KAUNAS UNIVERSITY OF TECHNOLOGY

FACULTY OF MECHANICAL ENGINEERING AND DESIGN

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DESIGN AND DEVELOPMENT OF ROBOTIC GRIPPER WITH MICROELECTROMECHANICAL SYSTEM

Master's Degree Final Project

Supervisor
Assoc. Prof. Dr. Rūta Rimašauskienė

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Design and development of robotic gripper with micro electro mechanical system

DECLARATION OF ACADEMIC INTEGRITY

2017 June 08

Kaunas

I confirm that the final project of mine, **Hemchander Jayaraman Kanthimathi**, on the subject "Design and development of robotic gripper with microelectromechanical system" is written completely by myself; all the provided data and research results are correct and have been obtained honestly. None of the parts of this thesis have been plagiarized from any printed, Internet-based or otherwise recorded sources. All direct and indirect quotations from external resources are indicated in the list of references. No monetary funds (unless required by law) have been paid to anyone for any contribution to this thesis.

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MASTER STUDIES FINAL PROJECT TASK ASSIGNMENT
Study programme MECHATRONICS

The final project of Master studies to gain the master qualification degree, is research or applied type project, for completion and defence of which 30 credits are assigned. The final project of the student must demonstrate the deepened and enlarged knowledge acquired in the main studies, also gained skills to formulate and solve an actual problem having limited and (or) contradictory information, independently conduct scientific or applied analysis and properly interpret data. By completing and defending the final project Master studies student must demonstrate the creativity, ability to apply fundamental knowledge, understanding of social and commercial environment, Legal Acts and financial possibilities, show the information search skills, ability to carry out the qualified analysis, use numerical methods, applied software, common information technologies and correct language, ability to formulate proper conclusions.

1. Title of the Project

Design and Development of Robotic Gripper with MicroElectroMechanical System.
Roboto griebtuvo su mikroelektromechanine sistema kūrimas ir tyrimas.

Approved by the Dean Order No.V25-11-8, 21 April 2017

2. Aim of the project

To improve the automation and mechanical design of a two-jaw parallel gripper by using capacitive pressure sensors for controlling the flow of pressure for doing the pick and place operations according to the material of object.

3. Structure of the project

To design the two jaw parallel gripper, To simulate the grippers, end effector by applying pressure and force, To design the capacitive pressure sensor (MEMS), To simulate the MEMS sensor, To Program the control part using TWINCAT PLC.

4. Requirements and conditions

Capacitive Pressure sensor(MEMS), TWINCAT control system, Mechanical design of two jaw gripper and converting into a smart gripper technology for good and better pick and place operation.

5. This task assignment is an integral part of the final project

6. Project submission deadline: 20__ ________ __st.

Student Hemchander Jayaraman Kanthimathi _______________________
(*Name, Surname of the Student*) (*Signature,date*)

Supervisor Assoc. Prof. Dr. Rūta Rimašauskienė _______________________
(*Position, Name, Surname*) (*Signature, date*)

Hemchander Jayaraman Kanthimathi. Design and Development of Robotic Gripper with MicroElectroMechanical System. Master's thesis in Mechatronics, Production Engineering Supervisor Assoc. Prof. Dr. Rūta Rimašauskienė; Faculty of Mechanical Engineering and Design, Kaunas University of Technology.

Research field and area: Production Engineering, Technological Sciences

Keywords: *Robotic gripper, modelling, MEMS, control, simulation, Solid works and Comsol.*

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SUMMARY

This thesis is a continuation of design automation studies focusing on impact research of Robotic gripper and the smart material MEMS technology in it. A research was carried on several types of gripper and its mechanism the main objective to implement the Capacitive Pressure Sensor(MEMS) to demonstrate the performance of grippers end effector when holding or picking the objects from the assembly process by applying the pressure required according to the object or the material performance in multi-disciplinary design environment. The context of this thesis is to design and development of two jaw parallel gripper to a smart gripper technology and the several studies, i.e. static, pressure, force etc. are carried concurrently to assemblage the knowledge between the end effectors relations. The thesis contributes to the goal of fully integrated robotics gripper to support in assembly process and manufacturing unit. Complete case study models on types of electromechanical pressure sensors were made and designed few pressure sensors using the COMSOl physics. All models were executing through the system to extract their geometric entities, domains and boundary conditions. After the study and design of sensor all the data was been simulated to find the diverse types of results. All obtained data was integrated with multi-disciplinary study results and various study response was generated.

The problem encountered during the thesis execution involved the designing of mechanical gripper according to the standard size and the selection of material for the end effector the hold the weight of the object and the analysis of static like stress, strain and displacement was been considered for the pressure and relating product design to its manufacturing aspects.

The work as led to more improvements like implementing part detection sensors, MEMS capacitive pressure sensor and the precision of pressure required to grasp an object according to the material. The presented system is just a simulation part of promising results to support the design of two jaw gripper with smart technology considering its performance and vitality.

Hemchander Jayaraman Kanthimathi. Roboto griebtuvo su mikroelektromechanine sistema kūrimas ir tyrimas. Magistro baigiamasis projektas / Assoc. Prof. Dr. Rūta Rimašauskienė; Kauno technologijos universitetas, Mechanikos inžinerija ir dizaino fakultetas, Gamybos inzinerijos katedra.

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SANTRAUKA

Šis tyrimas yra gamybos automatizavimo tyrimo, kuriuo siekiama ištirti robotų žnyples ir protingą MEMS technologiją jose, tęsinys. Tyrimas buvo vykdomas su įvairių tipų žnyplėmis ir jų mechanizmais; pagrindinis uždavinys buvo įtraukiant MEMS pademonstruoti žnyplių pajėgumus ir efektoriaus reakciją, kai žnyplės laiko ar paima objektus, vykstant gamybos procesui, pasinaudodamos reikiamu spaudimu, kuris nustatomas pagal objektą, medžiagą, iš kurios jis pagamintas, ar aplinkos sąlygas. Šio tyrimo tikslas – sukurti ir vystyti dvigubas žnyples, galiausiai jas paverčiant protingomis žnyplėmis; tam pasiekti atliekami įvairūs – statiškumo, slėgio, jėgos – bandymai, taip pat bandoma atrasti ryšį tarp efektorių. Tyrimas prisideda prie visiško robotų integravimo į gamybos procesą.

Buvo pagaminti pilni elektromechaninio slėgio jutiklių modeliai, o keli tokie jutikliai buvo pagaminti, naudojant COMSOl programą. Visi modeliai veikė sistemoje, kuriai perdavė duomenis apie savo geometrinę būseną, sferą ir ribas, kuriose veikia. Po tyrimo ir jutiklio sukūrimo visi duomenys buvo simuliuojami ir gauti labai įvairūs rezultatai. Visi gauti duomenys buvo susieti su daugelio mokslinių tyrimų duomenimis, todėl buvo gauta daug rezultatų. Problema, su kuria susidurta tyrimo metu, buvo mechaninių žnyplių kūrimas, naudojant standartinio dydžio modelį, bei medžiagų efektoriaus kūrimui pasirinkimas. Jos turėjo būti parinktos taip, kad efektorius išlaikytų objekto svorį bei statiškumo tyrimus, taikant tempimą ir vietos pakeitimą; šie tyrimai buvo atliekami, kad būtų galima patikrinti panašių produktų gamybos aspektus.

Šis darbas privedė prie gerų permainų, pavyzdžiui, dalių nustatymo sensorių, MEMS elektrinio slėgio sensorių „įdarbinimo“ ir tikslaus kiekio slėgio, kuris reikalingas pagriebti objektą, priklausomai nuo medžiagos, iš kurios jis pagamintas, nustatymo. Ši sistema yra tik simuliacinė dalis daug žadančių rezultatų, padėsiančių sukurti protingas dvigubas žnyples, turint omeny jų darbo savybes bei išliekamumą.

Table of Contents

List of Figures

ABSTRACT

In the machine world, nowadays the effect of the grippers in the machines are improved well ordered. According to that, in computerization, assembling and get together process industry, the grippers are controlled and kept up productively by utilizing controller innovation, with a specific end goal to enhance the effectiveness of the gripper and its plausible for the substantial scale fabricating units; we have to enhance the grippers end-effector and controlling components by actualizing MEMS innovation. And furthermore, by controlling the development of the end effector is basic to the gripper to keep away from the anxiety by controlling the drive and weight on gripper.

The primary goal of this postulation work is to get the control of weight at the grippers end effector position. In kind of that, it's vital to manage some hypothetical piece of the framework with displaying by utilizing the suitable suppositions to get the precise reaction by outlining the grippers end effector utilizing MEMS innovation with the vital prerequisites of the automated gripper. What's more, besides, the re-enactment of the framework is done through the propelled demonstrating with the planning instrument and the reproduction apparatus with the ideal running condition. In which the recreation has incorporated the charts of anxiety of the segments to manage most correct outcomes. To do that, the outline and the reproduction is finished with the assistance of Strong works and COMSOL instrument to accomplish a basic model of the gripper by utilizing the static investigation and by giving the coveted piezoelectric material or segments by utilizing the COMSOL and mimic it by continuous by Solid works.

The proposal is separated into two sections, in which the hypothetical part is acquired by the apparatus manuals and as per that, the plan is gotten by the progression and the kinematics of the mechanical gripper. Also, demonstrating the body of the gripper and its end effector with the vital mechanical segments by utilizing the Solid works and with the COMSOL to get the coveted yield from the end effector to get sane contribution of compel and weight to the framework in the constant as per the direction of the automated gripper.

1. INTRODUCTION

In the present scenario robotization and mechanical autonomy assumes an essential part to manufacture and create an alternate sort of items like riggings, auto parts, welding and gathering where the request and market necessity and desires is being expanded intermittently. In the measurements of 2012 to 2016, whole world is running behind the robotization and application of autonomy innovation to discover the improvement in the development of society.

So as indicated by that most of, many of the automated parts makers are giving the distinct fascination to enhance the productivity and enabled the hearty control of the apparatus to make the easy to understand condition to the clients and its makers. Because of this situation, current control phrasing is essential in mechanical technology and computerizations machines to enhance the gripper end effector framework highlights so that its valuable to decrease the association between the people and machine. In this way, by utilizing the auto controlling element of the MEMS weight sensor framework we can ready to activate the gripper end effector to pick and place the question in the sequential construction system as indicated by the material property by exerting the pressure yield in appropriate proportion.

In this project, the two-jaw mechanical gripper is used with the capacitive pressure sensor at one face of the gripper's holding position. The principle of this, is to hold the object of all types of materials like plastic, wood, metal and fibre, by calculating the amount of force or the pressure required to grasp the object or the material. So, when any type of objects is being placed on an assembly process, this gripper can calculate the pressure required to do the process.

The fundamental point of this theory work is to control the weight toward the end effector of the gripper which can evade the harm of the workpiece and control a lot of strain followed up on the gripper when the compel and weight is been high and enhance the productivity of the gripper. Because of this the gripper takes after the correct point of development and furthermore the life expectancy of the parts will be expanded exceptionally. What's more, because of this controlling technique, the framework could bring about the solid procedure in the assembling and mechanical production system.

Keeping in mind the end goal to actualize the controller portion and the pneumatic fragment the itemized outline of the direction development, degrees of flexibility, pneumatic properties and the controlling section of the capacitive pressure sensor utilizing MEMS innovation from the different abstract sources. From the prior reviews the large portion of the sensor which have been intended for gripper is made remotely mounted and furthermore which have a colossal structure and looks convoluted, however now in this postulation we are executing the MEMS capacitive pressure sensor at end effector to wipe out the strain on the gripper medium and permit the required weight stream to hold the protest as per the required level or material. The gripper is being planned by the standard size. What's more, the straight modules are done by the correct direction utilized beforehand utilized as a part of the framework. The mechanical structure of the gripper and its recreation is being done utilizing SolidWorks and the MEMS capacitive pressure sensor is done utilizing COMSOL.

The silicon nitrate and gold material is utilized as a pressure sensor in this venture to decide the gripper's grip as indicated by the material been utilized. Capacitive pressure sensor's working depends on rule of a precious stone which expresses that, 'At whatever point there is a mechanical compel connected, then there will be a voltage incited in the gem'. There are two jaws with the screw strings which will be consolidated with one jaw being associated with the servo engine for exact development, despite the other one which moves with its programmed activated movement of the partner.

Succeeding the above-expressed traits, the mechanical structure must be contrived in such a route, to the point that the particular Degrees of Opportunity of the individual jaws must be captured with equivalent extents, in this manner advancing exactness. The gripper will comprise of two information sources pneumatic and electrical units where the pneumatics gives the obliged suction to holding the question and the electrical for the assigned servo engine operation.

These applications can be broadly found for their utilization in enterprises. This can be utilized for the pick and place work of various questions in the ventures created for the diverse sorts of materials and configuration forms as required. The above-expressed application, for the most part, is utilized in the fabricate of automated arms with a sound mechanical structure and in this manner protecting the ideal adjustment required for the previous. This is fundamentally critical as the scattering of the riggings ends up noticeably unavoidable bringing about the drop of the exactness and accuracy measures when losing of the apparatuses happens as a type of human blunder.

1.1 **Aim:** To improve the automation and mechanical design of a two-jaw parallel gripper by using capacitive pressure sensors for controlling the flow of pressure for doing the pick and place operations according to the material of object.

1.2 **Tasks**:

1.2.1 To design the mechanical structure of two jaw parallel gripper.

1.2.2 To simulate the grippers, end effector by applying pressure, force and find out the vitality of the gripper from stress and strain results

1.2.3 To design the capacitive pressure sensor (MEMS) for implementing on end effector.

1.2.4 To simulate the MEMS capacitive pressure sensor and check the displacement on the diaphragm when the force is being applied .

1.2.5 To program the control part of gripper using TWINCAT PLC.

2. LITERATURE REVIEW

Patakota Venkata Prasad Reddy, performed an experiment on global gripper in industrial Robot which deals exclusively with gripping phenomenon of different varieties of materials/parts by using the Universal gripper to easily bypass the usage of one gripper type for individual parts. The end effector must consistently be created for the distinct resources. By comparison to the human hand, a robot's gripper is very limited in terms of its mechanical complexity, practical utility and general applications [1].

Tudor Deaconescu and Andrea Deaconescu, conducted an experiment on pneumatic Muscle Actuated Gripper with the study of operational behaviour of a fluidic driving system based on pneumatic muscles. A concrete application of air medium muscles is presented, namely two original non-anthropomorphic holding systems with two jaws and inbuilt control system, developed by them and found out the performance of the grippers responding time, influence of various air medium components included by the control cycles and parameter values for optimum variant gripper was obtained [2].

Bianca S. Homberg, Robert K. Katzschmann, Mehmet R. Dogar, and Daniela Rus conducted an experiment on modular soft robotic gripper were the gripper is capable of robustly grasping and analyze objects based on their internal state measurements. A soft jaw was adapted and integrated to form a three jaw gripper that can easily be attached to existing robots. Resistive bend sensors were added within each finger and the clustering algorithm was written to find the correspondence for individual grasping objects mainly used in manufacturing toys and related units [3].

Guoliang CHEN, Xinhan HUANG, designed a vacuum gripper as an actuator for an intelligent micromanipulator by using fuzzy control, vacuum unit and a control unit, and also designed a pressure sensor for controlling the vacuum pressure. The architecture of their model was formulated using MATLAB FUZZY LOGIC TOOLBOX, and is characterized by a steady and reliable performance supported by a simple structure. It was mainly designed for handling micro objects with a sub-mm size [4].

Vinayak D. Latake and Dr. V.M. Phalle had done a research on the factors that affect the selection of any mechanical gripper, where they concluded that 'For an industrial process ,a two jaw gripper is sufficient enough to carry out normal regulated operations with the exception of actuator and universal sensor implementations necessary in a two jaw gripper to promote refined optimization of the same", They have additionally undergone a research on the vacuum technology in a mechanical gripper [5].

Rituparna Data and Shikhar Pradhan designed a robotic gripper using the multi objective genetic algorithm and have modified the same by integrating an actuator model into the robotic gripper. The actuating system is modelled as a stack consisting the individual actuator elements arranged in series and parallel arrays in four different combinations. Multi objective evolutionary algorithm is used to solve the modified bi-objective problem and to optimally find the dimensions of links and the joint angle of a robot gripper [6].

Vaibhav Raghav along with Jitender Kumar, had conducted an experiment on the elimination of a finger from 3 jaw and hence using the same as a 2 jaw gripper, utilizing actuators and implementing an object detection sensor to determine the type of material employed for the pick and place operation. On contrary to the expectations, this experiment was not that successful because of a design flaw in the model [7].

Antonio Bicchi, Alessia Marigo conducted an experiment on the low – complexity of grippers that realize dexterous manipulation, so to overcome that they have used of putting Non-holonomy to work for fine manipulation, and achieved a high operational versatility with limited constructive complexity [8].

Carlos Blanes , Martin Mellado, conducted an experiment by implementing the accelerometers attached to the grippers to find the hardness, estimate pneumatic pressure and monitor the position and speed of gripper fingers movement. And implemented a technique that grippers used for plucking of fruits and vegetables and any soft materials can be controlled without using a fluid medium and mainly the implementation of tactile sensors was major in their work. [9]

Debanik Roy, worked on a concept of developing novel magnetic grippers for use in unregulated workspace robotic workspace, of the various layouts of the magnetic gripper for a customized operation of lifting ferromagnetic workpieces from an unstructured heap, made through Finite Element Analysis (FEA) as well as using contact mechanics-based grasp synthesis model. The prototype advancement of the sensor-instrumented magnetic gripper was made in-line with the test results and its workability under unstructured workspace was tested by deploying the robotic unit in an industrial shop floor [10].

R. Calliesa,, S. Fronzb, designed a manipulator equipped with vacuum grippers which are new and flexible element in innovative material- flow solutions, and technically proved that the limited holding forces of vacuum grippers require a elaborate strategies of control to prevent the contact between gripper and the load from base, and using mathematical model they approach is presented for the accurate solution to control the grasping error problem [11].

G. Dini, G. Fantoni, F. Failli, proposed a use of contactless grippers instead of normal grippers and implemented vacuum cups, the main objective of their project was to control the damage occurring in the leather products while grasping and producing imprints on their delicate surface. And achieved good stiffness and eliminated the imprints [12].

Dalibor Petkovic, conducted a experiment on robust compliant robotic gripper, implemented a new flexible robust grippers the ability to detect and recognize objects in any environments, to control the using of conventional techniques, novel design of an adaptive neuro fuzzy controller for controlling input displacement and new grippers implemented with embedded sensors as a part of its system, the use of such sensor was to recognize particular shapes of grasping objects [14].

A gripper is a gadget which empowers the holding of a question be controlled. The less demanding approach to depict a gripper is to think about the human hand. Much the same as a hand, a gripper empowers holding, fixing, dealing with and discharging of a question. A gripper is only one part of a mechanized framework [15]. A gripper can be appended to a robot or it can be a piece of a settled computerization framework. Many styles and sizes of grippers exist so that the right model can be chosen for the application.

2.1 Types of Gripper and Gripper Choices

There are diverse sorts of robot’s fingers and its component’s. And its types are:

- Jaw-type
- Vacuum type
- Magnetic type.

The types of grippers can be generalised into three groups.

