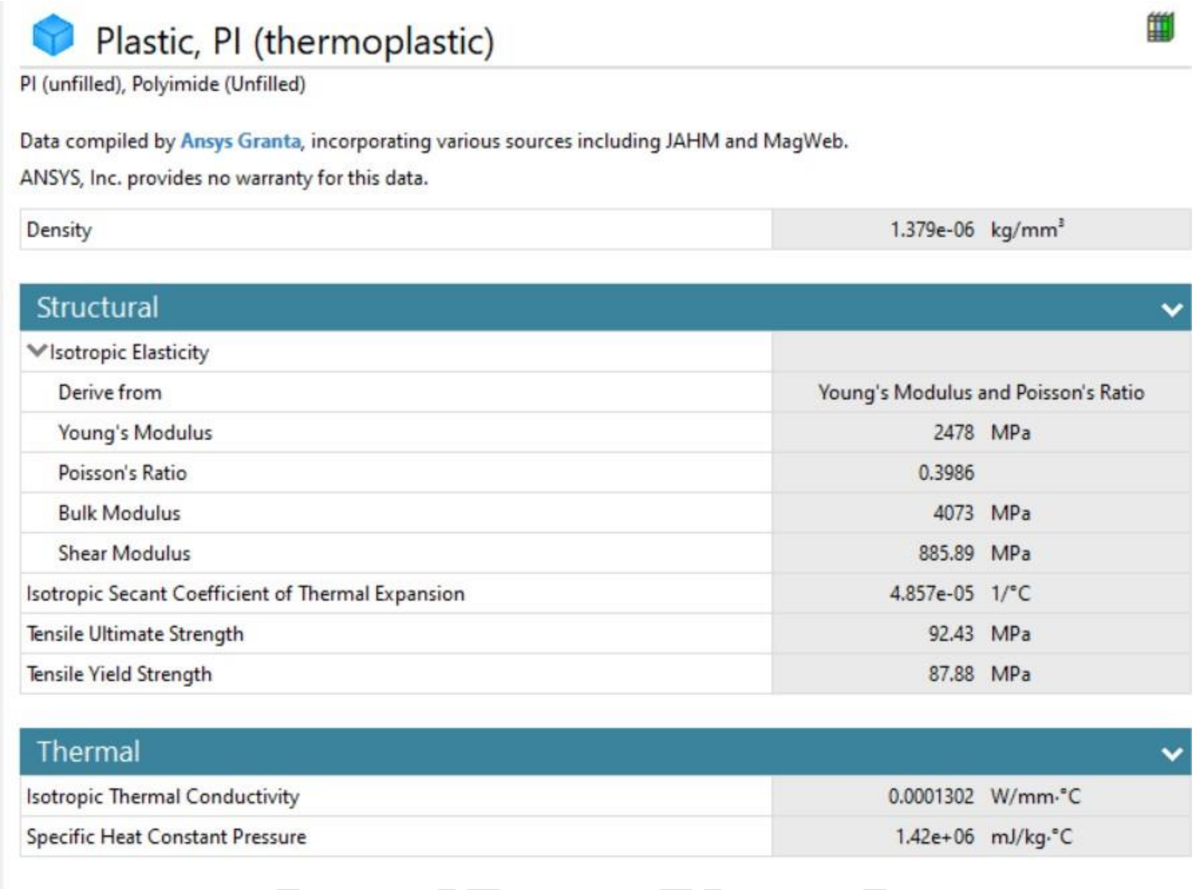


FIG. 5. Meshing of 3-Jaw Gripper for Static Structural Analysis

3.4 MATERIAL SELECTION

Once, the gripper was designed and assembled in NX using various designing tools and assembly constraints, it was time to determine the material to be used for FDM (Fused Deposition Modelling) as this would play an important role in strength, durability, toughness, and the gripper's ability to hold and withstand varying loads. In order make sure that we stay within the objective that is, to fabricate a gripper that can be produced with less effort and at a very low price, we chose PLA (Polylactic Acid) a biodegradable hydrolysable aliphatic semicrystalline polyester. PLA is generally derived from renewable, organic sources such as cornstarch and sugarcane. This being most used material for FDM, it was easy to source, cheap and biodegradable.

- As PLA is thermoplastic monomer, it has high stiffness to maintain its shape and size and resist deformation even under load.
- PLA is durable enough to withstand repeated use without showing signs of wear and tear.
- PLA has a certain degree of resistance to impact, which means that it can withstand sudden shocks or impacts without cracking or breaking. This is important for grippers that may need to grip objects that are dropped or bumped during handling.
- PLA is compatible with a wide range of adhesives, allowing for easy attachment to other parts of a robot or mechanical system. This means that PLA grippers can be easily integrated into existing systems.
- PLA is a popular material for 3D printing due to its ease of use. It can be printed at a relatively low temperature, and it does not require a heated bed or enclosure. This means that it can be easily printed on a wide variety of 3D printers.



Plastic, PI (thermoplastic)

PI (unfilled), Polyimide (Unfilled)

Data compiled by Ansys Granta, incorporating various sources including JAHM and MagWeb.

ANSYS, Inc. provides no warranty for this data.

Density	1.379e-06 kg/mm³
Structural	
Isotropic Elasticity	
Derive from	Young's Modulus and Poisson's Ratio
Young's Modulus	2478 MPa
Poisson's Ratio	0.3986
Bulk Modulus	4073 MPa
Shear Modulus	885.89 MPa
Isotropic Secant Coefficient of Thermal Expansion	4.857e-05 1/°C
Tensile Ultimate Strength	92.43 MPa
Tensile Yield Strength	87.88 MPa
Thermal	
Isotropic Thermal Conductivity	0.0001302 W/mm·°C
Specific Heat Constant Pressure	1.42e+06 mJ/kg·°C

FIG. 6. Mechanical Properties of Material Used

3.5 PARAMETERS USED FOR 3D PRINTING

Table 2: Description of Parameters used for 3D Printing

Parameter (Used/set values)	Description to the parameters
Layer Height (0.2 mm)	The thickness of each layer to be printed
Print Speed (60 mm/sec)	The speed at which the nozzle on the printer head moves to deposit the material
Extrusion temperature (60ºC)	The temperature to which the material is being heated before deposition.
In fill density (80 to 100%)	The total internal volume occupied by the material during the printing process.

