MONITOR ARM DESIGN FOR SIEMENS CIOS SELECT WITH FD

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF

MASTER OF TECHNOLOGY

IN

COMPUTATIONAL DESIGN (CDN)

SUBMITTED BY

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M.Tech (Computational Design) [Prashant Kundnani] 2019

STUDENT'S DECLARATION

I, Prashant Kundnani, Roll No(s). 2k17/CDN/03 student of M.Tech (Computational Design), hereby declare that the thesis entitled "**MONITOR ARM DESIGN FOR SIEMENS CIOS SELECT WITH FD**" which is submitted by me to the Department of Mechanical Engineering, Delhi Technological university, Delhi in partial fulfillment of the requirement for the award of the degree of Master Of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma Associateship, Fellowship or other similar title or recognition.

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CERTIFICATE

I hereby certify that the Dissertation entitled "**Monitor arm design for Siemens Cios Select with FD**" which is submitted by Prashant Kundnani, Roll No. 2k17/CDN/03 Mechanical Engineering Department, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree Of Master of Technology, is a record of the project work carried out by the students under my supervision. To the best of my knowledge this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.

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Professor
(Project Mentor)

Ms. Shamlin Sunny
External Guide
SHPL

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PRASHANT KUNDNANI

M. Tech (Computational Design)

2K17/CDN/03

ABSTRACT

Automation in healthcare, which reduces the effort. This project main aim is to reduce the unnecessary workflow, problem and efforts made by the doctors and technicians performing any operation. Currently Siemens Cios Select with FD has separate system of C arm and monitor trolley and there is a need to integrate both the system which will reduce the problem faced by the technicians during procedure. To integrate these two system a monitor arm is designed which is mounted on the C arm. To know the need monitor arm market analysis and research was performed. This project show the design of monitor arm using Solidworks, Structural analysis using ANSYS and kinematic analysis in MATLAB.

Keywords:

ANSYS, Solidworks, Gas spring, MATLAB.

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DH	denavit hartenberg
FEM	Finite element method
FD	Flat detector
DOF	Degree of freedom
F	Load
θ	Theta (Angle)
R	Radius
m	Metre
N	Newton
MPa	Mega Pascal
s	Second
mm	Milli Metre
KN	Kilo Newton
µ	Poisson’s Ratio
K	Stiffness
E	Young’s Modulus of Elasticit

CHAPTER 1
INTRODUCTION

1.1 Project Background:

Procedure performed in Cath Lab:

Cath lab is a laboratory where the angiogram procedures are performed, angiograms are of different types for example Coronary angiogram, renal angiogram, pulmonary angiogram etc. these procedure are basically imaging techniques using X-rays, in these angiograms catheter is used which is inserted inside the body of the patient and through which the contrast agent is supplied into the body. In coronary angiogram the catheter is inserted from wrist and is used to visualize the blockage in the arteries of heart. When the contrast agent from the catheter passes through the arteries it gives the image of the blockage with the help of x-ray images. Contrast agent absorb the x-ray and give the continuous live images in the screen. For this X ray generation C arm machine is used, which has a bed which can be moved according to the type of angiogram and patient's comfort. C arm consist of source and detector on the ends. On the back of the C arm generator is used for the supply of energy to the source.

The live X-ray images generated are displayed using the monitors, where the reference image of the angiogram and the current image of the angiogram is shown. This monitor system consist of central processing units and software for the clear images of the X-ray. These images are basically DICOM images which is only used for medical purpose and have high resolution.

Effectiveness of C arm:

- Images qualities provided by the C arm machine are high.
- The flexibility of the table in which patient is treated is more.
- Rotation of the C arm give the image at different angle which helps to visualize the problem easily.
- Software such as Syngo which gives high resolution in the monitor and have different features like 3D reconstruction and overlaying the live image on reference image.
- The radiation dosage are really less compared to other procedures.

Cios Select with FD Product design for Monitor Arm

The current surgery C arm has been featured with one separated monitor trolley resulting in inconvenience due to many cables. A new Surgery C Arm has been planned in the next product upgrade and the monitor trolley will be integrated into the C arm main frame resulting in a more compact system. Therefore, the goal of the project is to develop new ideas & concepts for the C arm Monitor Arm.