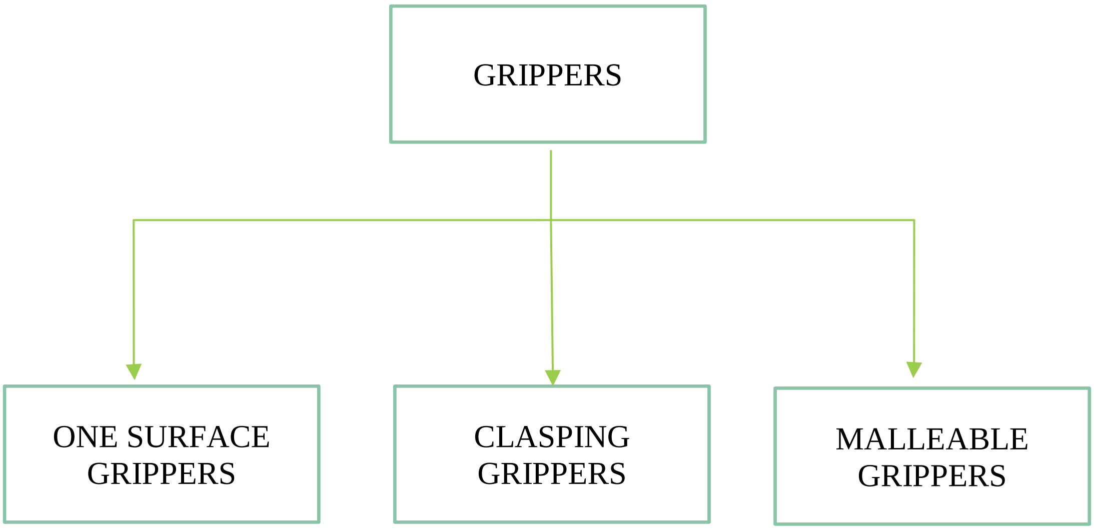


Figure 2.1 Gripper Types

At the point when there is just a single surface of a segment is accessible, the single-surface gripper is utilized for holding such kind of segments. These sorts of grippers are utilized essentially to grip light and substantial weight and the level segments, which are very hard to deal with by different means. [15]

2.1.1 Holding Grippers

The Two-jaw grippers and the three-jaw grippers are related to the grasping grippers and exists mostly in production units. The clamping gripper straps the object that can pick by handling the weight inner or outer faces. This type of gripper is driven by either air or fluid. Air is used in picking up of small objects that which is not too heavy, and the fluid is used for picking the heavy objects [19].

2.1.1.1 Two and Three Jaw Grippers

The gripper with two fingers is the very simplest type of robot hands, were it subsist with two hands end effectors which applies the pressure either outer or inner on the workpiece which is depended on the jaw design. The jaw design can be done depending on its shape and size of an object to achieve a accurate and secured movement. The two fingers can be recycled on both big and small compenents.

The three jaw grippers are also the same but it is used for more complex shapes and it is also more expensive [20].

Figure 2.2 Two and Three Jaw Gripper [20]

2.1.2 Gripper Mechanism

There are two types of gripper movement;

1. Rotation movement: As we can see in the below figure 2.3, this gripper is based on a rotation movement to pick the object.

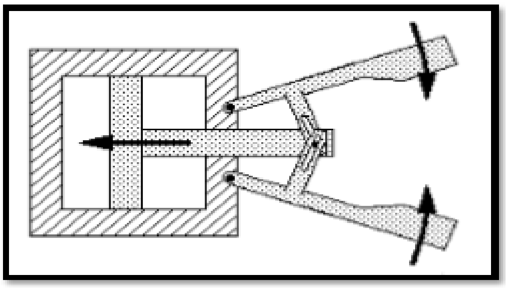


Figure 2.3 Example of A Gripper with Rotation Movement [21].

2. Translational movement: As we can see in the below figure 2.4, this gripper is based on a translation movement to pick the object.

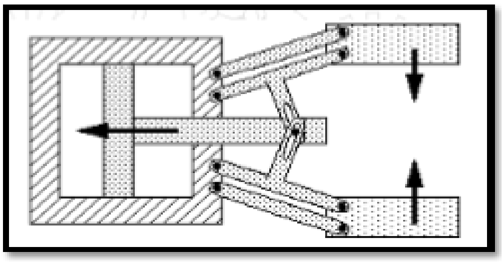


Figure 2.4 Example of A Gripper with Translation Movement [21].

2.2 Electromechanical Pressure Sensors

The Electromechanical pressure will convert the pressure applied as an electric signal. The different types of materials and technologies have been used in these type of devices, which results in performance vs. cost tradeoffs and its been suitable for applications. The electrical output signal also execute a variety of options for different applications according to its requirement.

The pressure sensor may be modelled as:

$$VOUT = kO + k1P$$

Where: k_O = offset

k_1 = pressure sensitivity in V/pressure unit

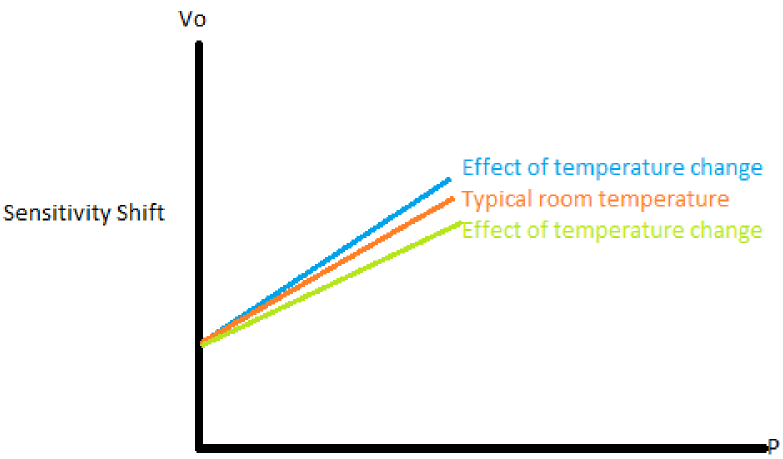


Figure 2.5 Sensitivity of a Pressure sensor

The types of pressure sensor technologies are:

1. Variable Pressure Sensors.
2. Inductive Pressure Sensors.
3. Capacitive Pressure Sensors.
4. Piezoelectric Pressure Sensors.
5. Strain Gauge Pressure Sensors.

2.2.1 Capacitive Pressure Sensors

The capacitive weight sensors utilize a thin stomach as one plate of a capacitor. At the point when the weight is being connected there will be an avoidance in the stomach and change in the capacitance. This sort of progress may not be direct and is normally on the request of a few picofarads out of an aggregate capacitance of 50-100 pF. To control the recurrence of swaying the adjustment in capacitance is utilized. The electronic gadget with the end goal of flag condition ought to be set close to the detecting component to avoid blunders because of stray capacitance.

The Capacitance of two parallel plates is given by:

$$C = \mu A/d$$

Where:

μ = the dielectric constant of the material between the plates

A = the area of plates

d = spacing between the plates

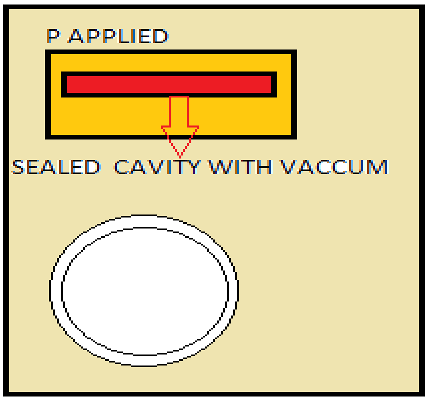


Figure 2.6 Capacitive Pressure Sensor with Two Plates

2.3 Part Detection Sensor

For applications that oblige you to pick parts, you presumably do not understand if the part is in the gripper or on the off chance that you simply missed it (accepting you don't have a dream framework yet!). All things considered, a section recognition application gives you criticism on your gripper position. For instance, if a gripper misses a section in its getting a handle on operation, the framework will distinguish a blunder and will rehash the Operation again to ensure the part is very much gotten a handle on [10].

Figure 2.7 Part detection Sensor [10].

Our Adaptive Grippers have part identification frameworks that needn't bother with any sensors. Truth be told, our Grippers are intended to handle parts with a given drive. Along these lines, the Gripper doesn't have to realize that the part is there or not, it will just apply enough drive to get the best hold on the question. Once the required drive is achieved, you realize that the question is in the Gripper and that it is prepared for the subsequent stage in the operation.

2.4 Servo Motor

A servomotor is a revolving actuator or straight actuator that takes into consideration exact control of precise or direct position, speed and quickening. It comprises of a reasonable engine coupled to a sensor for position criticism. It likewise requires a generally refined controller, regularly a devoted module outlined particularly for use with servomotors. Servomotors are not a particular class of engine in spite of the fact that the term servomotor is regularly used to allude to an engine appropriate for use in a shut circle control framework. A servomotor is a shut circle servomechanism that utilizations position input to control its movement and last position. The contribution to its control is a flag, either simple or computerized, speaking to the position told for the yield shaft. The engine is combined with some sort of encoder to give position and speed criticism. In the easiest case, just the position is measured. The deliberate position of the yield is contrasted with the summon position, the outer contribution to the controller. In the event that the yield position varies from that required, a blunder flag is produced which then makes the engine turn in either heading, as expected to convey the yield shaft to the fitting position. As the positions approach, the blunder flag decreases to zero and the engine stops [5].

The extremely least complex servomotors utilize position-just detecting through a potentiometer and blast control of their engine; the engine dependably pivots at full speed (or is halted). This sort of servomotor is not broadly utilized as a part of modern movement control, but rather it frames the premise of the straightforward and shabby servos utilized for radio-controlled models.

More complex servomotors utilize optical rotating encoders to quantify the speed of the yield shaft and a variable-speed drive to control the engine speed. Both of these improvements, ordinarily in mix with a PID control calculation, permit the servomotor to be conveyed to its instructed position all the more rapidly and all the more decisively, with less overshooting [8].

Figure 2.8 Servo Motor [8]

2.5 Servo Drive

1. An Input summon is sent to the gripper from a robot control unit. This unit is generally pre-customized by an administrator by means of an instruct pendant. With most electric grippers, the charge can be a position, a speed or a hold drive. The robot can send orders to the gripper utilizing computerized I/O's, or by utilizing any of the accessible robot correspondence conventions.

2. The summon from the robot is gotten by the gripper control module in charge of driving the gripper motor(s). This gripper module is once in a while inserted in the gripper however more often than not it comprises of a case sitting between the robot controller and the gripper.

3. The servo-electric engine responds to the flag. The pole will then pivot to the charged position, speed or drive. To empower shut circle control, criticism from the engine position is generally essential at the gripper level. Until there is a flag change, the servo will hold the position (and oppose change).

Figure 2.9 Servo Drive [8]

3. DESIGNING THE MECHANICAL PARTS OF GRIPPER

3.1 Designing of two jaw parallel gripper

The mechanical structure of the gripper is illustrated in Figure 3.1. The inner dimensions of the tip in the figure may not be precise. It is being calculated according to the outer dimensions. The fig illustrates the work principle of gripper and shouldn't be measured for detailed calculations. As it can be seen in the cross-section figure of the gripper, the jaws are connected with a shaft and the link mechanism for the actuation. A 115 lbs thrust linear actuator, placed on the ground is used to actuate the gripper. The force transmission from actuator to gripper is supplied by the means of flexible transmission. The gripper has only 1 DOF and have only two stages for actuating the grippers, open and close operation.

Concentrating on our current research work, the samples or pre-existing design is being considered in mind and according to the standard size and design we have designed the two jaw parallel gripper. As we look into the sample design made here each of the sample design exhibit their own degrees of freedom and structure. In this research work the general sample gripper which is been used is two jaw parallel gripper. This sample gripper is used to make as an MEMS technology to get the better performance and life of the mechanism.

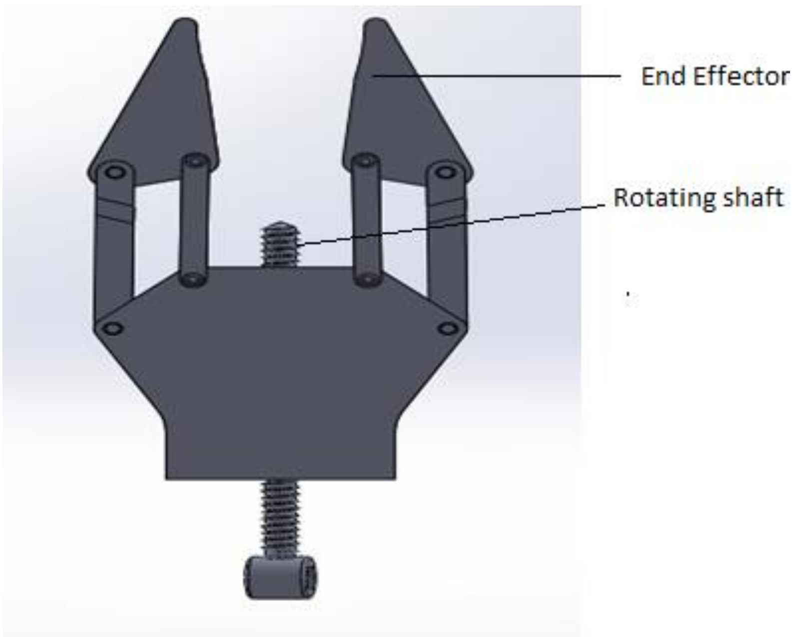


Figure 3.1 Two Jaw Parallel Gripper

As from the above design of two jaw parallel gripper the design is made using aluminium material and the standard size used to design the gripper is in mm. In this gripper, the main theory is to implement the MEMS pressure sensor at the end effector face. The capacitive pressure sensor is used as a pressure sensor and it's been designed using the COMSOL software.

Table 3.1 Properties of Aluminium Alloy 1060

Property	**Value**	**Units**
Elastic Modulus	6.9e + 010	N/m^2
Poisson's Ratio	0.33	N/A
Shear Modulus	2.7e + 010	N/m^2
Mass Density	2700	Kg/m^3
Tensile Strength	68935600	N/m^2
Compressive Strength		N/m^2
Yield Strength	27574200	N/m^2
Thermal Expansion Coefficient	2.4e – 005	/K
Thermal Conductivity	200	W/(m.K)
Specific Heat	900	J/(Kg.k)
Material Damping Ratio		

The material used to design the gripper is Aluminium alloy 1060. In solid works we have designed the complete gripper parts and been assembled it accurately to get the shape of the two jaw gripper.

The design of the gripper and its part will be explained in detail below.

Body of gripper

The Figure 3.1(a) illustrates the body design of gripper is a main part which is used to mount the end effectors by using the connecting the rod. The length of the body is 90mm and the width is of 60mm and it have 4 holes whose Diameter is 5mm, where the end effectors connecting rod will be placed and the other width is of 98mm where the angle is 26.57 degree which is made to correlate the shaft of the end effector and there is an internal extrude box which measure length 15mm and width 20mm which is been made an internal thread to move the end effector through an external medium. This body part of the gripper is being made using solid works and the material used is aluminium alloy. The internal thread diameter is 10mm.

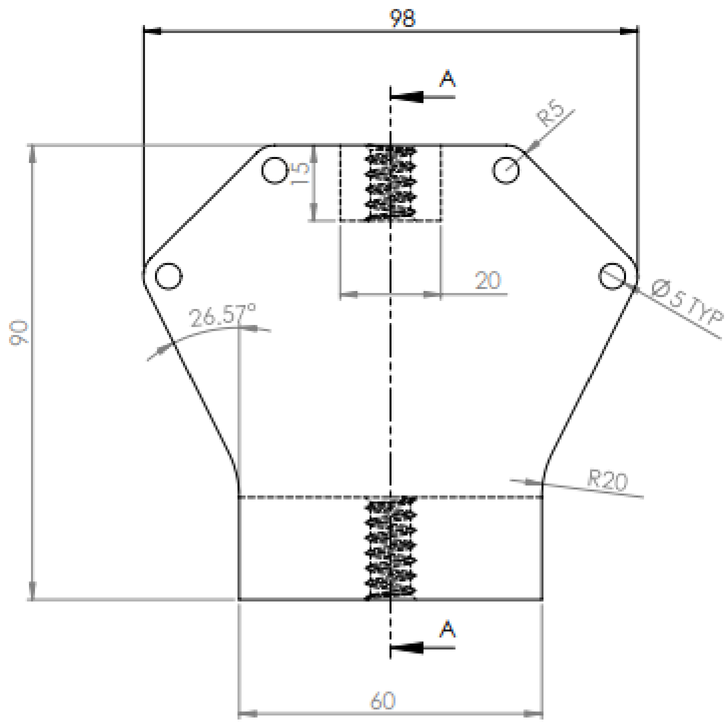
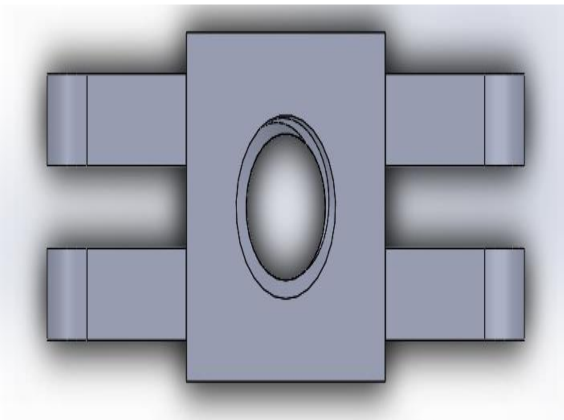


Figure 3.2 Body of the Gripper

Internal screw thread body

Figure 3.3(a) and (b) illustrates internal screw thread body is used to rotate the shaft when the motor is been energised it's a dynamic body which is a relative part for the movement of end effectors this body part measurements are the length is of 19mm and width is of 20mm and it consist of 2 holes at each side which is used for connecting the end effectors leg through a axle. And the main diameter of the internal thread is 10mm and the pitch is of 8mm. This is a stationary part which can move in to and fro motion.



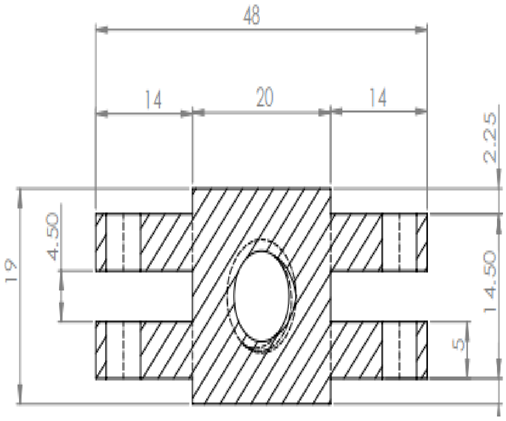
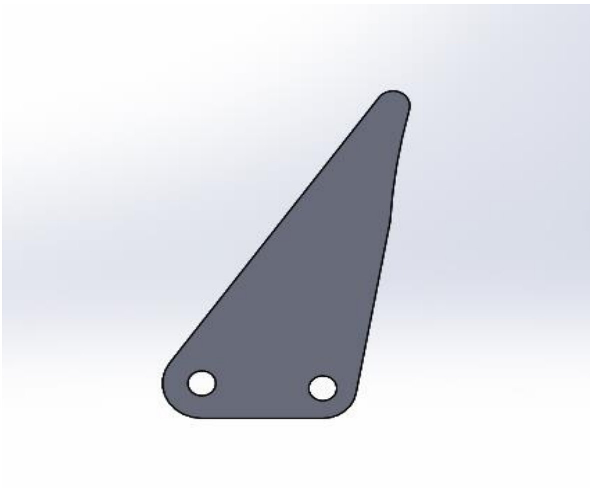


Figure 3.3(a) Internal screw thread body 3D part **Figure 3.3(b)** Internal screw thread body 2D sketch

End effector of gripper

The end effector this is the important part of the gripper to grasp the object and hold it. While designing the end effector the holding face should be designed in such a way that it should be compatible to hold the objects which is been illustrated in fig 3.4(b). The length of the end effector is 65.54mm and the width is of 24mm the grasping corner face is been chamfered with radius 3mm and the object holding face is of R120 mm. and the slanting angle of end effector is of 80 degrees which should be parallel opposite to the other which should mate each other surface.