4.1 RESULTS OBTAINED FROM SIMULATION

The motion simulation performed on the 3-Jaw Gripper was successful in producing expected results. The simulated model was able to accurately predict the performance of the 3-Jaw Gripper in various real-world situations. The results of the simulation provided valuable insights into the behavior of the 3-Jaw Gripper, which can be used to evaluate the safety and reliability of the system. The results showed that the stresses and displacements were within acceptable limits, indicating that the structural integrity of the components was maintained. This is an important aspect of the design, as it ensures that the 3-Jaw Gripper will perform safely and reliably under various loads and operating conditions. In addition to evaluating the structural integrity of the 3-Jaw Gripper.

Overall, the simulation results were consistent with the expected performance of the 3-Jaw Gripper. The results demonstrated that the 3-Jaw Gripper was designed effectively and efficiently to meet the desired performance criteria. These results can be used to further optimize the design and improve the performance of the 3-Jaw Gripper.

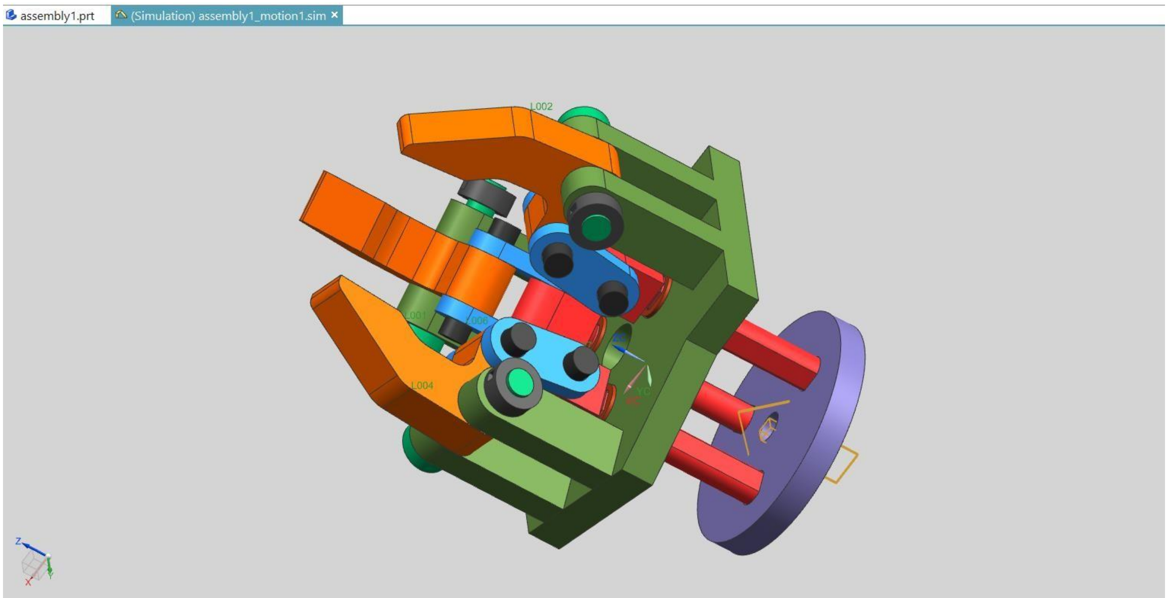
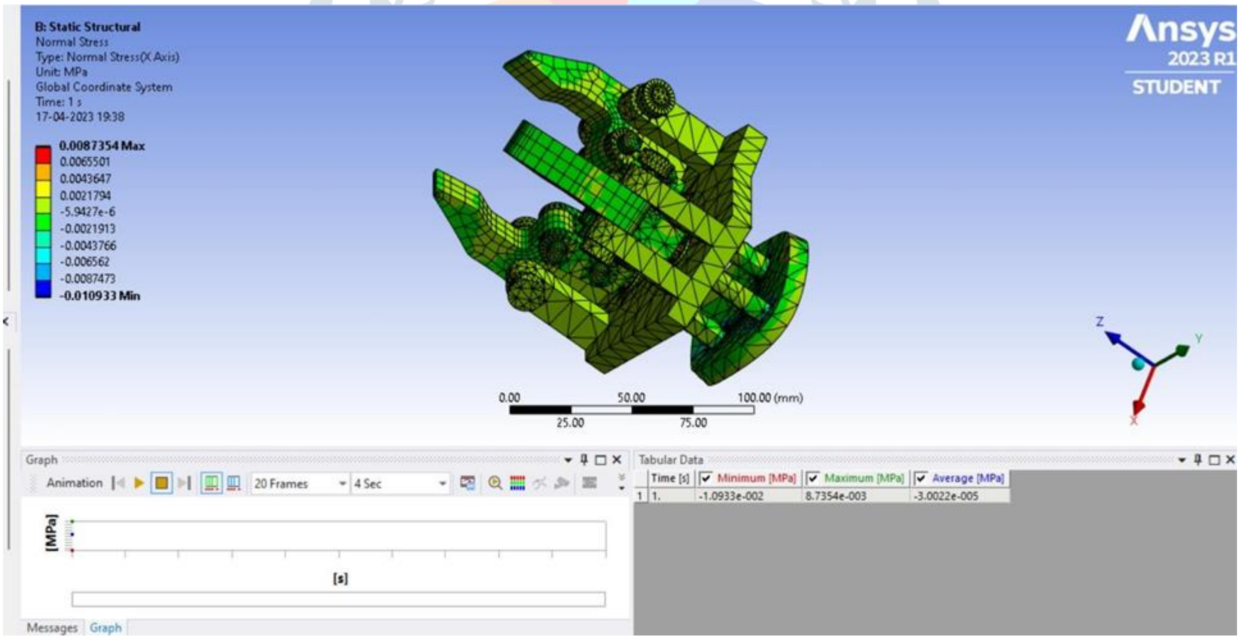


FIG. 7. Simulation Interface in SIEMENS NX

4.2 RESULTS OBTAINED FROM ANALYSIS

The structural analysis of the 3-Jaw Gripper was conducted to assess the structural integrity of the system under various loading conditions.