Fig 1.1: Siemens Cios Select with FD

Source: Siemens Intranet

1.2 Observation Phase:

The observation phase include the analysis done during the hospital visits in which we interviewed different technicians and doctors of Cath lab about and we got to know the problems they were facing during the procedure or operation.

In fig 1.2 as we can see the lamps on the ceiling which are approximately 2m high causes obstruction in the sight of the screen.

Fig 1.2: Obstruction because of lamp

Source: Siemens Intranet

We observed that the surgeon as to turn back to see monitor and he has limited space to move. He wear heavy radiation protective vest. Shown in fig 1.3.

Fig 1.3: Technician has turn and see the monitor

Source: Siemens Intranet

In fig. 4 it is shown the space in the Cath lab which is very less and technician gets uncomfortable during the procedure.

Fig 1.4: Space in the lab (Source: Siemens Intranet)

There are lot of obstruction during the procedure on the monitor sight as technician has to move monitor trolley to see the images which increases the unnecessary workflow. As we can see in fig 4 the obstruction while coordinating the ongoing procedure and monitoring.

Fig 1.4: Obstruction in ongoing procedure

Source: Siemens Intranet

1.3 Synthesis and objective:

The outcome of these observation showed that during the procedure surgeon should not have any obstruction in the line of sight of the monitor and should not include unnecessary steps. And there is a need to design a feasible workflow by integrating the monitor system and C arm. To do that a monitor arm is designed which will be mounted behind the C arm with specific degree of freedom so that technicians or doctors can easily reach the monitor arm and place it according to the comfortable line of sight.

Following are the findings of the observation:

1. Monitor has to visible from position where surgeon stays on site of C-Arm.
2. Monitor has to be big enough or two monitors
3. Should not make obstacles to the light on the ceiling and trolleys on the floor.