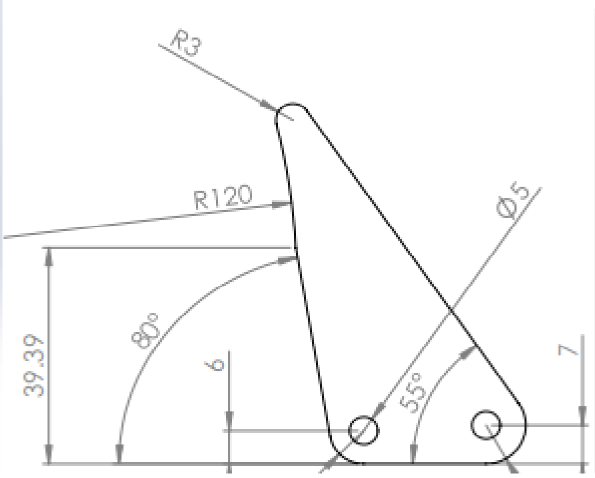
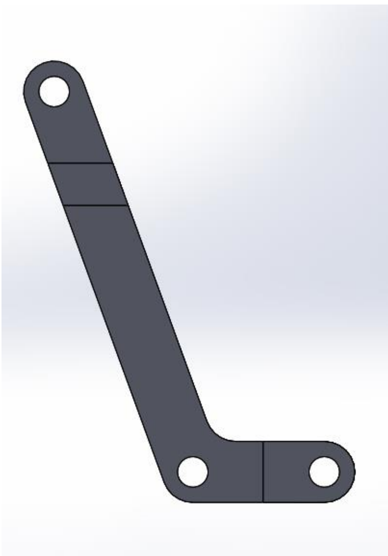


Figure 3.4(a) End Effector of Gripper 3D Part. **Figure 3.4(b)** End Effector of Gripper 2D Drawing

Angle shaft of the end effector

This is the connecting shaft from the end effector to the gripper body which is able to move the end effector when the internal shaft is rotating. The size of the shaft is 72.32 mm length and width is of 54.18mm which is having an angle of 110degree see figure 3.5(b). This angle shaft is connected to gripper end effector and the other end to the body of gripper but internally inside the body so that it won't be disturbance to the other object when the gripper is being moved on a work assembly.



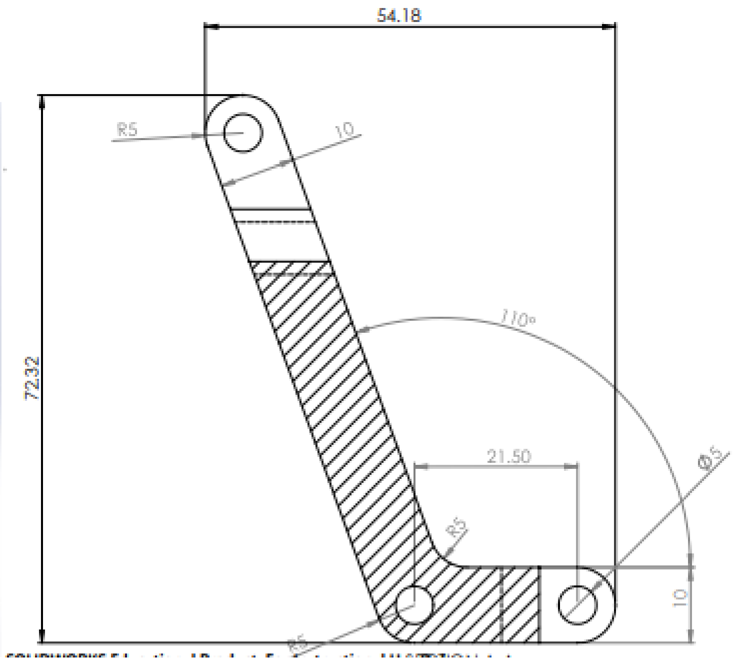


Figure 3.5(a) Angle Shaft of the End effector 3D Drawing. **Figure 3.5(b)** Angle Shaft of the End effector 2D Drawing

4. DESIGNING OF CAPACITIVE MEMS PRESSURE SENSOR

MicroElectroMechanical Systems (MEMS) denote systems that include one or more small microstructures (sub- μm to mm) that often are fabricated using a technology named micromachining, and materials, that originates partly from the semiconductor industry's processes and partly from precision mechanics.

Capacitive -based MEMS are generally attractive due to their high sensitivity and low electrical noise in sensing applications and high-force output in actuation applications.

Exploiting the capacitive materials into microelectromechanical systems (MEMS)

In this research work we are designing a Capacitive Pressure MEMS sensor to calculate the pressure that should be applied when the gripper grasps any type of object and its main theory is that the pressure should be managed according to the type of material been on a assembly or manufacturing process.

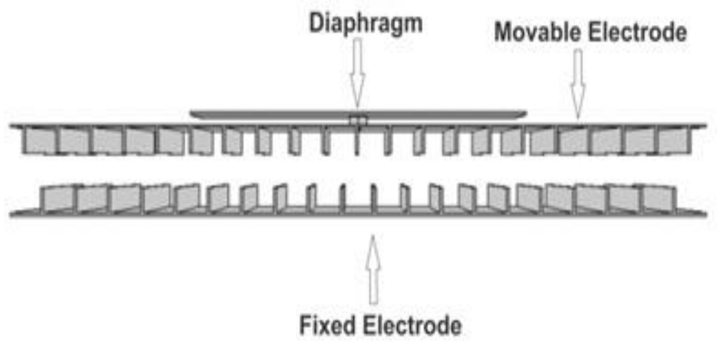


Figure 4.1 Comb Drive Type Capacitive Pressure Sensor

Design:

Dimensions : 375 µ X 375 µ X 3 µ (Diaphragm)

750 µ X 750 µ X 3 µ (Comb drive base)

20 µ X 750 µ X 3 µ (Fringe)

Material **: Silicon nitrate for diaphragm Gold for comb drive**

Working Principle : The operating principle of the comb drive pressure sensor is, when there is a force been applied on the diaphragm the capacitor plates will get compressed and comes close to each other, When the load is acting on the top plate we are giving uniform load , so deformation takes place when deformation happens the capacitive plates also compress and increase the capacitance.

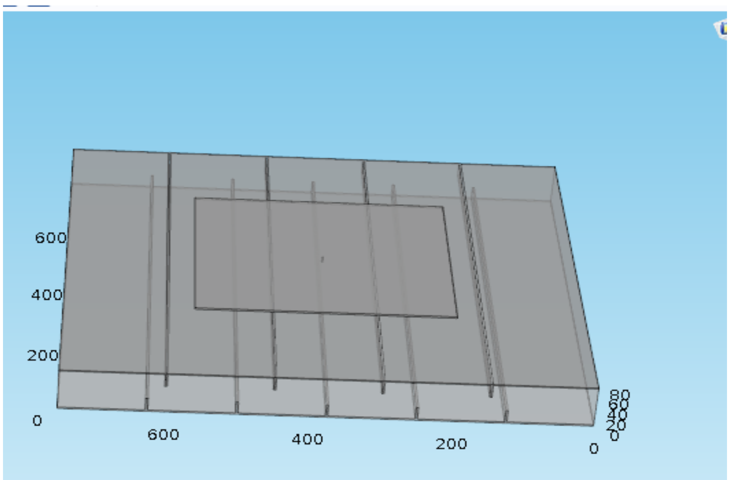


Figure 4.2 Structure of Capacitive Pressure sensor

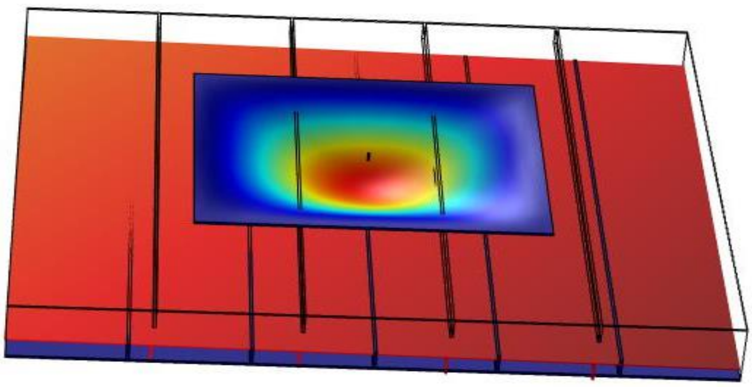


Figure 4.3 Deformed Structure of Capacitive Pressure Sensor

An itemized 2D area through the practical piece of the gadget is appeared in figure 4.2. A thin layer is holded at a settled capability of 1V. this layer is been isolated from the beginning plane chamber which is fixed with high vacuum. At the point when the weight outside the fixed chamber changes, the weight distinction makes the film divert. The thickness of the air hole will fluctuate over the film and its capacitance to ground subsequently changes.

5. SIMULATION RESULTS

5.1 MECHANICAL STRUCTURE ANALYSIS OF GRIPPER FOR FORCE

STRESS ANALYSIS: As illustrated in the below figure 5.1, we are calculating the stress by applying the force of 9.81 N on the grippers end effector face, we can see that when the force is applied on the end effectors face there is not much of stress happening at one end effector and there is a change in its relative connecting part the minimum stress at Node 28538 is 0 N/m^2 and the maximum stress at node 1.55908e+007.

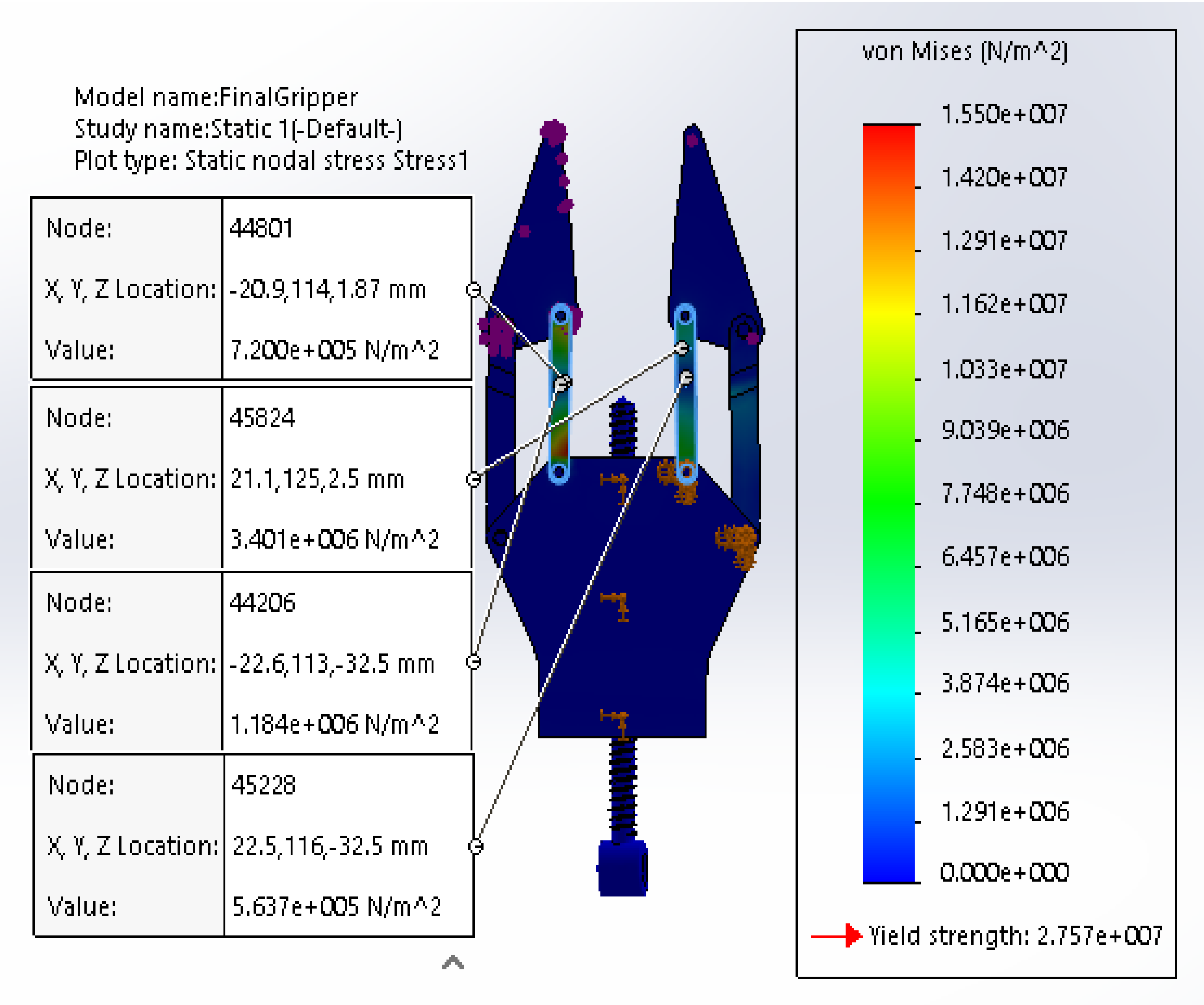


Figure 5.1 Stress Analysis of Force on Gripper End Effector

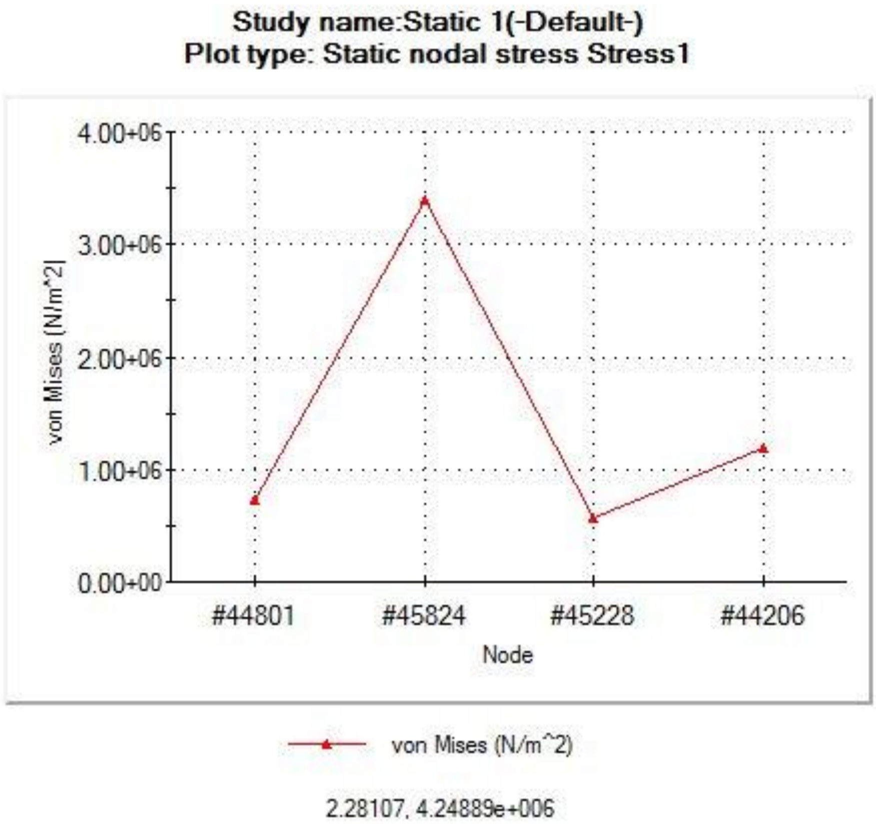


Figure 5.2 Stress analysis Plot of Force on Gripper End Effector

Table 5.2 Values of Force Stress on Gripper End Effector

Node	**Value (N/m^2)**	**X (mm)**	**Y (mm)**	**Z (mm)**	**Components**
44801	7.20E+05	-20.85960007	113.8398514	1.86957443	RELATION-1-2
45824	3.40E+06	21.13656235	124.756134	2.5	RELATION-1-4
45228	5.64E+05	22.53348541	115.5530014	-32.5	RELATION-1-3
44206	1.18E+06	-22.56943512	112.7754517	-32.5	RELATION-1-1

DISPLACEMENT ANALYSIS: As illustrated in the below figure 5.3, we are calculating the displacement by applying the force of 9.81 N on the grippers end effector face, we can see that when the force is applied on the end effectors face there is too much of displacement happening at one end effector and there is a change in its relative connecting part. And the chances of breakage of the gripper shaft are more the reason for more displacement at one end effector is due to fault while assembling the part and the minimum displacement at node 75 is 0mm and the maximum is of 0.0736661mm at node 25441