4.2.1 STRESS ANALYSIS OF THE MODEL



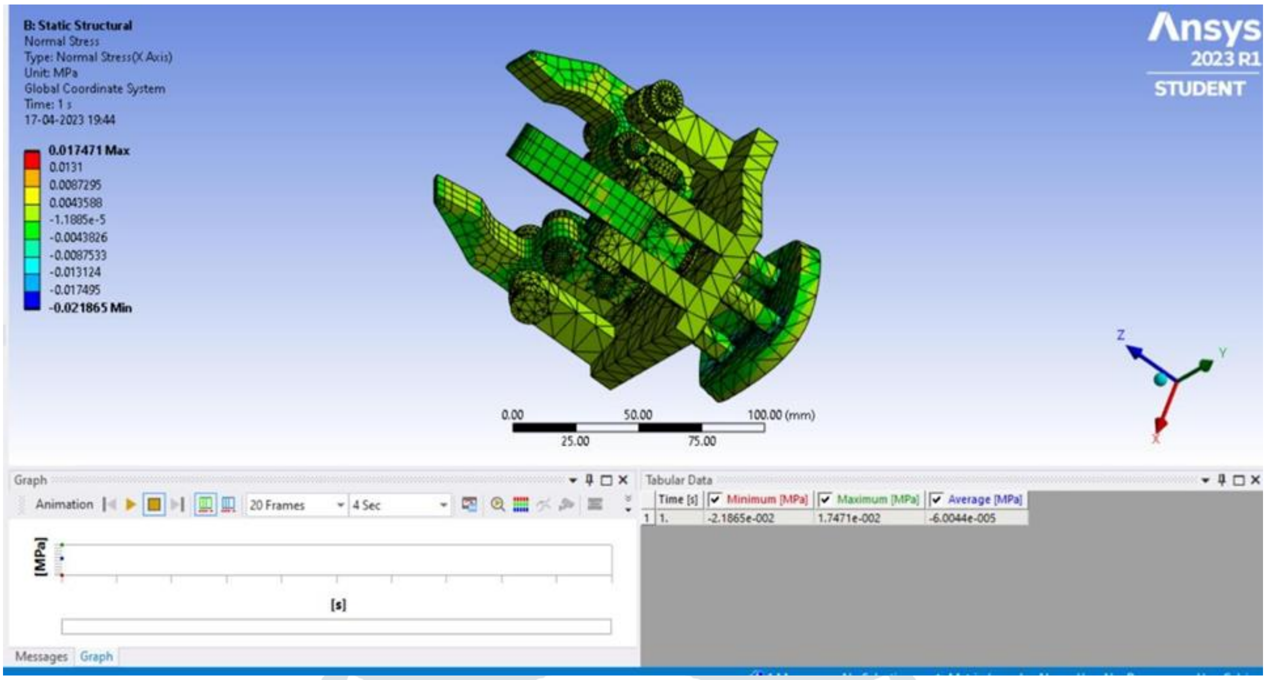
B: Static Structural
Normal Stress
Type: Normal Stress(X Axis)
Unit: MPa
Global Coordinate System
Time: 1 s
17-04-2023 19:38

0.0087354 Max
0.0065501
0.0043647
0.0021794
-5.9427e-6
-0.0021913
-0.0043766
-0.006562
-0.0087473
-0.010933 Min

Tabular Data

	Time [s]	☑ Minimum [MPa]	☑ Maximum [MPa]	☑ Average [MPa]
1	1.	-1.0933e-002	8.7354e-003	-3.0022e-005

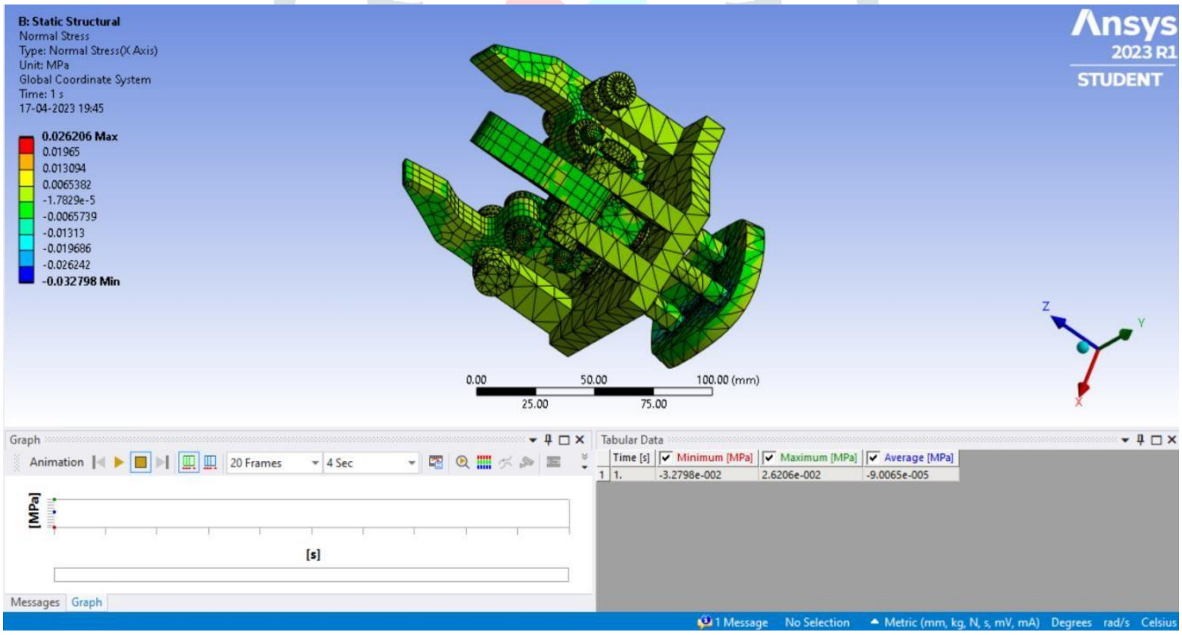
FIG. 8. Maximum and Minimum Stress under Static Load of 5N