4. Easily operated with one hand by C-Arm operator.

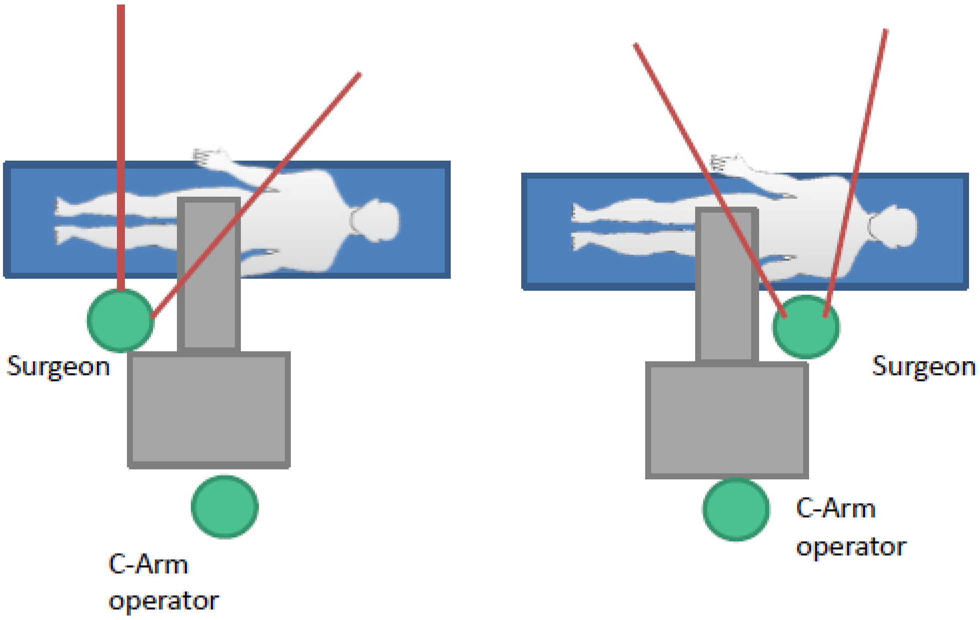

Fig 1.5: Line of sight of technician in lab

Source: Siemens Intranet

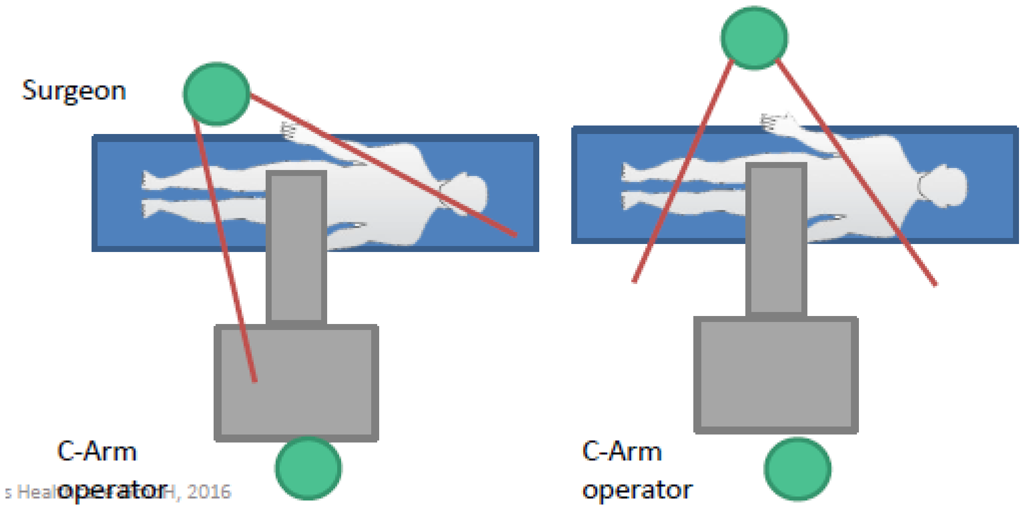

Fig 1.6: Line of sight of technician in lab from front

Source: Siemens Intranet

1.4 Dimension of C arm and required monitor arm:

Below figure shows the dimension of C arm and the monitor arm when it will be mounted above it

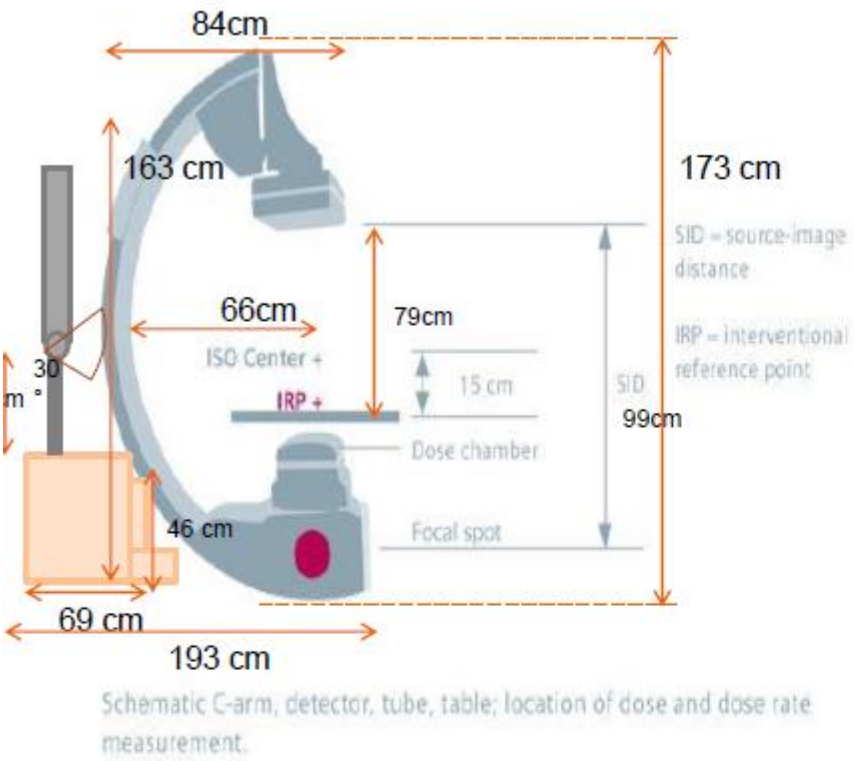

Fig 1.7: Dimension of C arm

Source: Siemens Intranet

Monitor dimensions

Monitor Cart Length = 69 cm

Height = 163 cm

Depth = 69 cm

C arm dimensions

Main C-arm Frame Length = 193 cm

Height = 173 cm

Depth = 84 cm

SID = 99 cm

Free space in Arc = 79 cm

Depth of Arc = 66 cm

Vertical travel = 46 cm

Free Space = 13.8"

Dimensions Bed:-Overall: 97" l x 26" w (246 x 66 cm) with OR accessory rails-Tabletop: 97" l x 24" w (246 x 61 cm) –choice of classic contoured or rectangular design