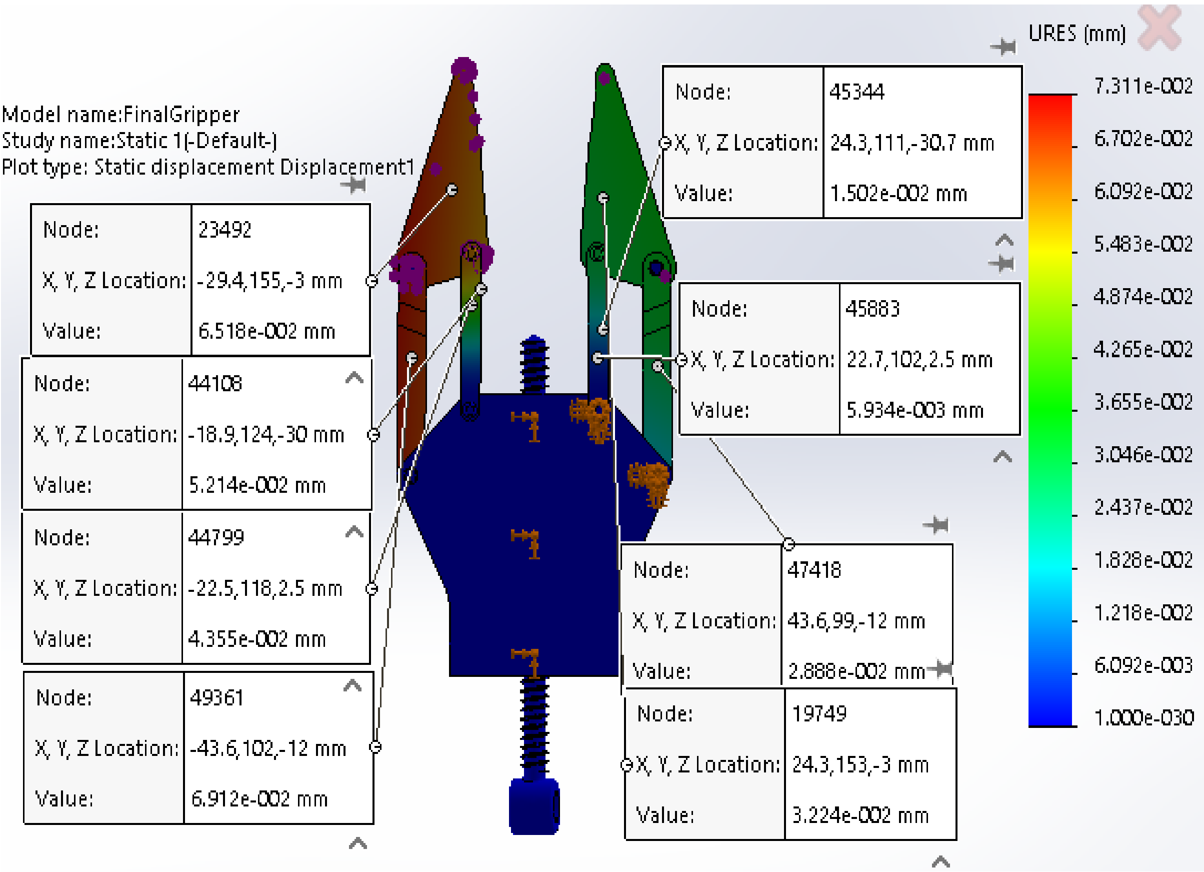


Figure 5.3 Displacement Analysis of Force on Gripper End Effector

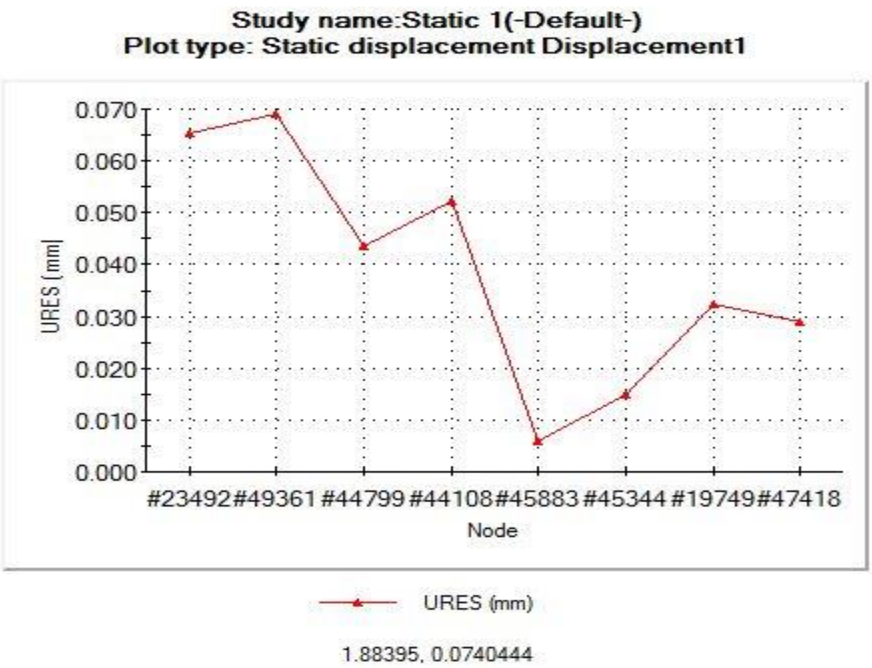


Figure 5.4 Displacement Analysis Plot of Force on Gripper End Effector

Table 5.3 Values of Displacement Analysis plot of Force on Gripper End Effector

Node	Value (mm)	X (mm)	Y (mm)	Z (mm)	Components
23492	6.52E-02	-29.40770721	155.3312988	-3	FINGER-2
49361	6.91E-02	-43.57117844	101.8439941	-12	RELATION-3-3
44799	4.36E-02	-22.49753571	118.3305435	2.5	RELATION-1-2
44108	5.21E-02	-18.92757988	123.7128906	-30	RELATION-1-1
45883	5.93E-03	22.71323395	101.6652756	2.5	RELATION-1-4
45344	1.50E-02	24.298172	110.5892334	-30.65077209	RELATION-1-3
19749	3.22E-02	24.29946899	152.5478058	-3	FINGER-1
47418	2.89E-02	43.59730148	98.9672699	-12	RELATION-3-2

STRAIN ANALYSIS: As illustrated in the below figure 5.4, we are calculating the strain by applying the force of 9.81 N on the grippers end effector face, we can see that when the force is applied on the end effectors face there is Equivalent strain happening at both the end effector and there is no change in its relative connecting part. And the chances of breakage of the gripper shaft is not possible and the strain at element 29754 is the minimum and the maximum at the element 26535 is 0.000141272.

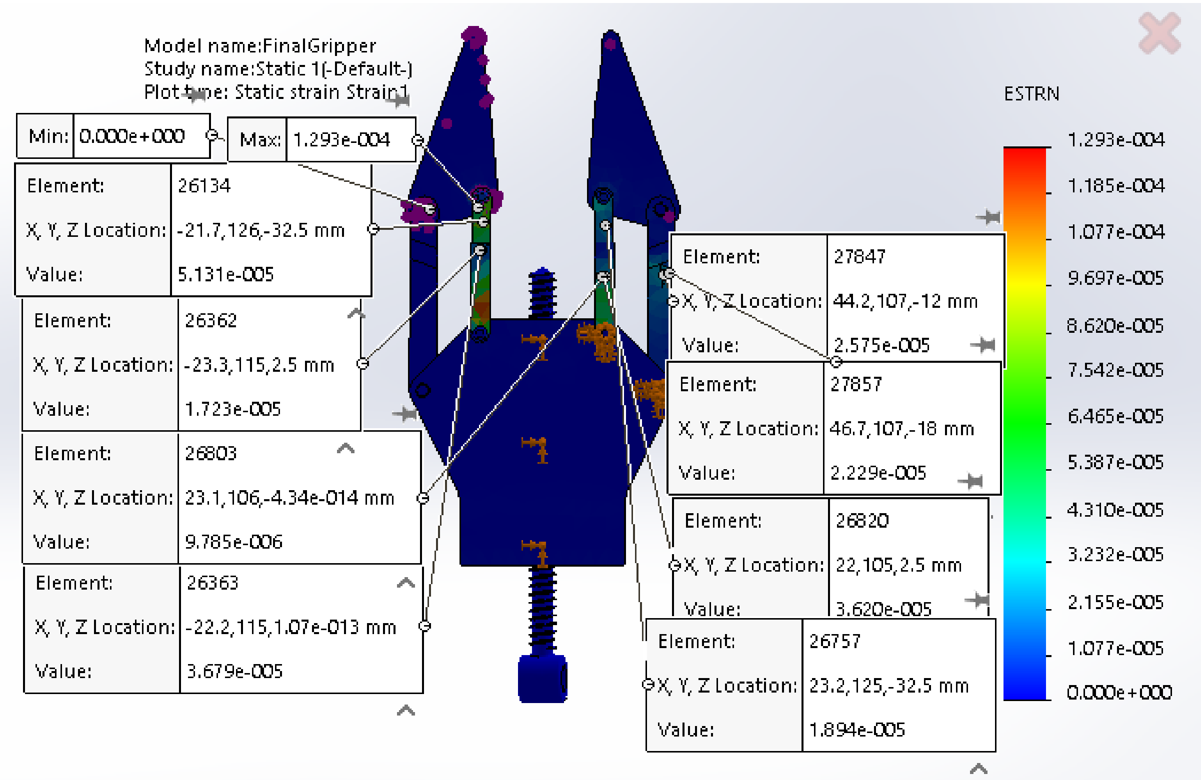


Figure 5.5 Strain Analysis of Force on Gripper End Effector

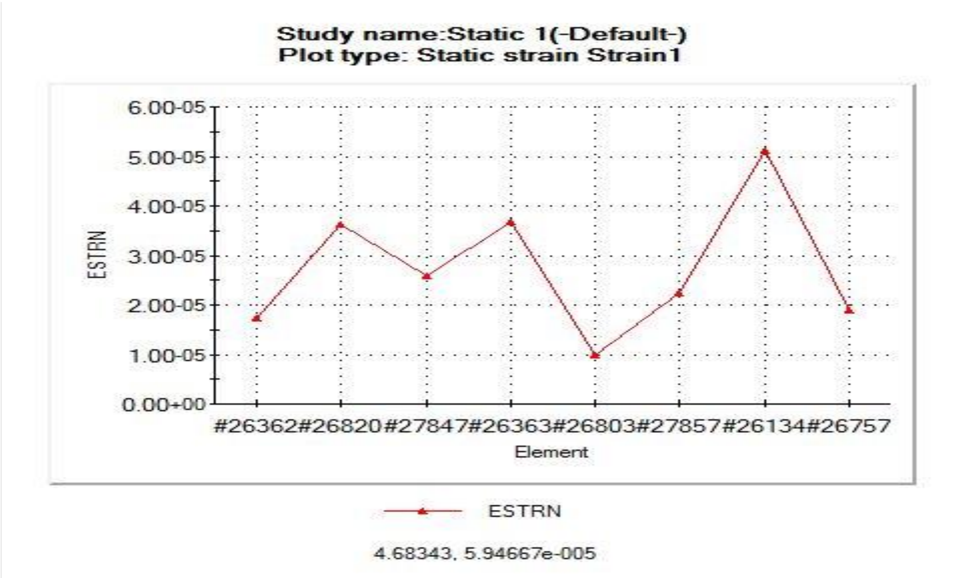


Figure 5.6 Strain Analysis Plot of Force on Gripper End Effector

Table 5.4 Strain Analysis Values of Force on Gripper End Effector

Element	**Value**	**X (mm)**	**Y (mm)**	**Z (mm)**	**Components**
26362	1.72E-05	-23.28680992	115.1359024	2.5	RELATION-1-2
26820	3.62E-05	22.01442719	105.4986572	2.5	RELATION-1-4
27847	2.58E-05	44.19621277	106.6379242	-12	RELATION-3-2
26363	3.68E-05	-22.2310257	115.4175949	0	RELATION-1-2
26803	9.79E-06	23.07021523	105.7803421	0	RELATION-1-4
27857	2.23E-05	46.73009872	107.3139801	-18	RELATION-3-2
26134	5.13E-05	-21.74433136	125.9740143	-32.5	RELATION-1-1
26757	1.89E-05	23.21340561	124.8241806	-32.5	RELATION-1-3

Resultant Forces

Reaction forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	0.0010071	0.00213663	-19.6205	19.6205

5.2 MECHANICAL STRUCTURE SIMULATION OF GRIPPER FOR PRESSURE

STRESS ANALYSIS: As illustrated in the below figure 5.6, we are calculating the stress by applying the pressure of 1 N/m^2 on the grippers end effector face holding position, we can see that when the pressure is applied on the end effectors face there is not much of stress happening at one end effector and there is a change in its relative connecting part. And the chances of breakage of the gripper shaft and the end effector is zero percent and the minimum stress at Node 28538 is 0 N/m^2 and the maximum stress at node 44765 is 1483.66 N/m^2 .

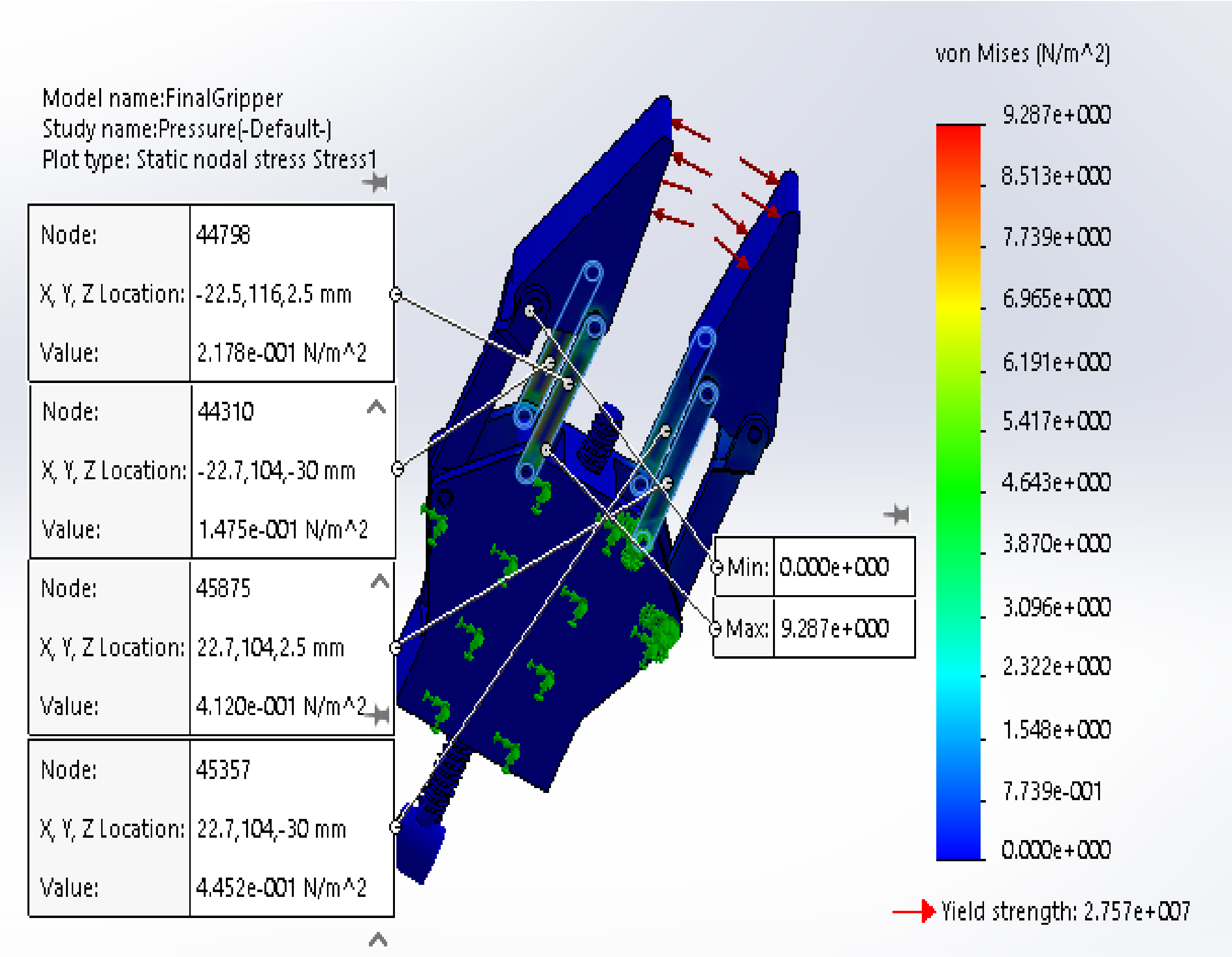


Figure 5.7 Stress Analysis of Pressure on Gripper End Effector

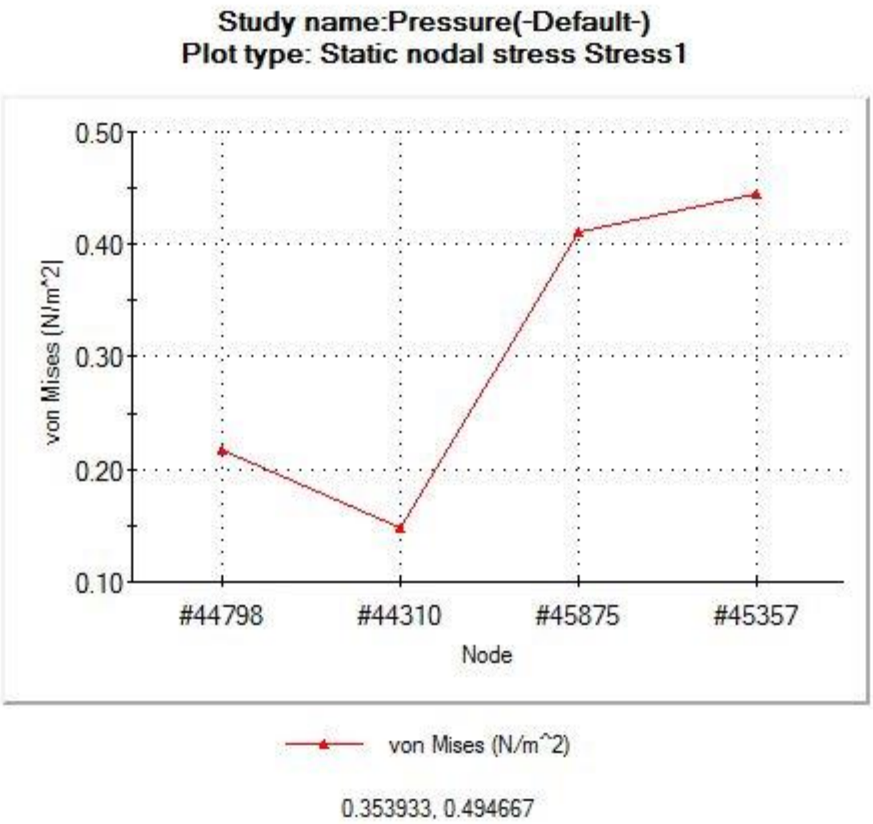


Figure 5.8 Stress Analysis Plot of Pressure on Gripper End Effector

Table 5.5 Stress Analysis Value of Pressure on Gripper End Effector

Node	Value (N/m^2)	X (mm)	Y (mm)	Z (mm)	Components
44798	2.18E-01	-22.53348541	115.5530014	2.5	RELATION-1-2
44310	1.48E-01	-22.6877861	103.6314316	-30	RELATION-1-1
45875	4.12E-01	22.67728424	104.4428177	2.5	RELATION-1-4
45357	4.45E-01	22.6877861	103.6314316	-30	RELATION-1-3

DISPLACEMENT ANALYSIS: As illustrated in the below figure 5.8 we are calculating the displacement by applying the pressure of 1 N/m^2 on the grippers end effector face holding position, we can see that when the pressure is applied on the end effectors face there is too much of displacement happening at one end effector and there is a change in its relative connecting part. And the chances of breakage of the gripper shaft and the end effector are more fault while assembling the part and the minimum displacement at node 75 is 0mm and the maximum is of 1.76942e-005 mm at node 25395.