B: Static Structural
Normal Stress
Type: Normal Stress(X Axis)
Unit: MPa
Global Coordinate System
Time: 1 s
17-04-2023 19:44

Time [s]	☑ Minimum [MPa]	☑ Maximum [MPa]	☑ Average [MPa]
1	-2.1865e-002	1.7471e-002	-6.0044e-005

FIG. 9. Maximum and Minimum Stress under Static Load of 10N

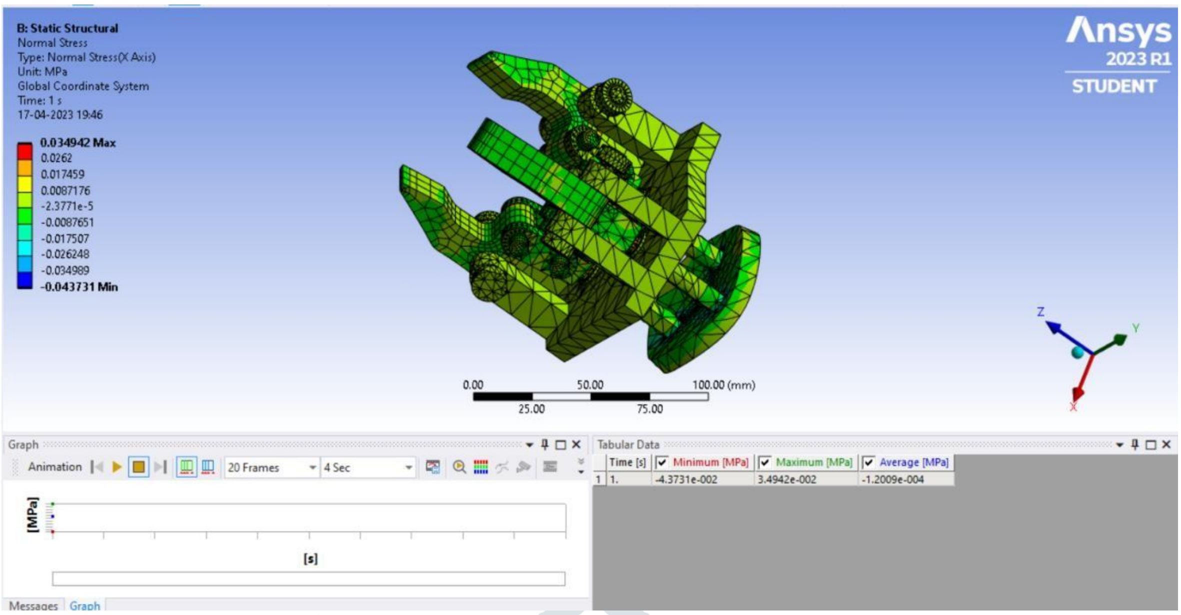


B: Static Structural
Normal Stress
Type: Normal Stress(X Axis)
Unit: MPa
Global Coordinate System
Time: 1 s
17-04-2023 19:45

Time [s]	☑ Minimum [MPa]	☑ Maximum [MPa]	☑ Average [MPa]
1	-3.2798e-002	2.6206e-002	-9.0065e-005

1 Message No Selection Metric (mm, kg, N, s, mV, mA) Degrees rad/s Celsius

FIG. 10. Maximum and Minimum Stress under Static Load of 15N



B: Static Structural
Normal Stress
Type: Normal Stress(X Axis)
Unit: MPa
Global Coordinate System
Time: 1 s
17-04-2023 19:46

Time [s]	☑ Minimum [MPa]	☑ Maximum [MPa]	☑ Average [MPa]
1 1.	-4.3731e-002	3.4942e-002	-1.2009e-004

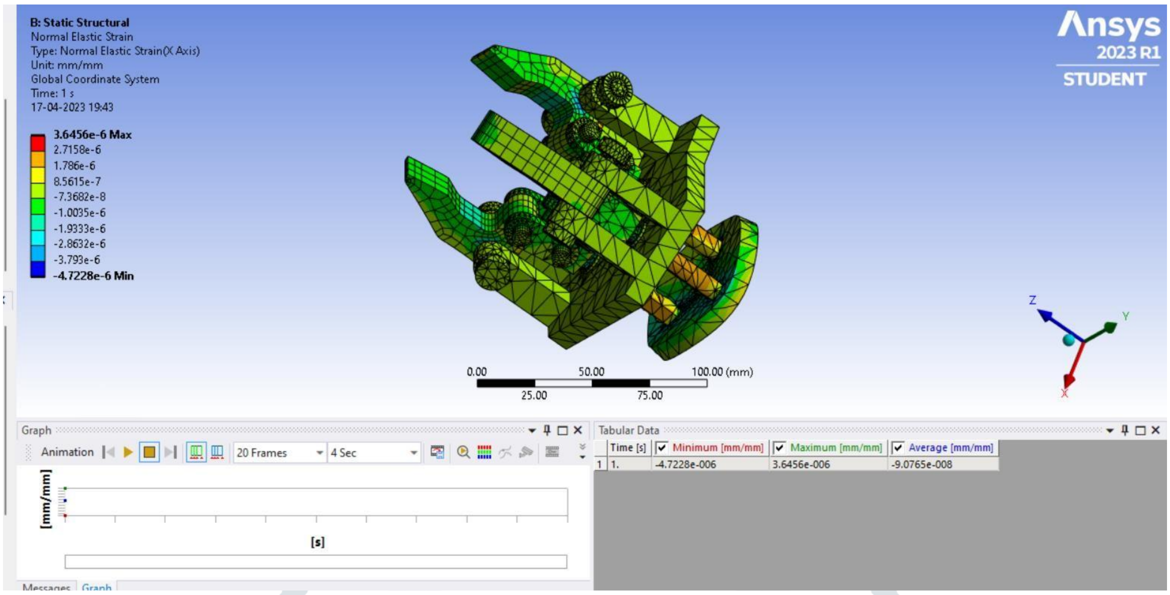
FIG. 11. Maximum and Minimum Stress under Static Load of 20N

To determine the maximum stress in each element, ANSYS evaluates the stresses at each node within the element and interpolates them to find the maximum stress value. The maximum stress value is then reported in the results for that element. The maximum stress in a model can be used to evaluate the safety and reliability of the design, and can help identify areas where design modifications may be necessary to reduce stress concentrations and improve the overall structural integrity of the model.