Radiolucent Area: 75" l x 24" w (191 x 61 cm)

Tabletop Material: Carbon Fiber with integral head section

Mattress: Seamless, 2" thick (5 cm)

Attenuation: 1.2 mm Aluminum equivalence

Motions:-Height: Adjustable from 32" to 42" (81 to 106 cm)-Tabletop X Motion (head-to-toe float): 35" (89 cm)-Tabletop Y Motion (side-to-side float): 10" (25.4 cm)

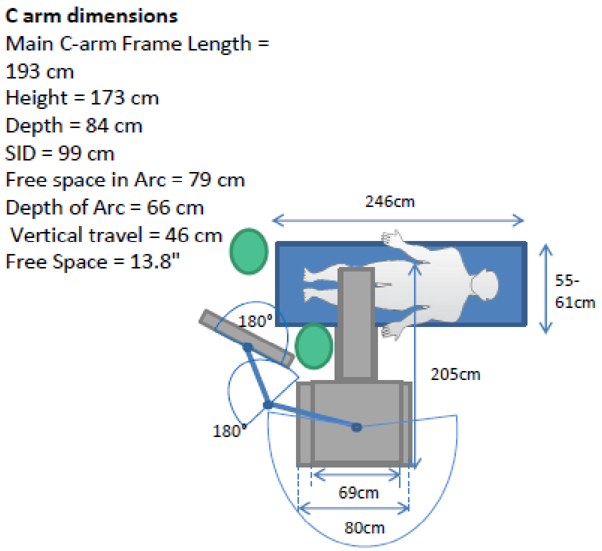

Fig 1.8: Top view of C arm

Source: Siemens Intranet

1.5 Market Research:

Market research showed different companies who were providing solutions for the current problem, as there were different cons about the solution which technicians did not require.

Below are the demerit of the different solutions provided by different companies:

- Not clear where is the transport position. User has to Stretch out full height, rise up hand to move monitor.

- No handle bars on monitors. No possibility to lower, raise monitor.
- Not enough degrees of freedom.
- No vertical adjustment.
- Construction not rigid.

1.6 Ideation:

Types of Joints

Types of joints used mostly in the arrangement of monitor display:

•RotationalJoint

•TwistingJoint

•RevolvingJoint

•Combination of these joints enables us to reach the desired output of the monitor arm

Basic requirement for the gas spring monitor arm

Net weight	Less than 8 kg
Monitor size support	27”
Support weight monitor	More than 11 kg
Swivel	At least +- 90 degree
Height adjustment range	More than 350 mm
Swivel (Hinge)	+- 90 degree
Tilt (Hinge)	At least 20 degree

Table 1.1: Basic Requirements for design

CHAPTER 2

LITERATURE REVIEW

Jamshed Iqbal, Raza ul Islam, and Hamza Khan Modelling and Analysis of a 6 DOF Robotic Arm Manipulator:

This paper shows the kinematic analysis of the arm. For robotic manipulators having high Degrees Of Freedom (DOF) with multiple degrees in one or more joints, an analytical solution to the inverse kinematics is probably the most important topic in robot modelling. This paper develops the kinematic models a 6 DOF robotic arm and analyses its workspace. The proposed model makes it possible to control the manipulator to achieve any reachable position and orientation in an unstructured environment. The forward kinematic model is predicated on Denavit Hartenberg (DH) parametric scheme of robot arm position placement. Given the desired position and orientation of the robot end-effector, the realized inverse kinematics model provides the required corresponding joint angles. The forward kinematic model has been validated using Robotics Toolbox for MATLAB while the inverse kinematic model has been implemented on a real robotic arm. Experimental results demonstrate that using the developed model, the end-effector of robotic arm can point to the desired coordinates within precision of ±0.5cm. The approach presented in this work can also be applicable to solve the kinematics problem of other similar kinds of robot manipulators.

A.N.W.Qi, K.L.Voon, M.A.Ismail, N.Mustaffa, M.H.Ismail Design and Development of a Mechanism of Robotic Arm for Lifting:

The main focus of this project was to design and develop the mechanism for robotic arm for lifting. The robotic arm was designed with four degrees of freedom and programmed to accomplish accurately simple light material lifting task to assist in the production line in any industry. 3D printing method is used in this project to fabricate the components of the robotic arm. Therefore, it provided more precise dimensions and huge time and cost-saving in fabrication. The robotic arm is equipped with 4 servo motors to link the parts and bring arm movement. Arduino, an open-source computer hardware and software is applied to control the robotic arm by driving servo motors to be capable to modify the position. Wireless control was done by using a smart phone with android operating system through a Bluetooth module. The robotic arm was under testing and validating its performance and the results indicates that it can perform the lifting task properly.