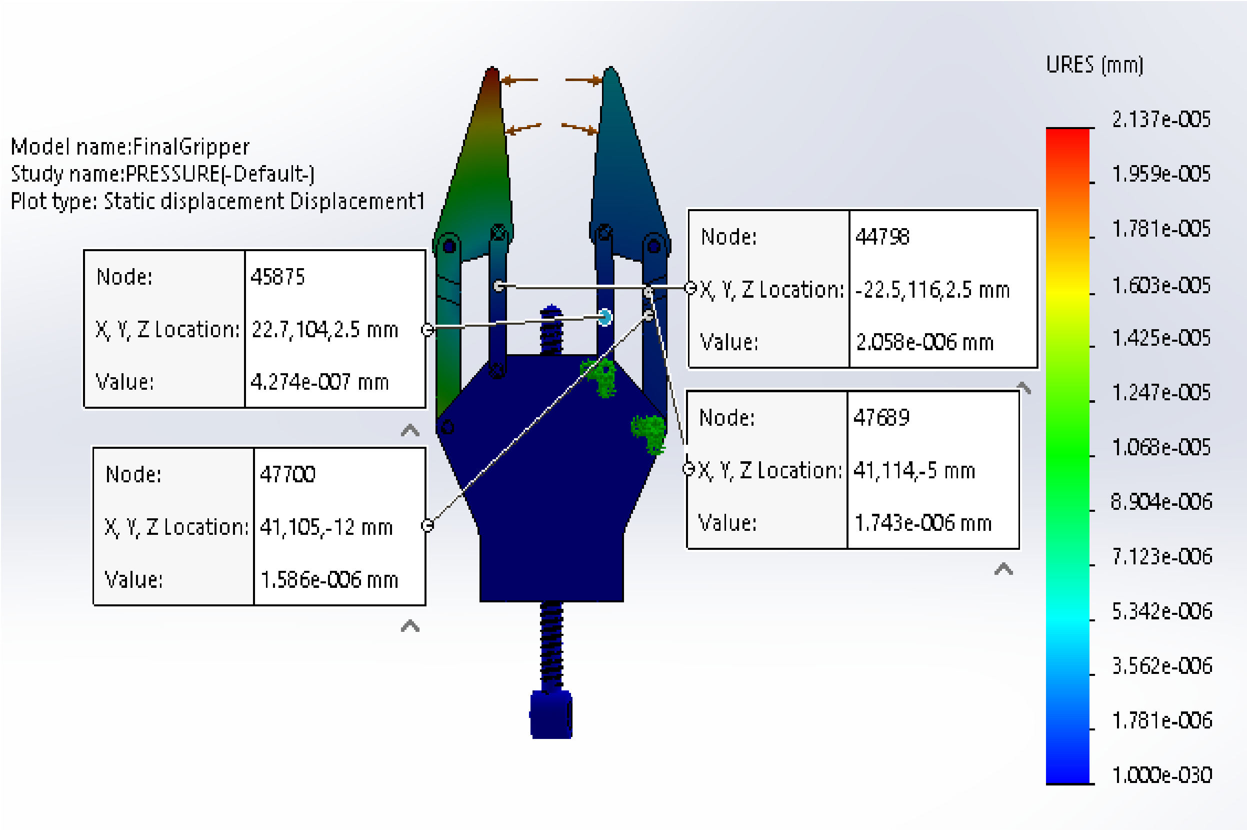


Figure 5.9 Displacement Analysis of Pressure on Gripper End Effector

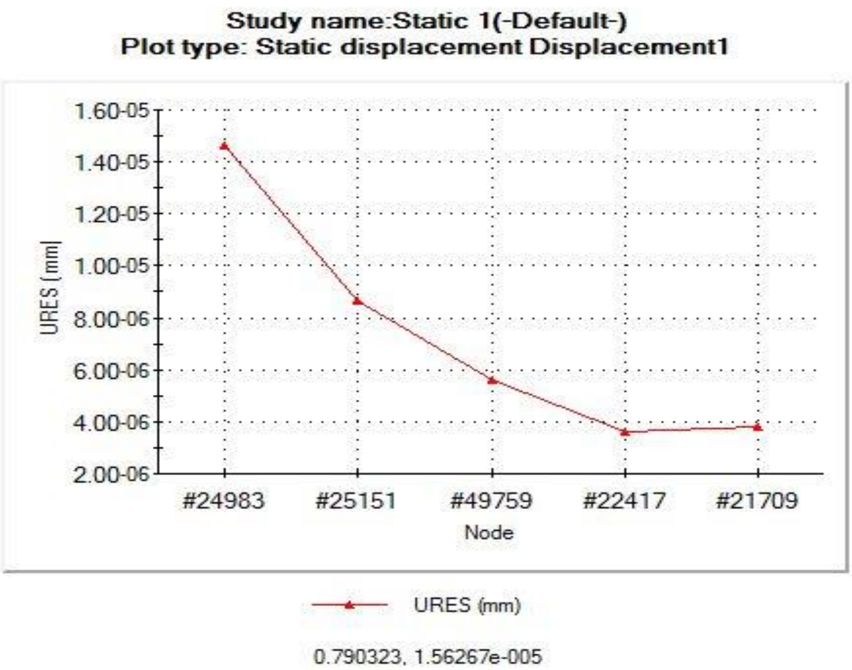


Figure 5.10 Displacement Analysis plot of Pressure on Gripper End Effector

Table 5.6 Displacement Analysis Values of Pressure on Gripper End Effector

Node	Value (mm)	X (mm)	Y (mm)	Z (mm)	Components
24983	1.46E-05	-19.4015522	181.5069885	-12	FINGER-2
25151	8.65E-06	-32.86615372	151.344986	-3	FINGER-2
49759	5.62E-06	-42.73726273	96.07020569	-12	RELATION-3-3
22417	3.60E-06	24.71095657	175.9505615	-3	FINGER-1
21709	3.78E-06	19.4015522	181.5069885	-18	FINGER-1

STRAIN ANALYSIS: As illustrated in the below figure 5.10, we are calculating the strain by applying the pressure of 0.006236 N/m^2 on the grippers end effector face holding position, we can see that when the pressure is applied on the end effectors face there is too much of stress happening at one end effector and there is a change in its relative connecting part. And the chances of breakage of the gripper shaft and the end effector is not possible and the strain at element 29754 is the minimum and the maximum at the element 26237 is 1.25213e-008.

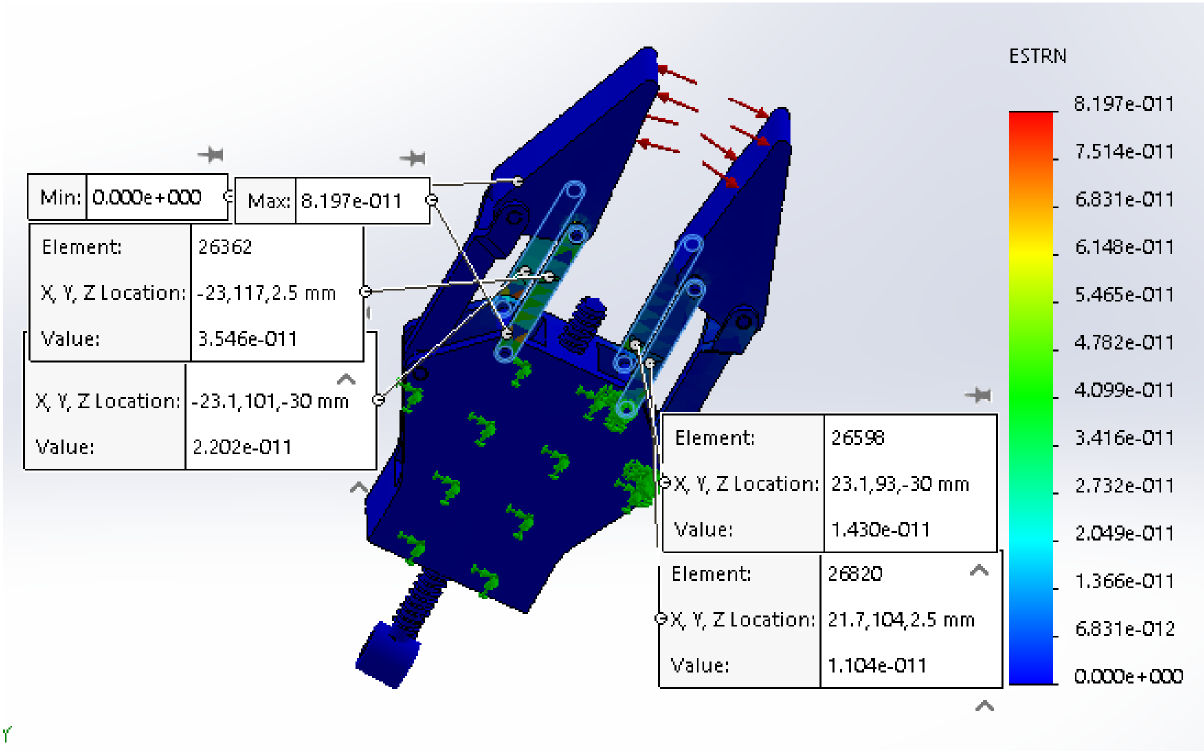


Figure 5.11 Strain Analysis of Pressure on Gripper End Effector

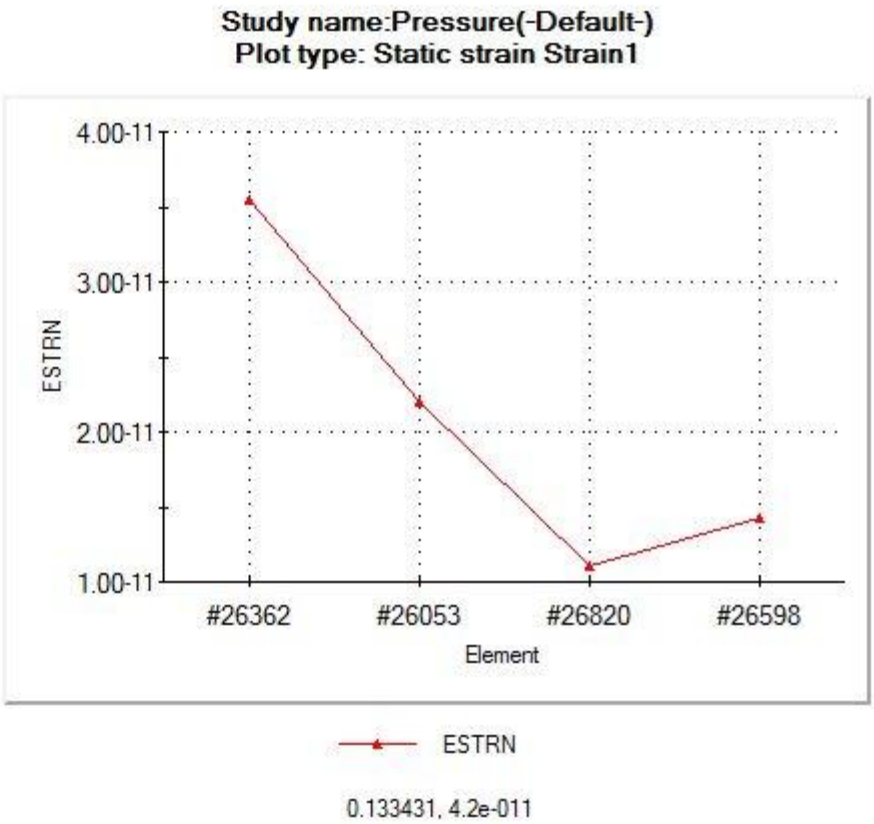


Figure 5.12 Strain Analysis of Pressure on Gripper End Effector

Table 5.7 Strain Analysis Plot of Pressure on Gripper End Effector

Element	**Value**	**X (mm)**	**Y (mm)**	**Z (mm)**	**Components**
26362	3.55E-11	-23.04970741	117.0396423	2.5	RELATION-1-2
26053	2.20E-11	-23.05892181	100.5640488	-30	RELATION-1-1
26820	1.10E-11	21.68439293	103.754921	2.5	RELATION-1-4
26598	1.43E-11	23.1263485	92.96858215	-30	RELATION-1-3

Resultant Forces

Reaction forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	1.27071e-007	0.000122326	-1.6568e-007	0.000122327

Formula :

$$Force = Mass \times Gravitational\ Acceleration(G)$$

FORCE = 9.81N

$$Area = Length \times Width$$

Area = 65.54*24= 1572.96 mm^2 (10^3mm = 1m. Therefore 1mm = 10^{-3}m; $1mm^2 = 10^{-9}$m)
= 1572.96*$10^{-9}m^2$

$$Pressure = \frac{Force}{Area}$$

Pressure = 9.81/65.54/24

Pressure = 0.006236

5.3 MICROELECTROMECHANICAL SYSTEM ANALYSIS OF GRIPPER PRESSURE SENSOR

In this thesis work we have used COMSOL Multiphysics software to design the capacitive pressure sensor. The materials used to design the pressure sensor is Silicon nitrate material and Au (Gold).

The n-type Silicon for diaphragm and p-type for bridge. Comb Drive type pressure sensor.

In figure 5.12 and 5.13 the illustration of the uniform load is applied equally and it is acted on the top surface of the plate, when the load is applied the deformation takes place once the deformation happens the capacitive plates will get compressed and there will be an increase in capacitance. It means due to the force applied above the capacitive plates will come very near to each other and the voltage will also change according to the pressure applied. The pressure range is from 0 – 10000N.