Table 3: Analyzed data for the 3-jaw end effector under static loading

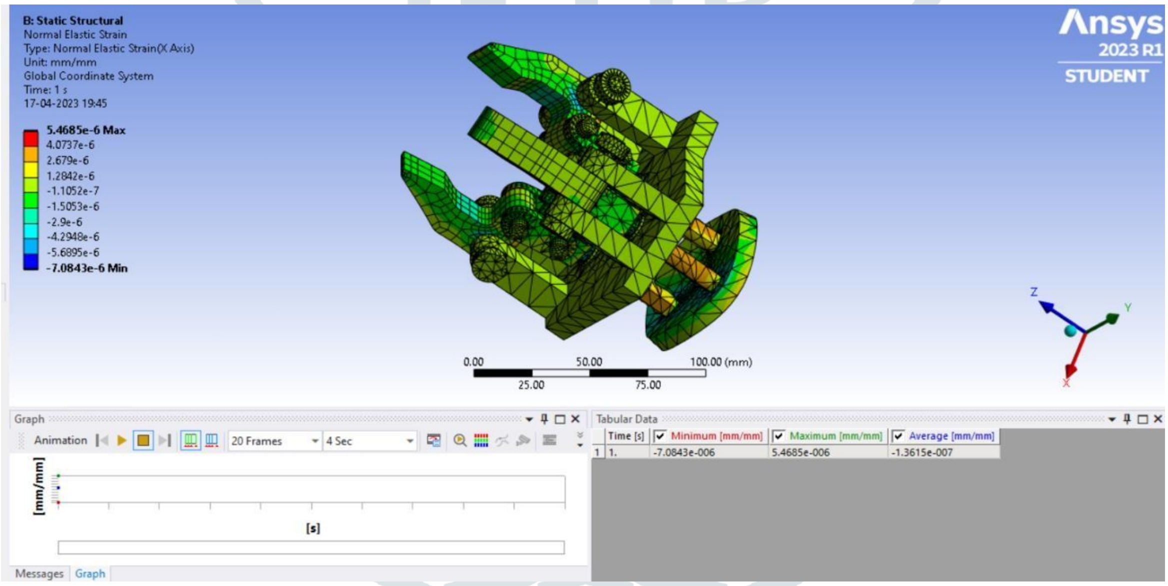
SR.NO	COMPONENT NAME	LOAD APPLIED	MINIMUM STRESS(MPA)	MAXIMUM STRESS(MPA)	AVERAGE STRESS(MPA)
1)	3 JAW END EFFECTOR	5N	-1.0933e-002	8.7354e-003	-3.0022e-005
2)		10N	-2.1865e-002	1.7471e-002	-6.0044e-005
3)		15N	-3.2798e-002	2.6206e-003	-9.0065e-005
4)		20N	-4.3731e-002	3.4942e-002	-1.2009e-004

4.2.2 STRAIN ANALYSIS OF THE MODEL


B: Static Structural
Normal Elastic Strain
Type: Normal Elastic Strain(X Axis)
Unit: mm/mm
Global Coordinate System
Time: 1 s
17-04-2023 19:43

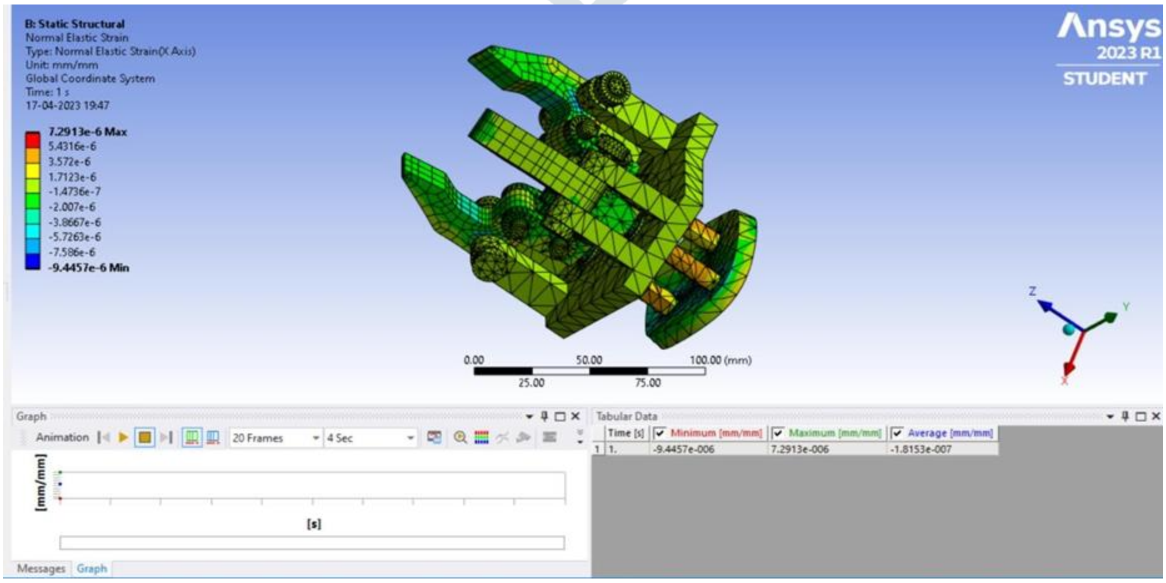
	Time [s]	☑ Minimum [mm/mm]	☑ Maximum [mm/mm]	☑ Average [mm/mm]
1	1.	-4.7228e-006	3.6456e-006	-9.0765e-008

FIG. 12. Maximum and Minimum Strain under Static Load of 10N


B: Static Structural
Normal Elastic Strain
Type: Normal Elastic Strain(X Axis)
Unit: mm/mm
Global Coordinate System
Time: 1 s
17-04-2023 19:45