K llangovan S. Krishna Kumar N Krishnakumar Optimization of drafting door using Finite element method: The main objective of this project was to optimize the shape and size of the sheet metal component in drafting door assembly by applying FEA technique. Hypermesh, Radioss linear and optistruct software have been used to find out the stress, defelection to optimize its design thereby reducing its thickness to the minimum. Design modification was carried out in drafting door assembly model for the ease of manufacturing, assembly, reducing material wastage and cost saving by maintaining a uniform sheet metal of 1.5mm thick for entire assembly. Thus the conventional design of various sheet metal thickness for the existing model can be eliminated.

Peter Nordgren, Stockholm (SE): Stina Juhlin, Gustavsberg (SE); Magnus Olsson, Stockholm (SE) Monitor arm for a medical device :

This is the patent which shows the monitor arm which is used in the hospital

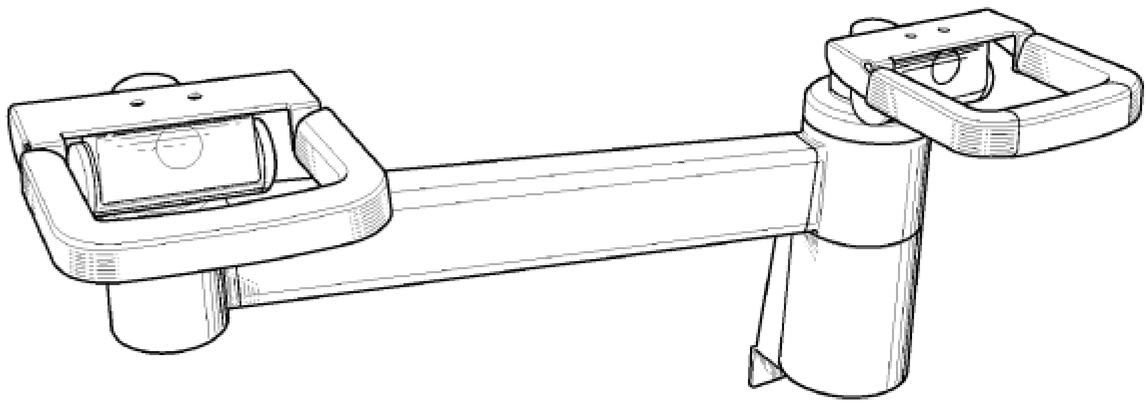

Fig 2.1: Patent for arm to carry monitor [1]

CHAPTER 3

DESIGNING OF MONITOR ARM

Design of the monitor arm's main focus is to make the technician comfortable while performing procedure, to do so the monitor arm should have appropriate degree of freedom so that the operator can move the monitor to desired position, and the dimension of the monitor arm should be like the monitor is visible to the technician and the screen is in line of sight of the technician. To mount the monitor arm it should have base which can be fixed behind C arm. The height of the monitor from the ground should be appropriate so that operator can easily see the screen and can be able to change the position of the monitor easily without stretching or getting uncomfortable.

3.1 Mechanical Design:

The end product should have good strength and lifespan. For that there should be detailed analysis of the arm's strength and capacity. It should be designed with appropriate dimensions so that the monitor arm can withstand the load.

Desired functionality: the arm should be able to lift the weight of the monitor and can be easily moved and lifted from one position to another without making lot of efforts, the number of links required depends on the degree of freedom and the position of monitor we desire. To easily lift the monitor arm without making efforts gas spring is used which is pneumatic spring.

Reliability of the product: Reliability of the product shows the life span of the product and how long it can withstand the monitor load and the movement of the monitor. So, the arm should be able to move consistently with the smooth movement of joint.

Movement: As the gas spring is used in the arm, it should have appropriate speed of the motion of the arm so no one gets hurt, the gas spring should be able to lift the weight of the monitor to the desired position

Weight: Material selection for the arm should be so that the mass of the arm is minimum and it can carry the load. The monitor weight is fixed. And the arm weight should be less so that it can be easily move from one position to another and also gas spring can bear and lift the weight of the arm and monitor.