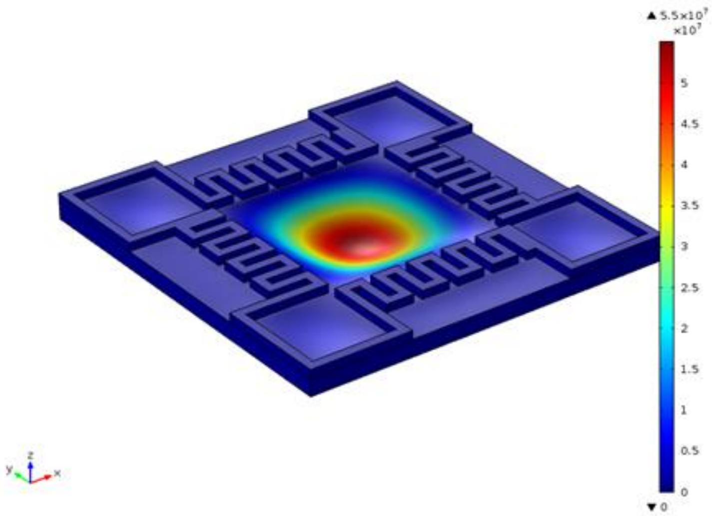


Figure 5.13 Diaphragm deflection

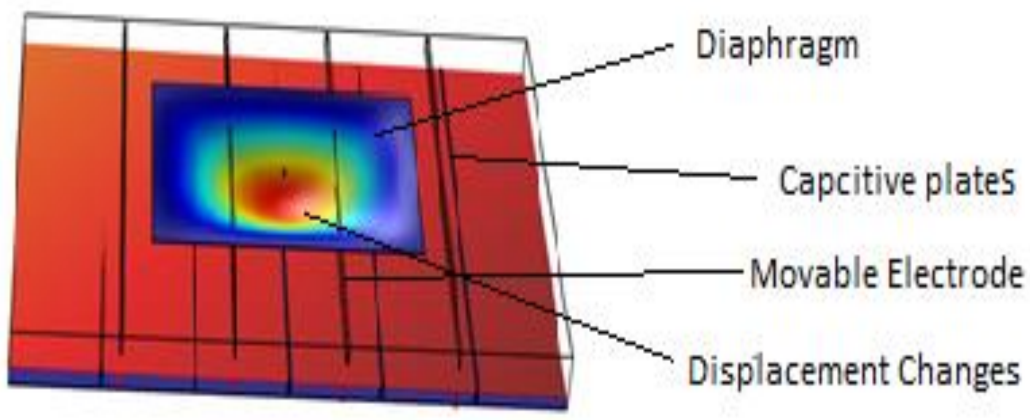


Figure 5.14 Diaphragm Deformation

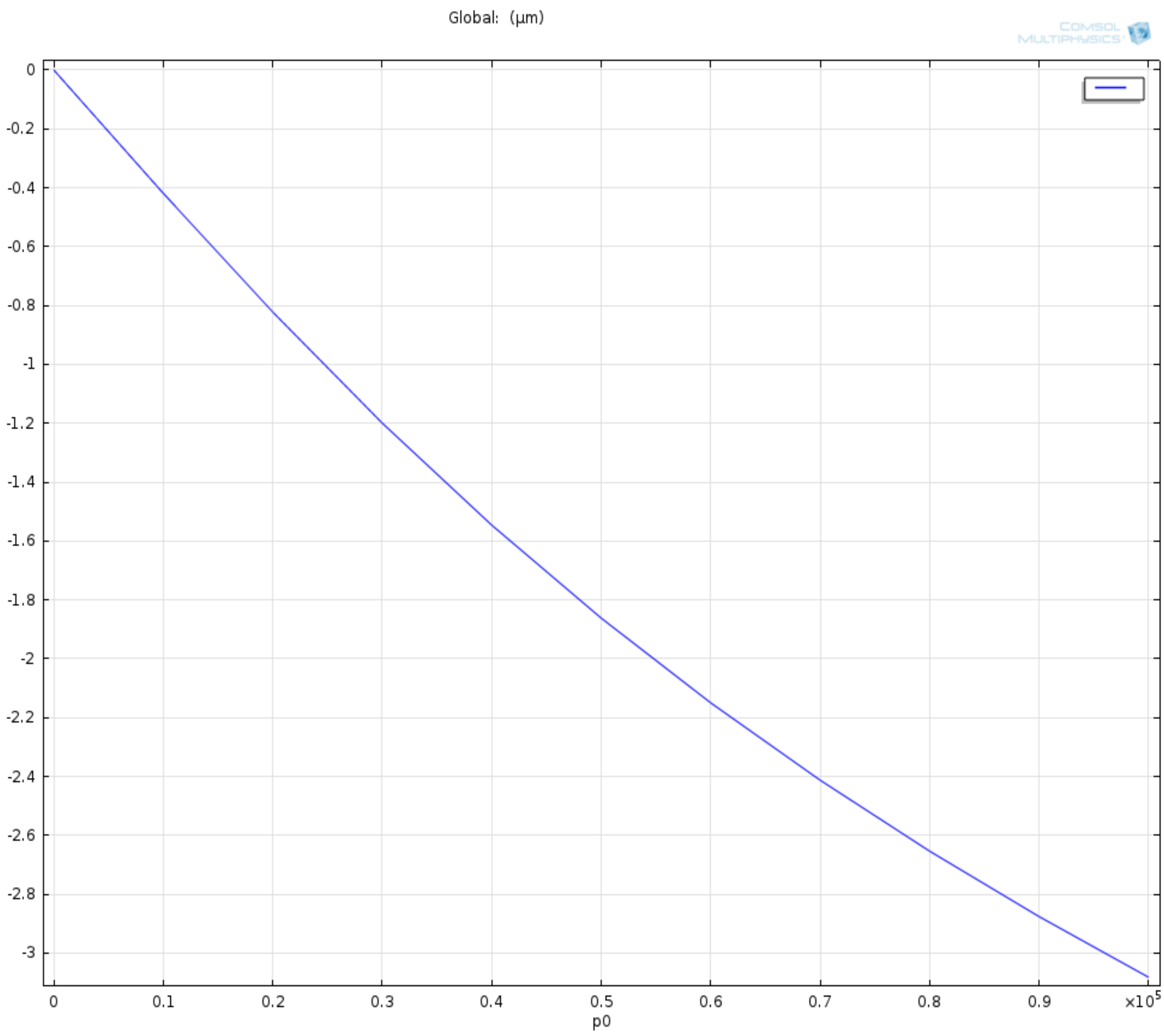


Figure 5.15 Deformation Plot

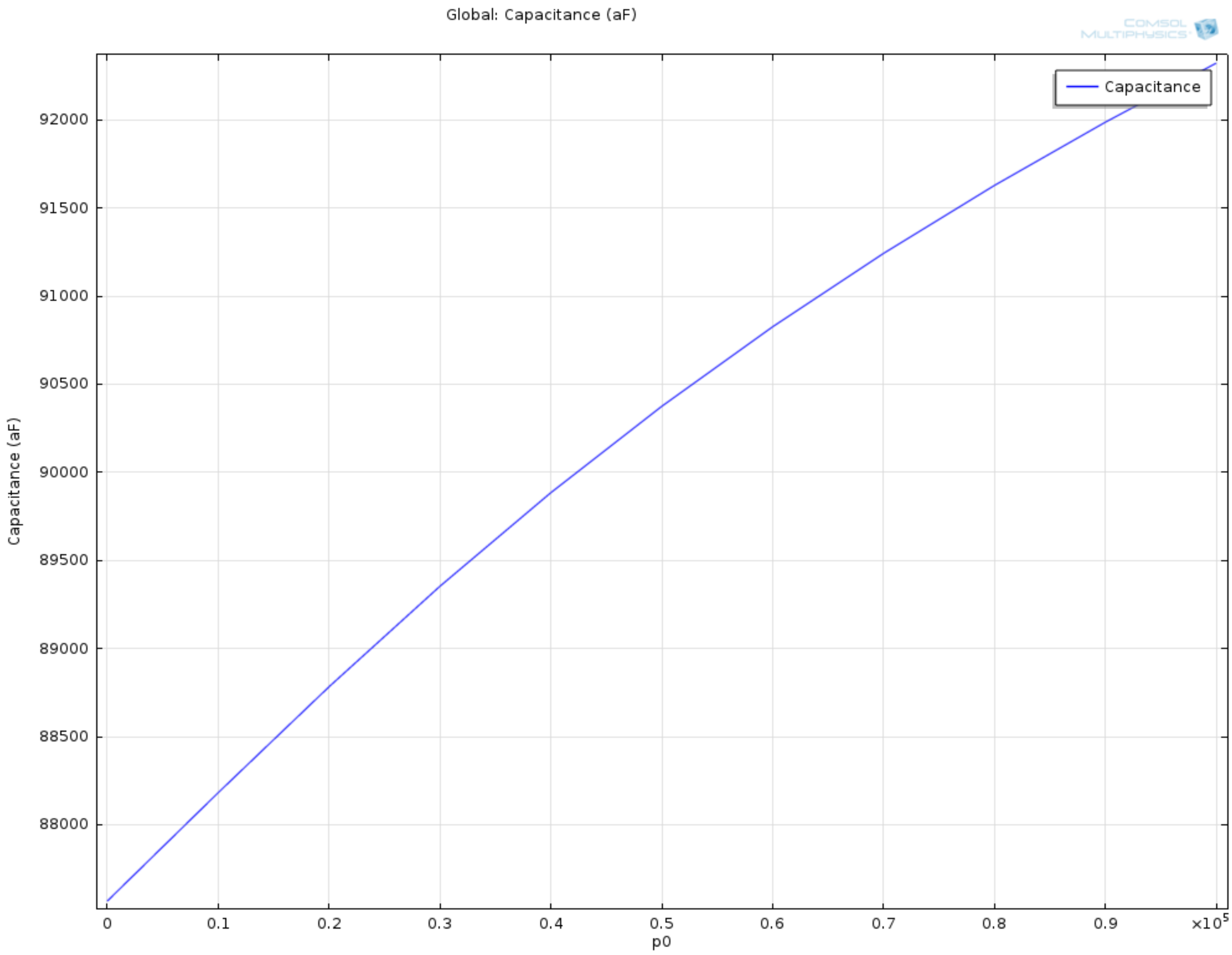


Figure 5.16 Capacitance Plot

Dimensions **: 375 µ X 375 µ X 3 µ (Diaphragm)**

750 X 750 µ X 3 µ (Comb drive base)

20 µ X 750 µ X 3 µ (Fringe)

Material **:** Silicon Nitrate for diaphragm

Gold for Comb drive

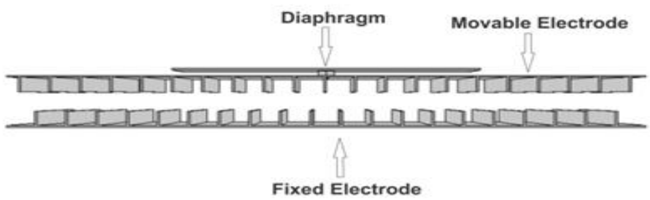


Figure 5.17 Comb Drive Capacitance Pressure sensor

Merits

- Highly linear
- Sensitivity is high

Demerits:

- ◦ Highly temperature dependent
- ◦ Effects by Noise is high

Result

From the above analysis, it is concluded that the proposed comb drive type pressure sensor is best suited for pressure measurement as it is inert to temperature change and its sensitivity is 120 aF/kPa which is increased compared to parallel plate whose sensitivity is 85 aF/kPa. Comb drive’s output is also linearized compared to parallel plate capacitor.

6. CONTROL PART

The two jaw robotic grippers control system is designed using TwinCAT Programming Logic Controller software. Which is a part of bechkoff automation unit. There are different types of programming language in PLC like Structure Text, Instruction list, Functional block, Ladder logic and the Sequential Function. In my thesis work for controlling part I am using the ladder logic language for programming, the reason for choosing the ladder logic is it's easy to understand the step by step process of execution in both simulation and the real time process and the programming is more compatible then coding because the each input and outputs will be assigned and named accordingly and also the indications of start, stop, emergency and failure in the machine can be identified easily. Then compared to other microcontroller devices PLC is more user friendly to communicate with the robot or the machines. The PLC can have a good command on the machines and its execution takes place very fast and there wont be delay in the process.

The PLC controls the servo motor, servo drive, sensor actuation, electrical part and pneumatics system of the gripper.

The type of PLC I am using is Bechkoff's IEC 61131-3 Multi-PLC.

Operating Principle:

when the grippers object detecting sensor detects the workpiece and the type of material to grasp it sends the information to the PLC memory, the memory receives the data store it and encode the data and checks the information and analyse the process then it sends to the Capacitive pressure sensor to read the message or the command and indicates to open the pressure to the required value. Also, the servo motors get the information to open and close the jaw or the end effector. The grippers servo motor van encode and decode the input signals from the PLC

The advantage of using the PLC in robotics is its saves energy and time of operation.

In the below flow chart, we will see the operation of PLC in a hierarchical diagram:

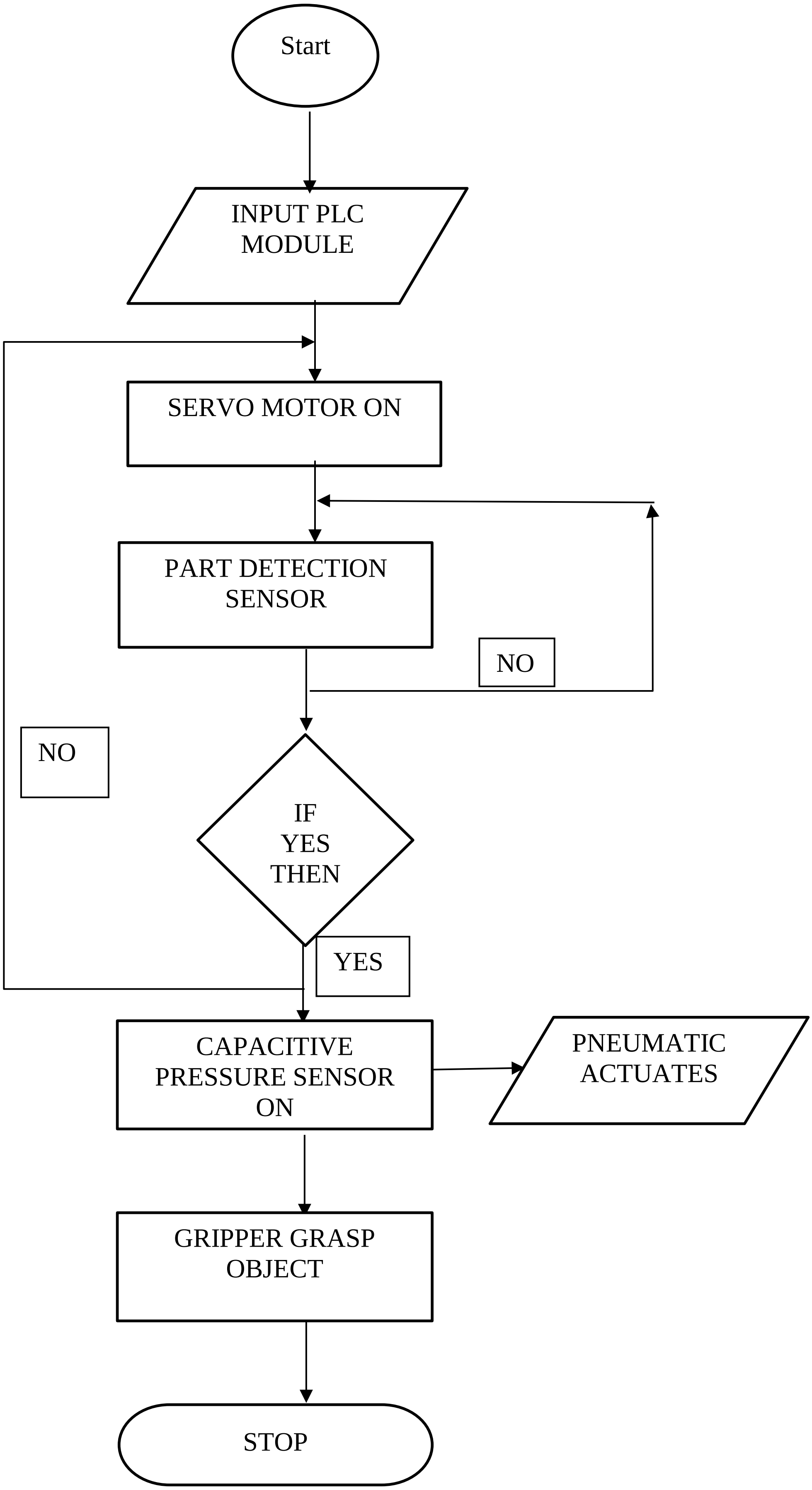


Figure 6.1 Process Control System of Capacitance Pressure Sensor and Gripper

Program: Ladder Logic

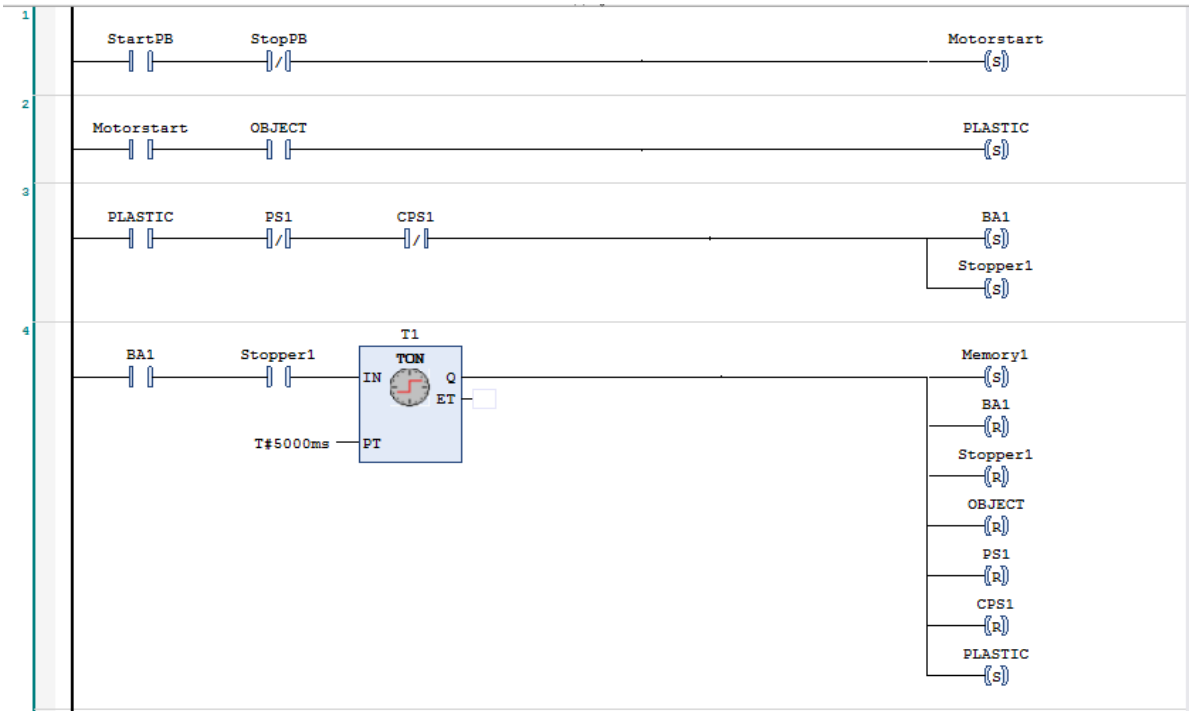


Figure 6.2(a) Ladder Logic of Gripper Control System for Motor Activation

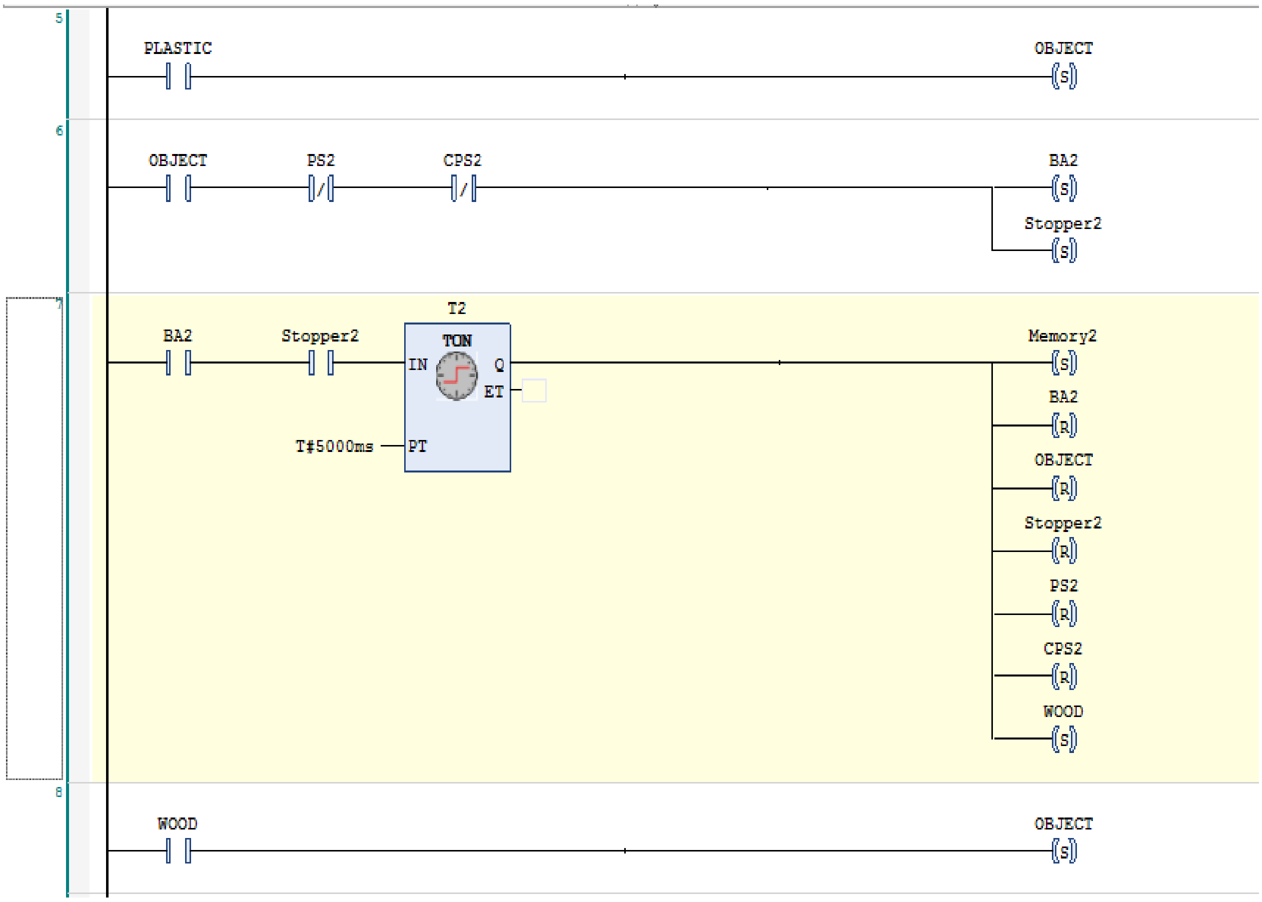


Figure 6.2(b) Ladder Logic of Gripper Control System for Sensor

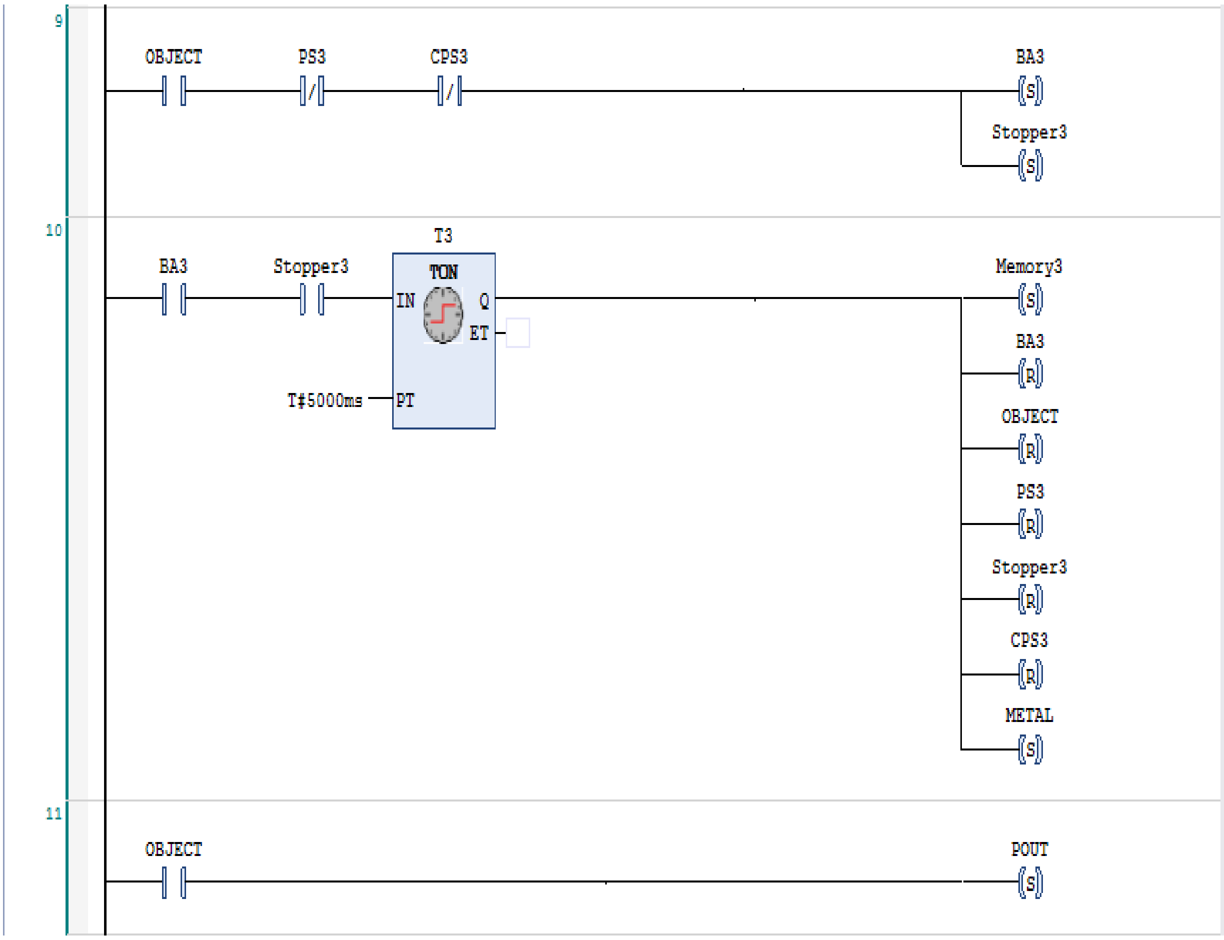


Figure 6.2(c) Ladder Logic of Gripper Control System for Capacitive Pressure Sensor

In figure 6.2 (a) the detailed ladder logic structure is made using TWINCAT software. We are using normally open contact, normally close contact, set coils, reset coils, memory coils, timers and the output coils, there is an emergency stop button and the indication lamps for knowing the work process, the process will be carried out in both step by step cycle or loop cycle according to the material been placed on the assembly process. The timer sends the information to the sensors and motor for how long the process should take to complete the task. And the set coil will assign the values for sensor to calculate the pressure from sensor and reset coil will shifts the data to the next object. The memory coils works like an accumulate where it stores each and every single work process for the future references of programming like changing the input values. And the PLC can have n number of inputs and n number of outputs as per the requirement.