	Time [s]	☑ Minimum [mm/mm]	☑ Maximum [mm/mm]	☑ Average [mm/mm]
1	1.	-7.0843e-006	5.4685e-006	-1.3615e-007

FIG. 13. Maximum and Minimum Strain under Static Load of 15N


B: Static Structural
Normal Elastic Strain
Type: Normal Elastic Strain(X Axis)
Unit: mm/mm
Global Coordinate System
Time: 1 s
17-04-2023 19:47

	Time [s]	☑ Minimum [mm/mm]	☑ Maximum [mm/mm]	☑ Average [mm/mm]
1	1.	-9.4457e-006	7.2913e-006	-1.8153e-007

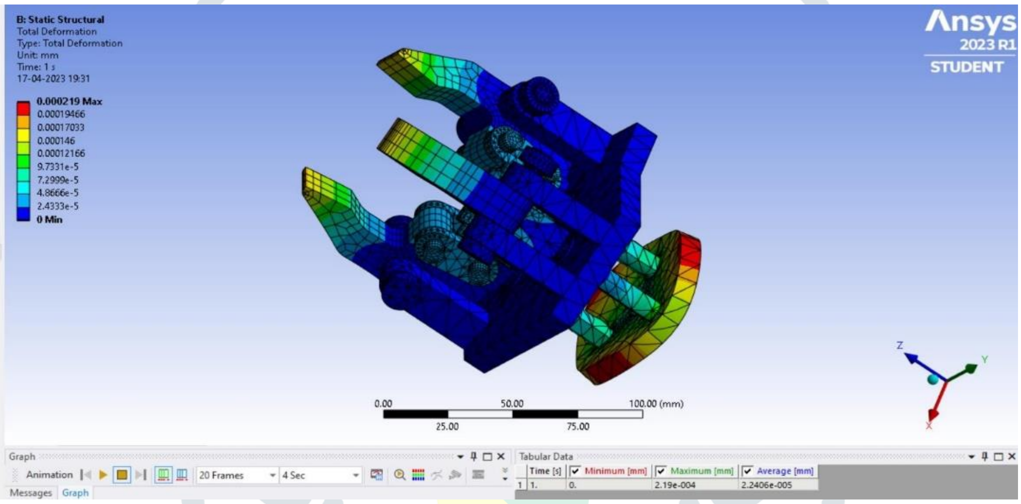
FIG. 14. Maximum and Minimum Strain under Static Load of 20N

Strain analysis helps in understanding the material's mechanical properties such as stiffness, ductility, and strength. By analyzing the strain distribution, we can identify areas of the structure that are experiencing high or low levels of strain. This information can help in the optimization of the design, by modifying or reinforcing the high-stress areas to improve the structural integrity and reduce the risk of failure. Additionally, strain analysis can also be used to identify the critical locations in a structure where fatigue damage may occur due to cyclic loading, which is important in the maintenance and durability of the structure.

Table 4: Analyzed data for the 3 Jaw end effector under static loading

SR.NO	COMPONENT NAME	LOAD APPLIED	MINIMUM STRAIN	MAXIMUM STRAIN	AVERAGE STRAIN
1)	3 JAW END EFFECTOR	10N	-4.7228e-006	3.6456e-006	-9.0765e-006
2)		15N	-7.0643e-006	5.4645e-006	-1.3615e-007
3)		20N	-9.4457e-006	7.2913e-006	-1.8153e-007

4.2.3 DEFORMATION ANALYSIS OF THE MODEL

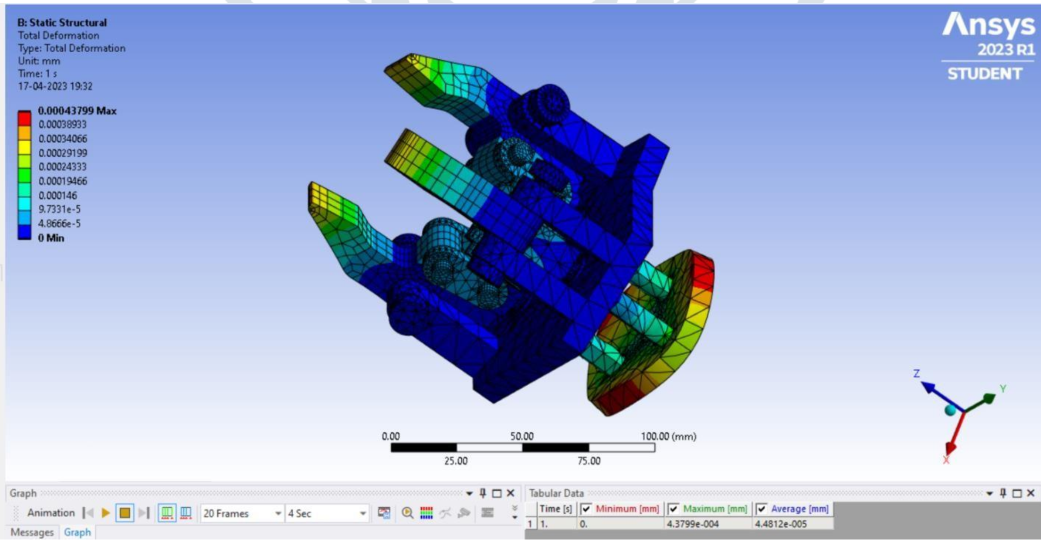


B: Static Structural
Total Deformation
Type: Total Deformation
Unit: mm
Time: 1 s
17-04-2023 19:31

Tabular Data

	Time [s]	☑ Minimum [mm]	☑ Maximum [mm]	☑ Average [mm]
1	1.	0.	2.19e-004	2.2406e-005