Line of sight: The dimensions and degree of freedom of the arm should be appropriate so that monitor can be positioned to the line of sight of the technician and technician should not move or turn himself to see the monitor.

3.2 Base:

Base of the monitor arm will be mounted on the C arm so it should have dimension and design so that it can be fixed and can hold the weight of the monitor arm and monitor itself.

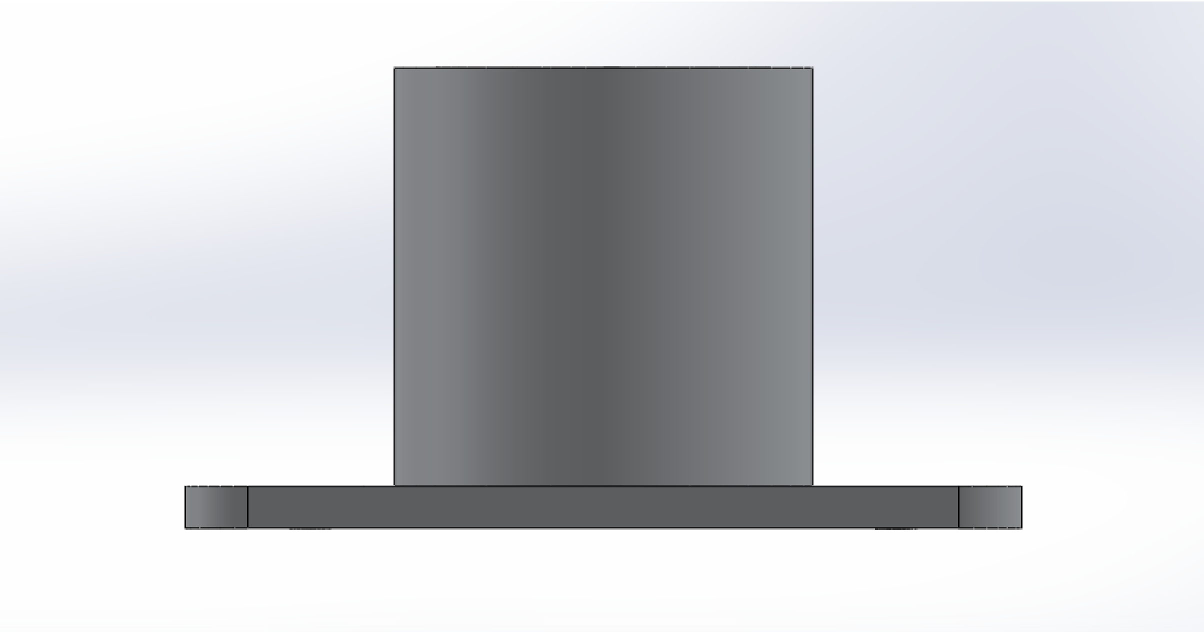

Fig 3.1: Front view base 1 (Solidworks 2015)