7. CONCLUSION

1. The research carried out on designing a two-jaw parallel gripper was done using SolidWorks the appropriate measurements have been considered and drawn. And achieved the final desired product.

2. The simulation of the grippers end effector by applying pressure and force was made, where the pressures output like stress, strain and displacement were calculated. The grippers holding capacity of external load was simulated and found that the gripper material should be selected properly for holding more load and the change in displacement will be reduced. There was a change in displacement of gripper when there was more external load on the end effector, which may have chances to damage the grippers connecting shaft.

3. The selection of sensor was a major task to implement in the gripper with a Capacitive Pressure Sensor (MEMS) of size 700 microns and this sensor plays a vital role of calculating and controlling the pressure when the object is being grasped from the assembly process.

4. The simulation part of MEMS to find out the displacement and change in capacitance was made with required parameters, the analysis concludes that the proposed comb drive type pressure sensor is best suited for pressure measurement as it is inert to temperature change and its sensitivity is 120 aF/kPa which is increased compared to parallel plate whose sensitivity is 85 aF/kPa.

5. The control part for the gripper is made using PLC where the control flow is easier and each movement and the actuation of sensors is been recorded as data bits and stores the value of number of times of gripper movement and sensors data.

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9. APPENDIX

A-1. Axe 1 solid works drawing worksheet

A-2. Axe 2 solid works drawing worksheet

A-3. Axe 3 solid works drawing worksheet

A-4 Body 1 solid works drawing worksheet

A-5 Body 2 solid works drawing worksheet

A-6 Helical Hand solid works drawing worksheet

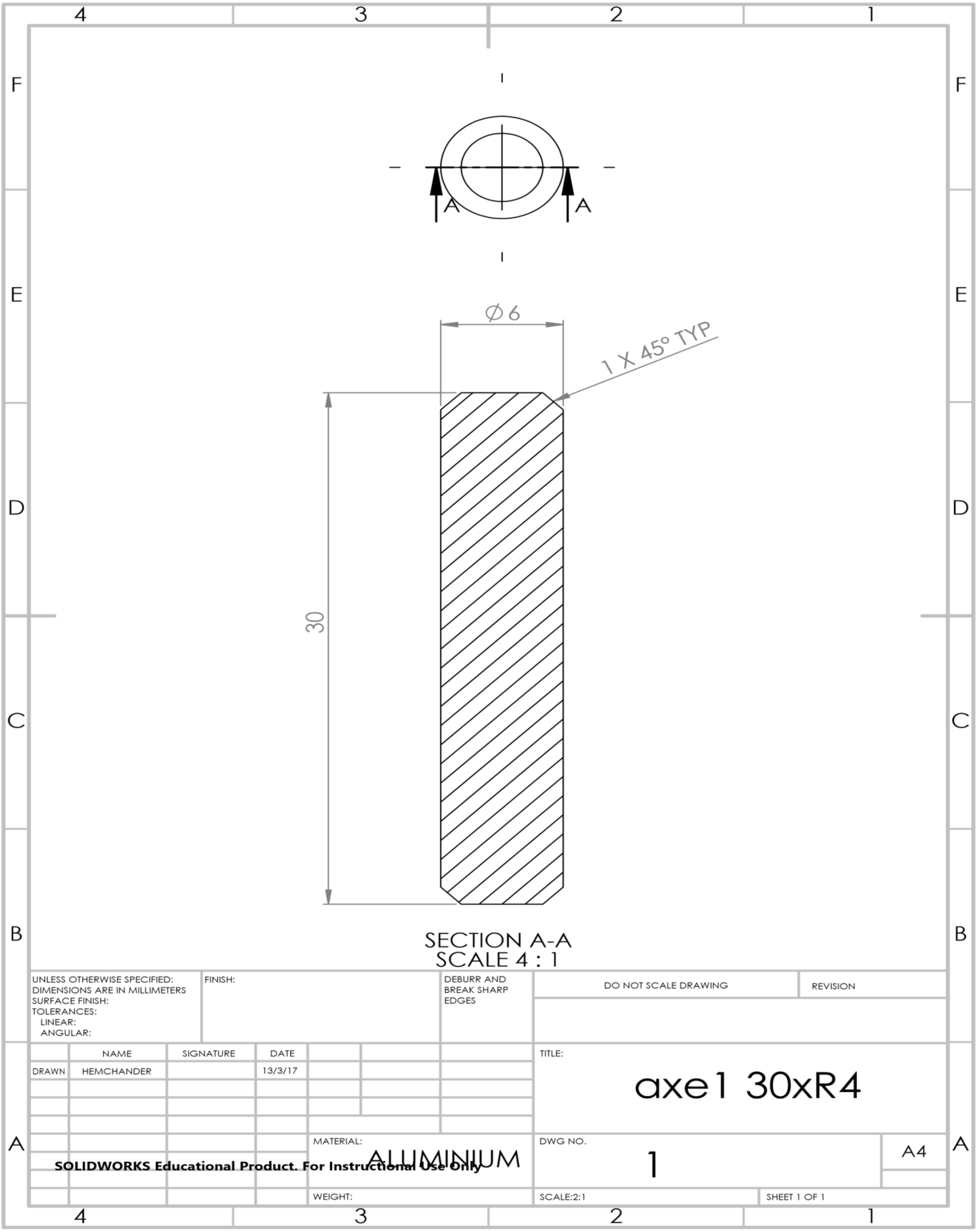
A-7 Relation1 solid works drawing worksheet

A-8 Relation2 solid works drawing worksheet

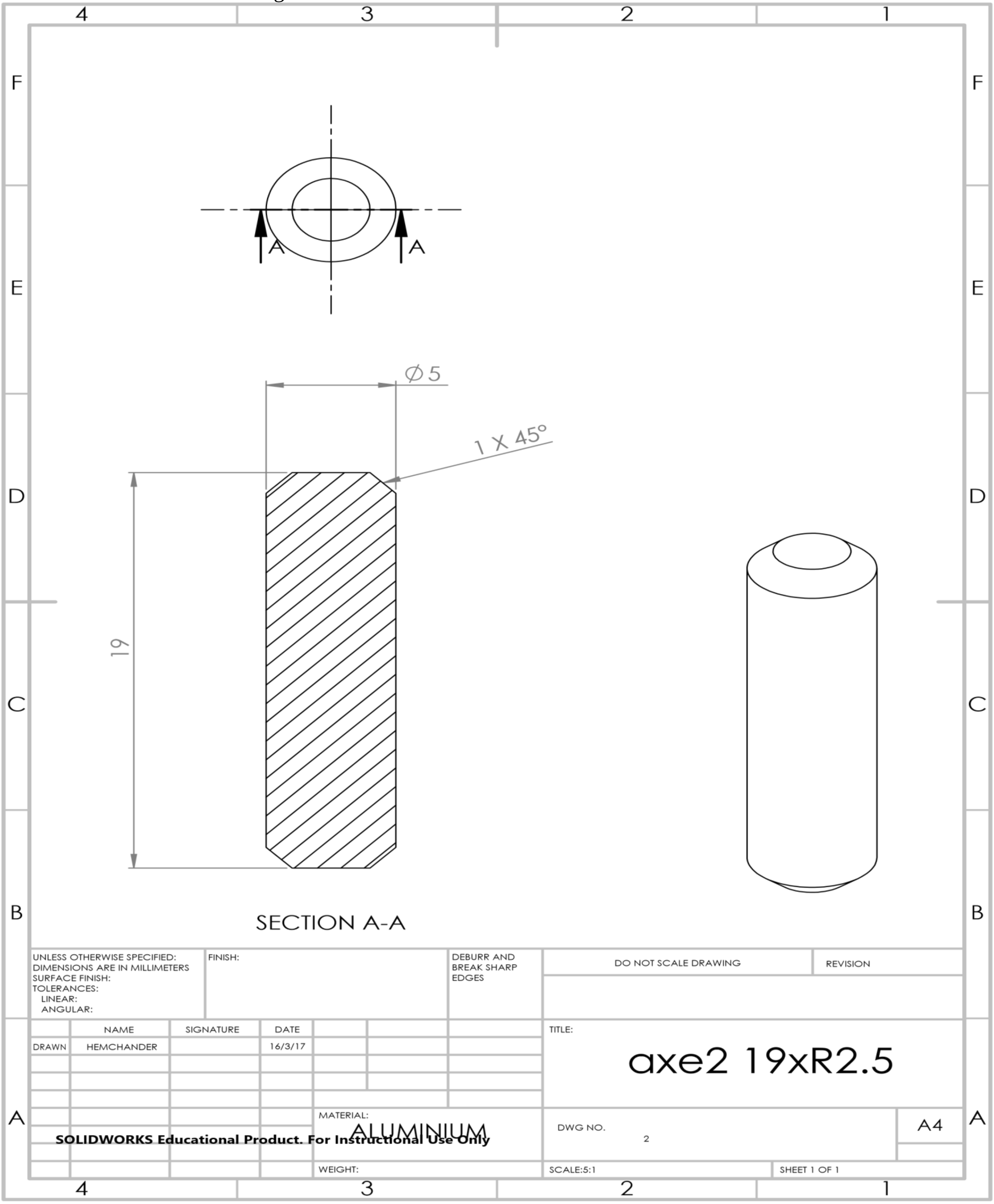
A-9 Connecting Shaft solid works drawing worksheet

A-10 PLC program of gripper actuation by capacitive pressure sensor

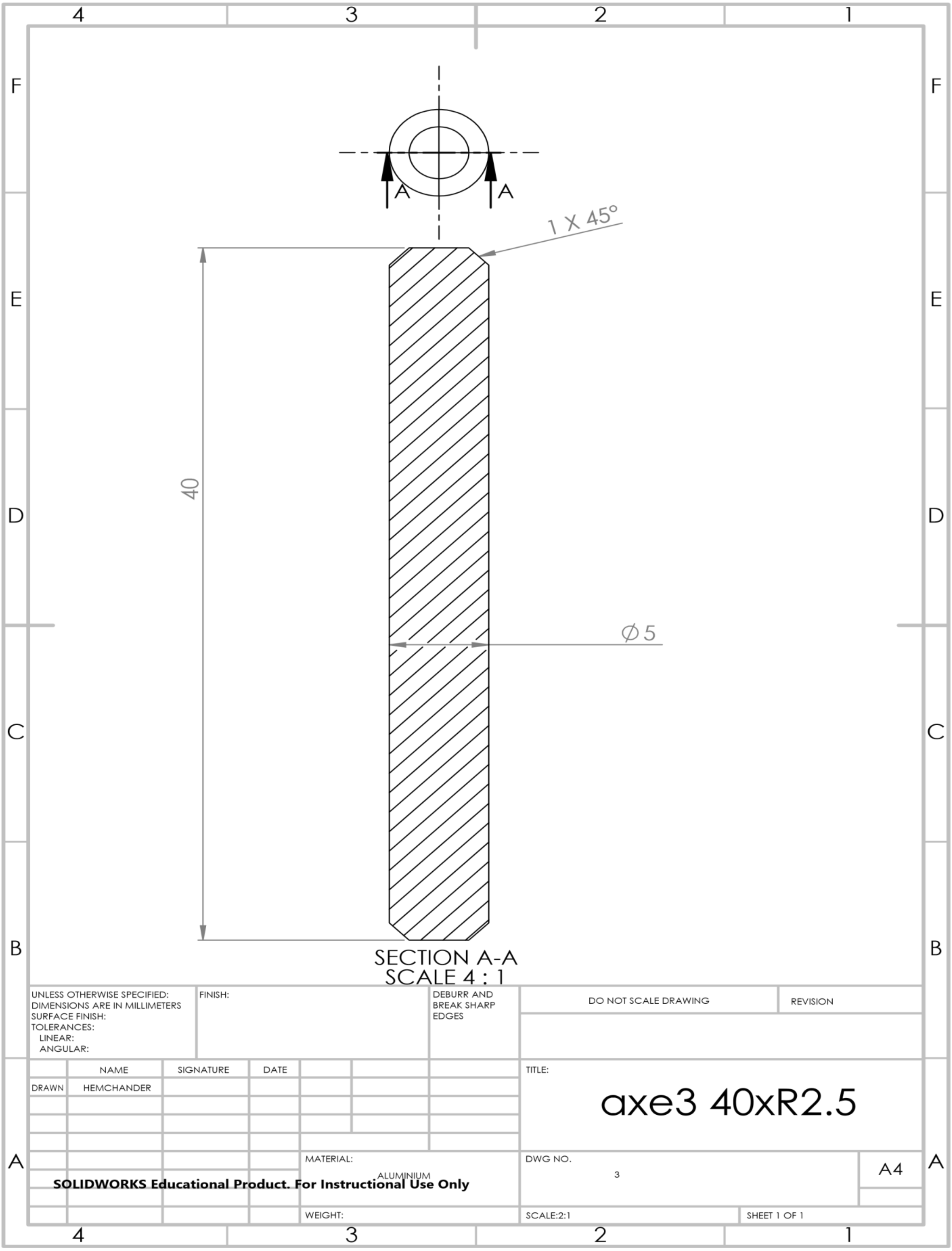
A-1. Axe 1 solid works drawing worksheet



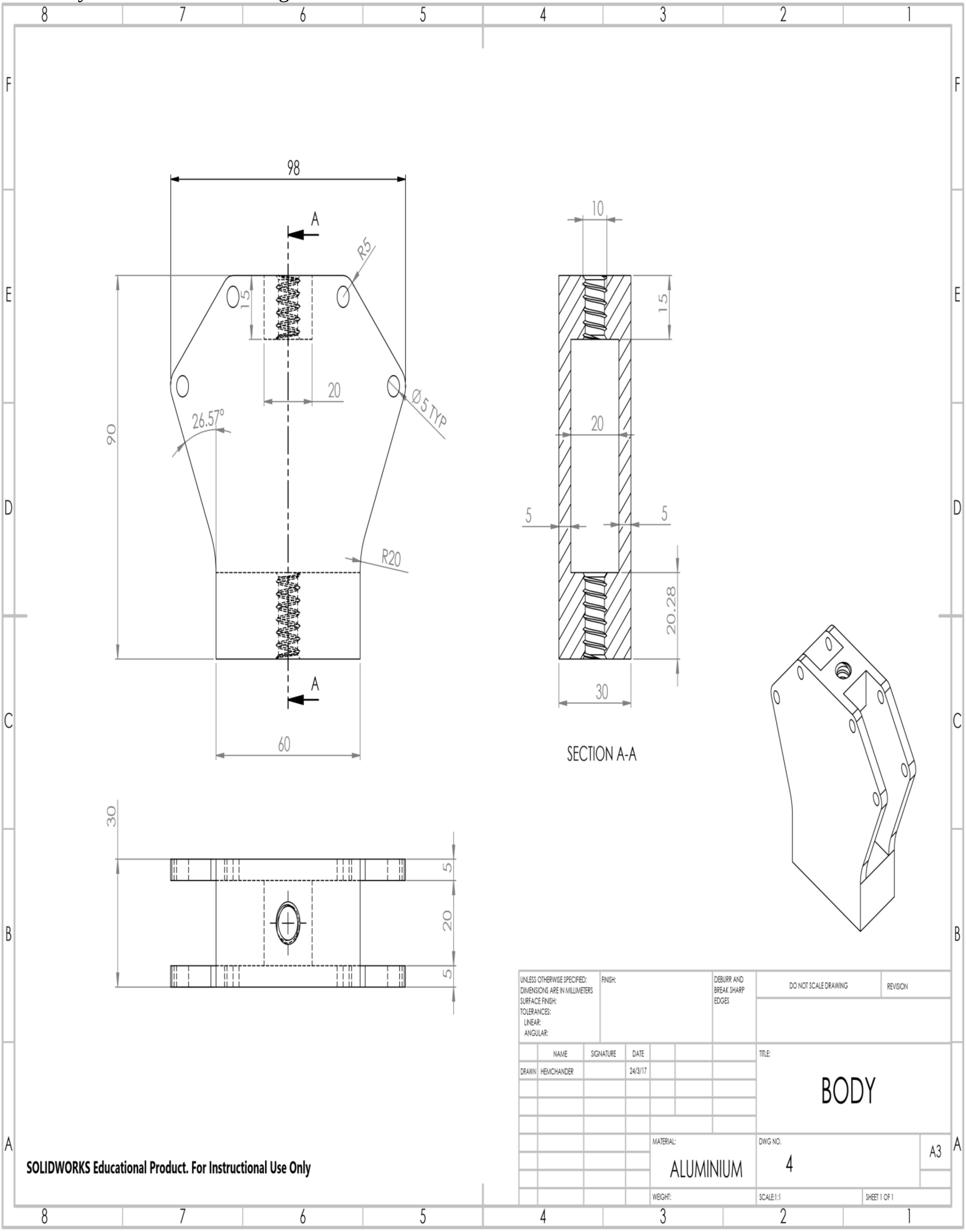
A-2. Axe 2 solid works drawing worksheet