FIG. 15. Maximum and Minimum Deformation under Static Load of 5N

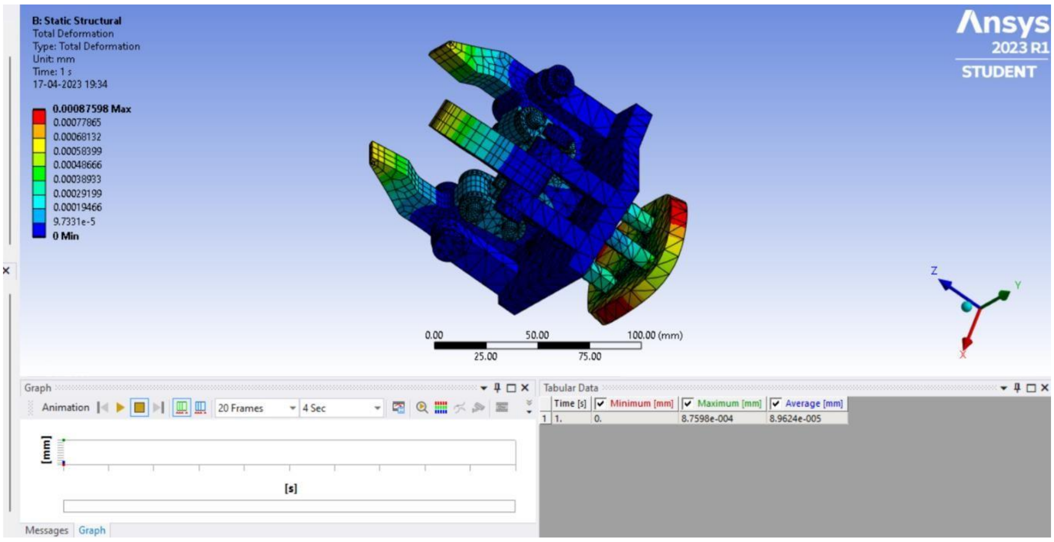


B: Static Structural
Total Deformation
Type: Total Deformation
Unit: mm
Time: 1 s
17-04-2023 19:32

Tabular Data

	Time [s]	☑ Minimum [mm]	☑ Maximum [mm]	☑ Average [mm]
1	1.	0.	4.3799e-004	4.4812e-005

FIG. 15. MAXIMUM AND MINIMUM DEFORMATION UNDER STATIC LOAD OF 10N

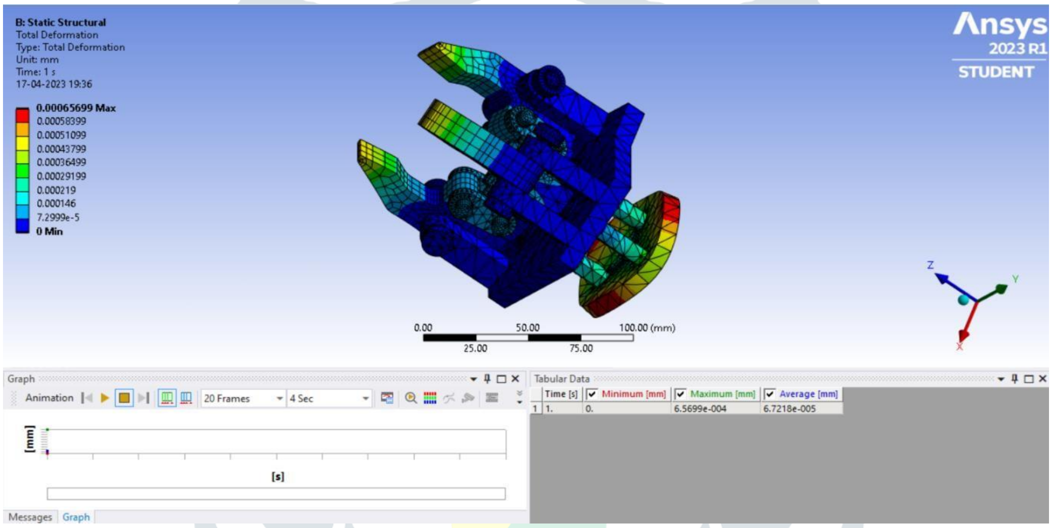


B: Static Structural
Total Deformation
Type: Total Deformation
Unit: mm
Time: 1 s
17-04-2023 19:34

Tabular Data

	Time [s]	☑ Minimum [mm]	☑ Maximum [mm]	☑ Average [mm]
1	1.	0.	8.7598e-004	8.9624e-005

FIG. 16. Maximum and Minimum Deformation under Static Load of 15N



B: Static Structural
Total Deformation
Type: Total Deformation
Unit: mm
Time: 1 s
17-04-2023 19:36

Tabular Data

	Time [s]	☑ Minimum [mm]	☑ Maximum [mm]	☑ Average [mm]
1	1.	0.	6.5699e-004	6.7218e-005

FIG. 17. Maximum and Minimum Deformation under Static Load of 20N

The maximum deformation result from structural analysis helps in determining the amount of displacement that the structure experiences when subjected to loads. It helps in identifying the critical locations of the structure that undergo large deformations, which may result in failure. This data is important in determining the design of the structure, such as the selection of appropriate materials, cross-sections, and reinforcement, to ensure that it can withstand the expected loads without excessive deformation. Additionally, the maximum deformation result can also help in verifying if the structure meets the required design criteria, such as the maximum allowable deformation limits specified in the applicable design standards or codes. This information can be used to optimize the design of the structure and ensure its safety and reliability.

Table 5: Analyzed Data for the 3-Jaw end effector under Static Loading

SR.NO	COMPONENT NAME	LOAD APPLIED	MINIMUM DEFORMATION	MAXIMUM DEFORMATION	AVERAGE DEFORMATION
1)	3 JAW END EFFECTOR	5N	0	2.19e-004	2.2406e-005
2)		10N	0	4.3799e-004	4.4512e-005
3)		15N	0	8.7598e-004	8.9624e-005

4)		20N	0	6.5699e-004	6.7218e-005

4.2.4 DISCUSSION FROM THE RESULTS OF ANALYSIS

To improve the structural integrity based on the structural analysis results, the following steps could be taken:
Material selection:

1. The use of stronger and more durable materials for critical components, such as the base plate, jaw, connecting rod could improve the structural integrity and reduce the risk of failure.
2. Redesign of components: The design of certain components, such as the jaw or disc plate, could be modified to reduce stress and strain and improve their durability.
3. Improved maintenance and inspection: Regular maintenance and inspection can help identify and address any issues before they lead to failure.
4. Increased safety factor: Increasing the factor of safety by using lower stress levels or stronger materials can provide a greater margin of safety and reduce the risk of failure.
5. Increasing the thickness or size of the components that are prone to failure.