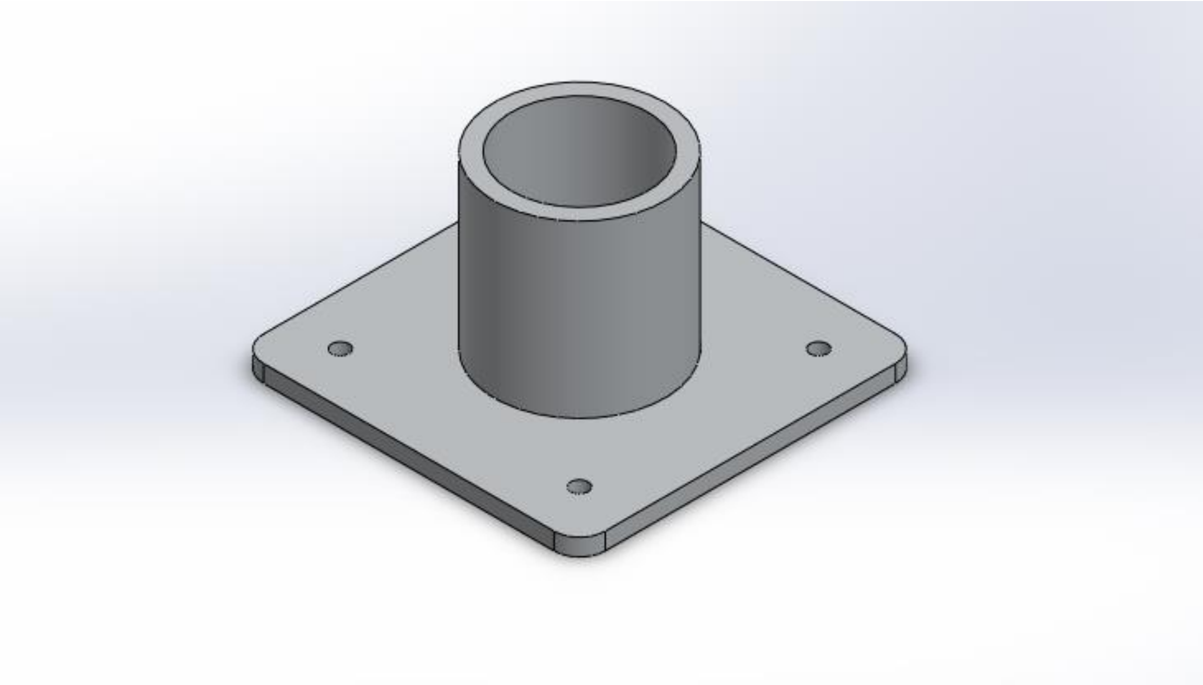

Fig 3.2: isometric view base 1 (Solidworks 2015)