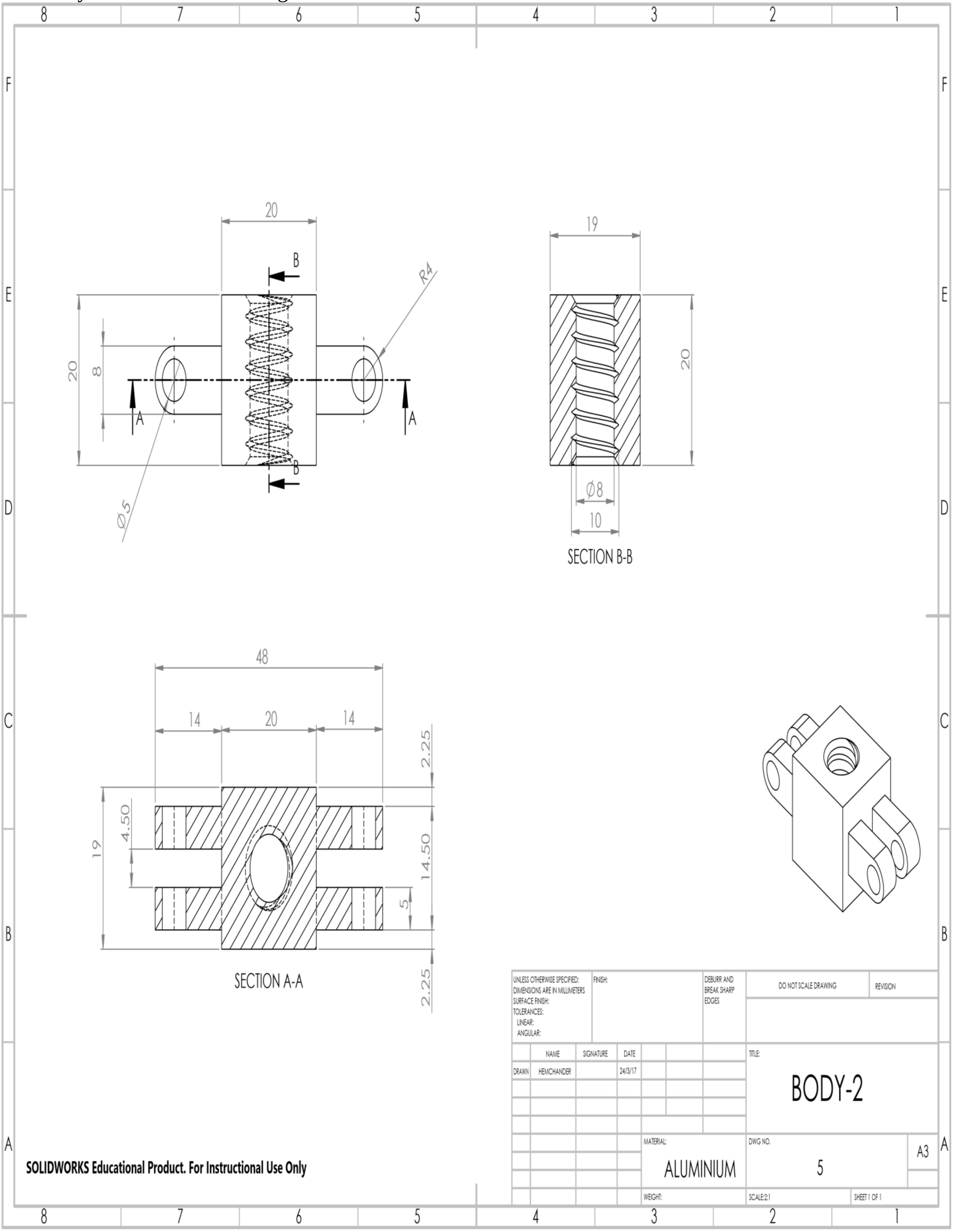
A-3. Axe 3 solid works drawing worksheet



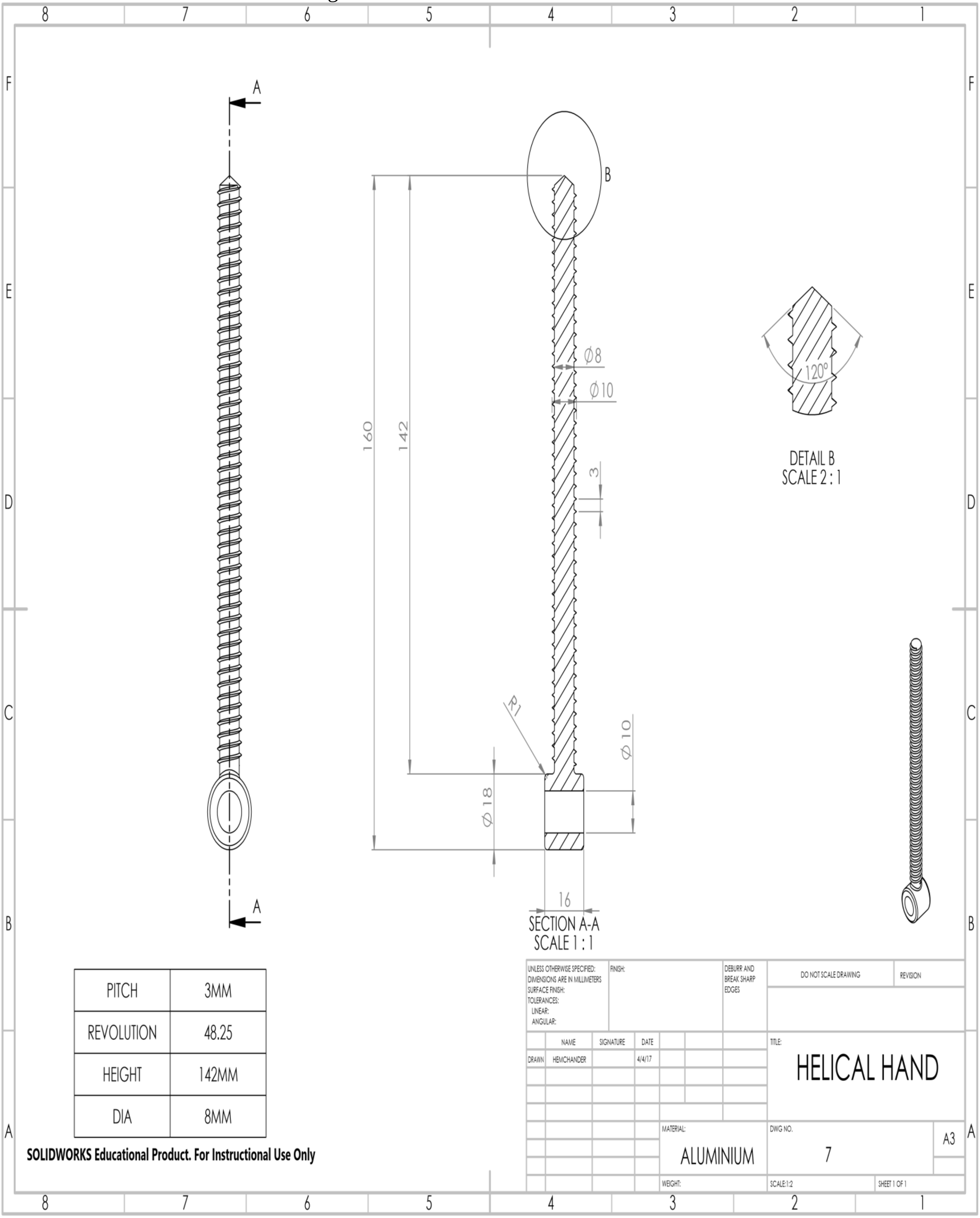
A-4 Body 1 solid works drawing worksheet



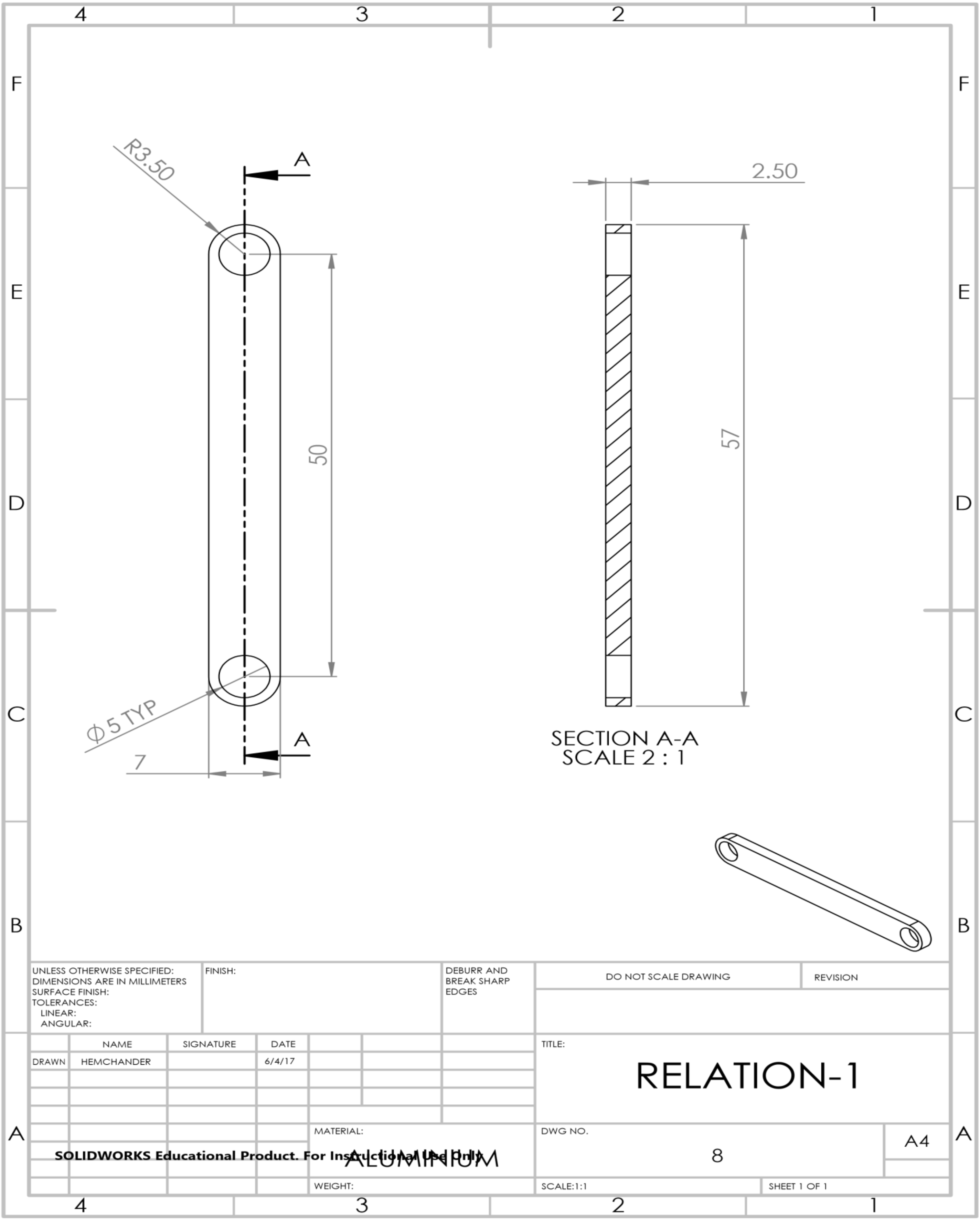
A-5 Body 2 solid works drawing worksheet



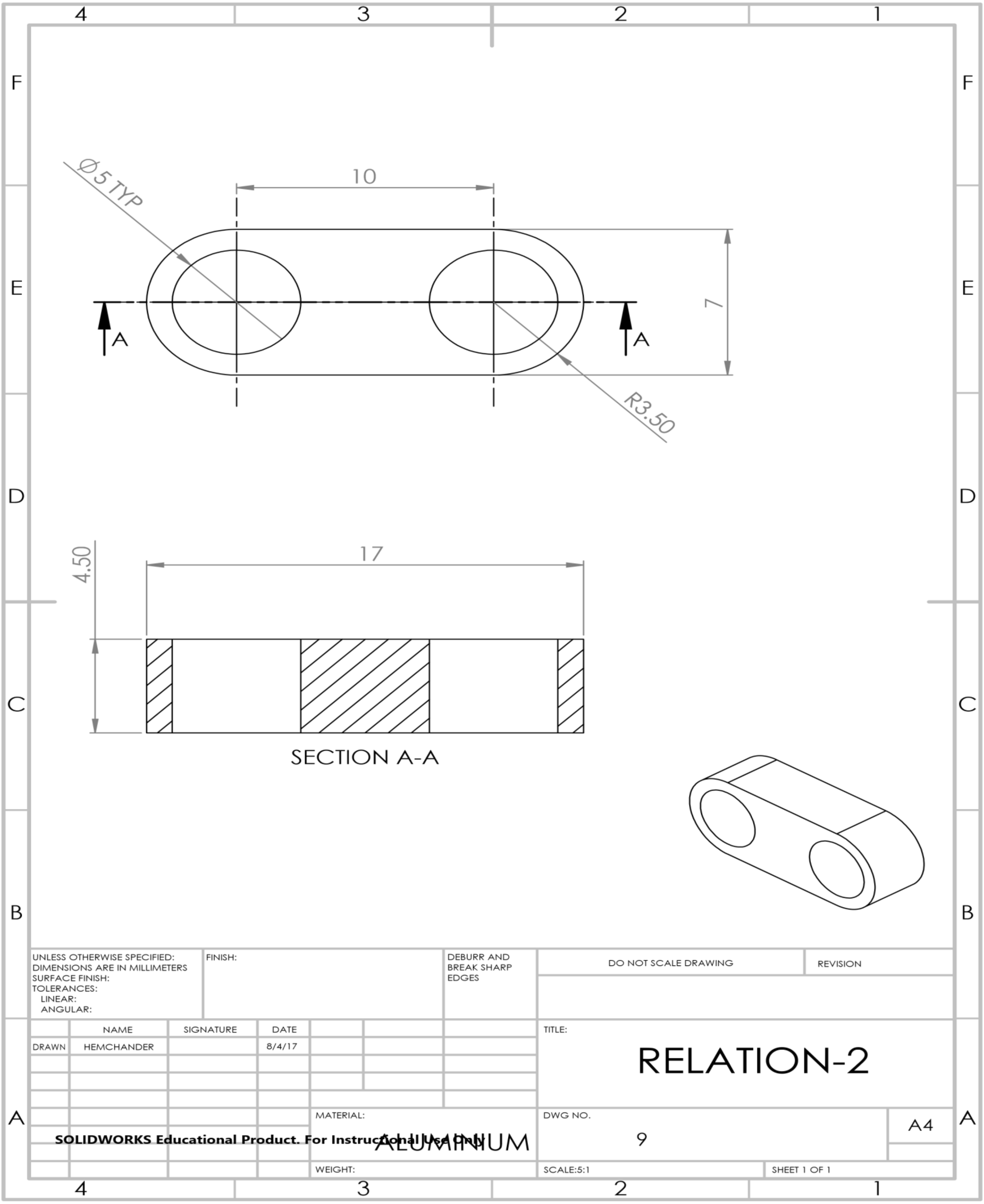
A-6 Helical Hand solid works drawing worksheet



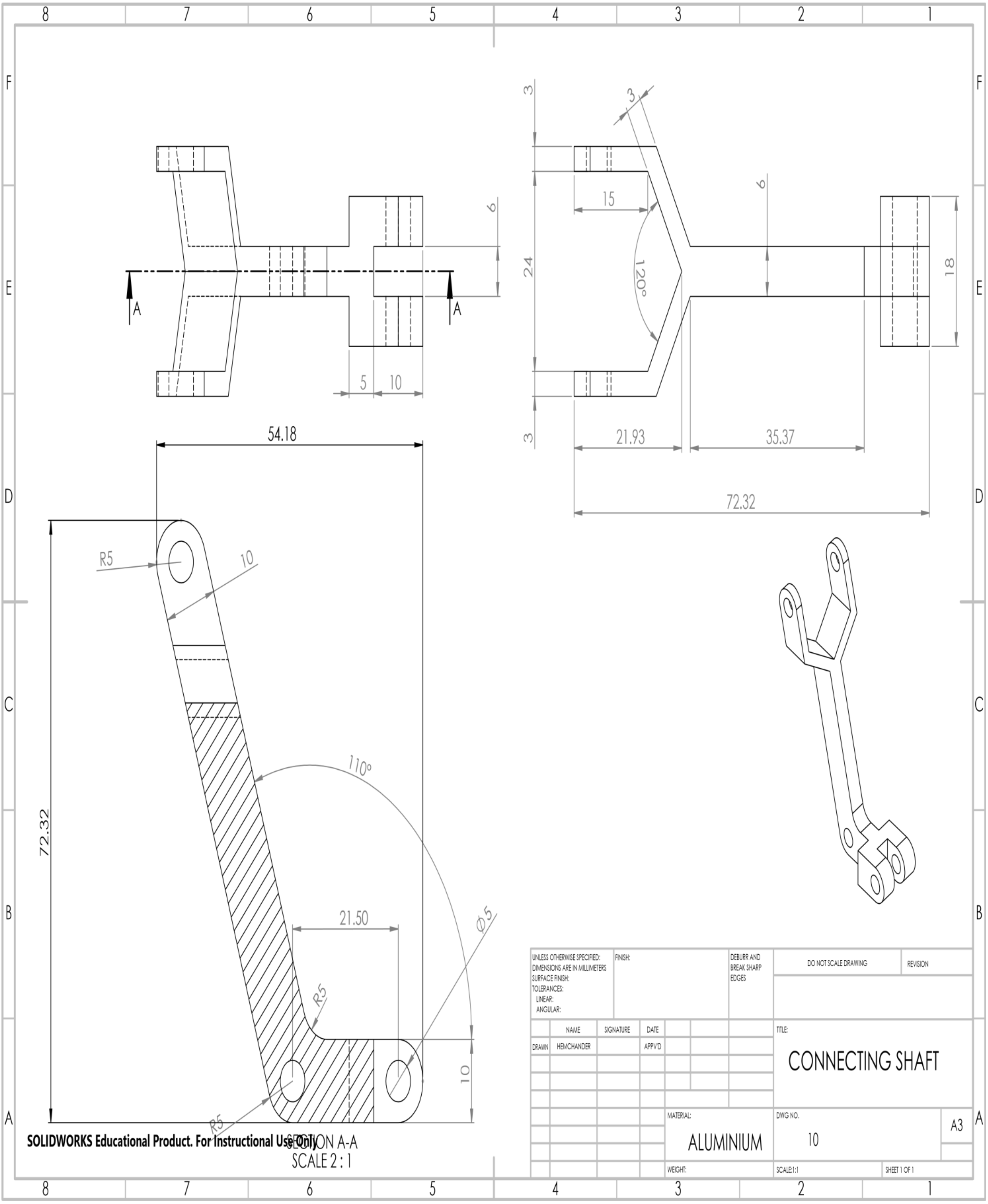
A-7 Relation1 solid works drawing worksheet



A-8 Relation2 solid works drawing worksheet



A-9 Connecting Shaft solid works drawing worksheet



A-10 PLC PROGRAM OF GRIPPER ACTUATION BY CAPACITIVE PRESSURE SENSOR

```
VAR
    StartPB: BOOL;
    EmergencyStop: BOOL;
    Motorstart: BOOL;
    OBJECT: BOOL;
    WS1: BOOL;
    PS1: BOOL;
    CPS1: BOOL;
    BA1: BOOL;
    Stopper1: BOOL;
    T1: TON;
    Memory1: BOOL;
    PLASTIC: BOOL;
    WS2: BOOL;
    PS2: BOOL;
    CPS2: BOOL;
    BA2: BOOL;
    Stopper2: BOOL;
    T2: TON;
    Memory2: BOOL;
    INT5: TIME;
    WOOD: BOOL;
    WS3: BOOL;
    PS3: BOOL;
    CPS3: BOOL;
    BA3: BOOL;
    Stopper3: BOOL;
    T3: TON;
    Memory3: BOOL;
    METAL: BOOL;
    POUT: BOOL;
    StopPB: BOOL;
```