4.3 OUTCOME OF DESIGN AND 3D PRINTING

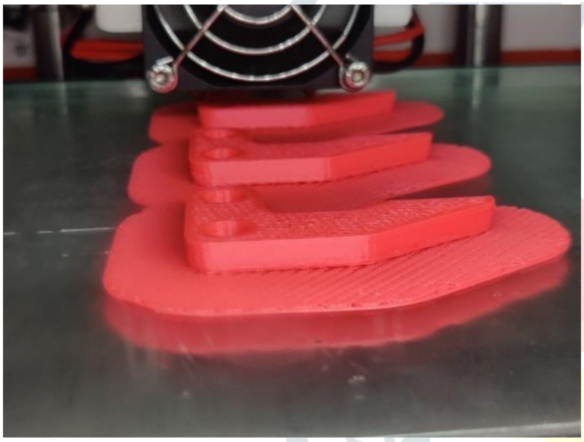


FIG. 18. Jaw

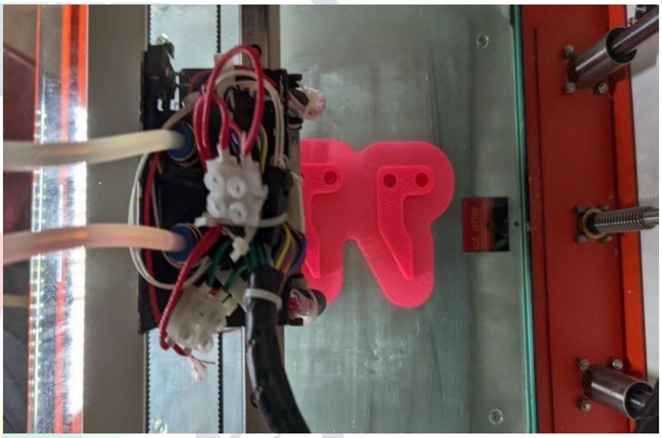


FIG. 19. Jaw (Top View)

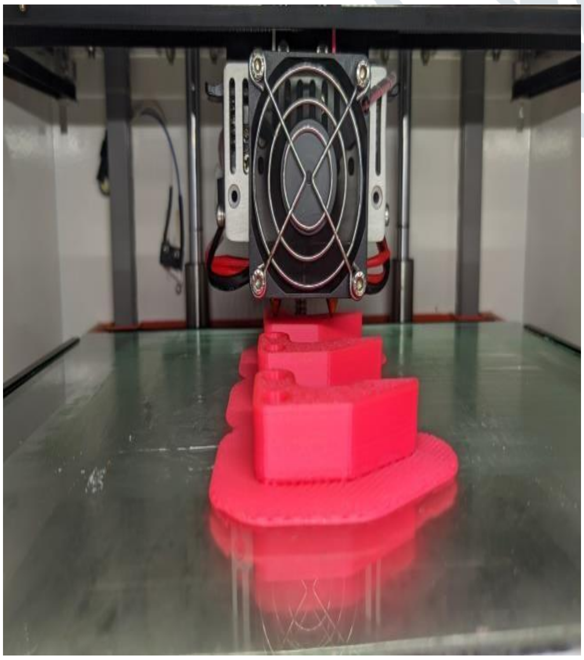


FIG. 20. 3D Printing of Jaws

FIG. 21. 3-Jaw Gripper (Front View)

FIG. 22. 3-Jaw Gripper (Left Side View)

5.1 CONCLUSION

The design and development of a 3-jaw pneumatic end effector for material handling has been successfully achieved in this research. The end effector demonstrated strong gripping force and reliable performance for a wide range of objects, including cylindrical, rectangular, and irregular shapes. The use of 3D printing technology for the fabrication of the end effector allowed for fast and cost-effective production, as well as easy customization and adaptability.

The following are the main conclusions of this research:

- The 3-jaw pneumatic end effector can handle a wide range of objects, making it a versatile tool for various industries, including manufacturing, healthcare, and construction.
- Structural analysis and motion simulation helped optimize the design for maximum efficiency and reliability.
- The use of 3D printing technology allowed for fast and cost-effective production of the end effector, as well as easy customization and adaptability to different requirements.
- The end effector demonstrated a moderate force-to-weight ratio, making it a capable tool for material handling.
- The research has demonstrated the potential of 3D printing technology in the development of pneumatic end effectors for material handling and creates possibilities for further advancements in this field.

5.2 FUTURE SCOPE OF WORK

While the 3D-printed gripper designed and developed in this research demonstrated strong gripping force and reliable performance, there is still room for improvement and further development. Some of the potential areas for future research and development include:

- Optimization of the gripper design to enhance its performance and durability under different operating conditions. This could involve exploring new materials, structural designs, or manufacturing methods to further enhance the gripping force and efficiency of the gripper.
- Integration of advanced sensors and control systems to enable more precise and efficient material handling. This could involve the use of machine learning algorithms to optimize the grip and handling of objects, as well as providing feedback to improve the performance of the gripper.
- Testing of the gripper under a wider range of conditions to determine its full range of capabilities and potential limitations. This could involve testing the gripper with different types of objects, as well as under different environmental conditions such as temperature, humidity, or pressure.
- Exploration of potential applications for the gripper in various industries, such as automotive manufacturing, aerospace, and healthcare. This could involve working with industry partners to identify areas where the gripper could be applied to improve efficiency and productivity.
- Development of a more advanced and sophisticated control interface to enable the user to operate the gripper more easily and intuitively.

Overall, the future scope of work for the development of 3D-printed grippers for material handling is promising and has the potential to revolutionize the field of material handling and manufacturing. By further optimizing the design and capabilities of the gripper, we can unlock even greater efficiencies and productivity gains in various industries.

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