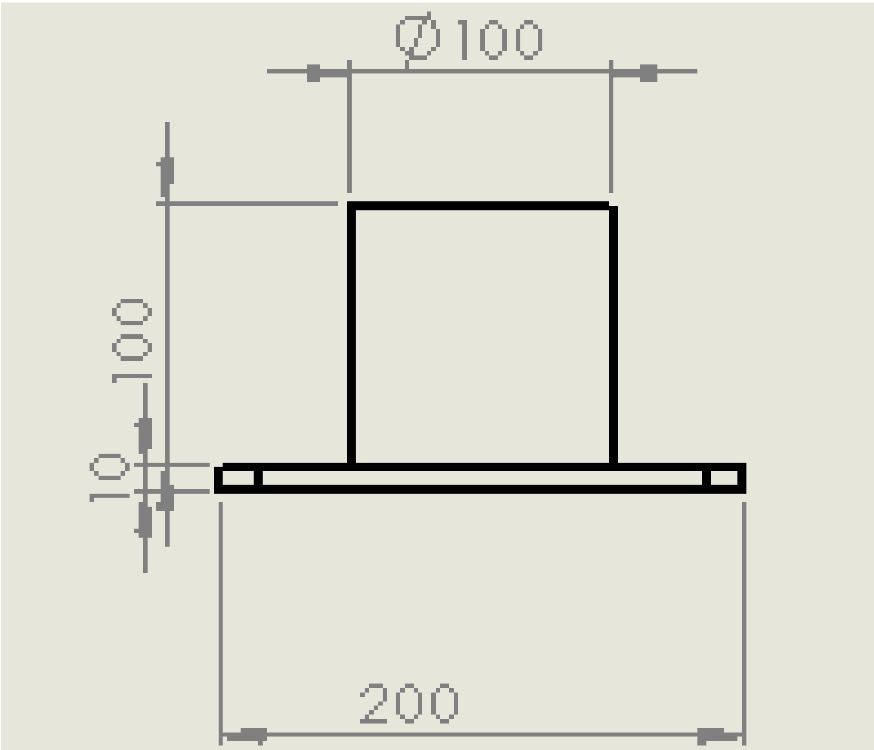

Fig 3.3: Dimensions of base 1 front view

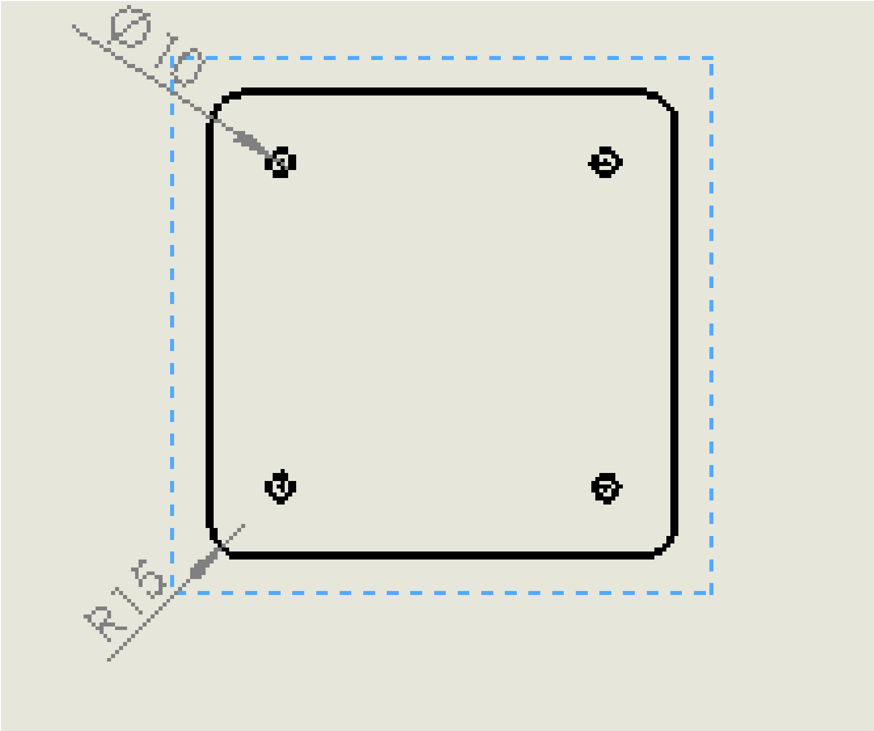

Fig 3.4: Dimension of base 1

3.3 Arm 1:

Arm one is the link which is connected to the base and base of arm 2. It's a hollow arm which provide space for the wires of the monitor which can be hidden. There are to holes in arm one through which wire goes in and out. To make arm look good and to avoid tangling of the wires which are used to give power to the monitor and for different connection these holes were made so that the wires can be hidden inside arm one.

There is a revolute joint between base and arm one which is having same axis as of base. The arm one can be rotated 360 degree n the base.

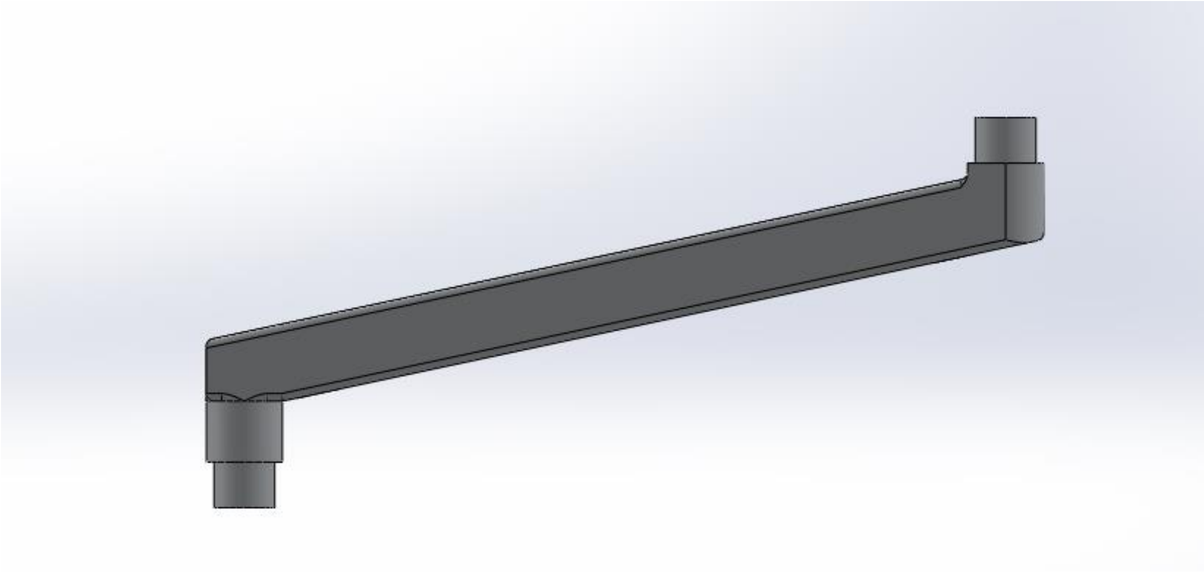

Fig 3.5: Front view arm 1 (Solidworks 2015)

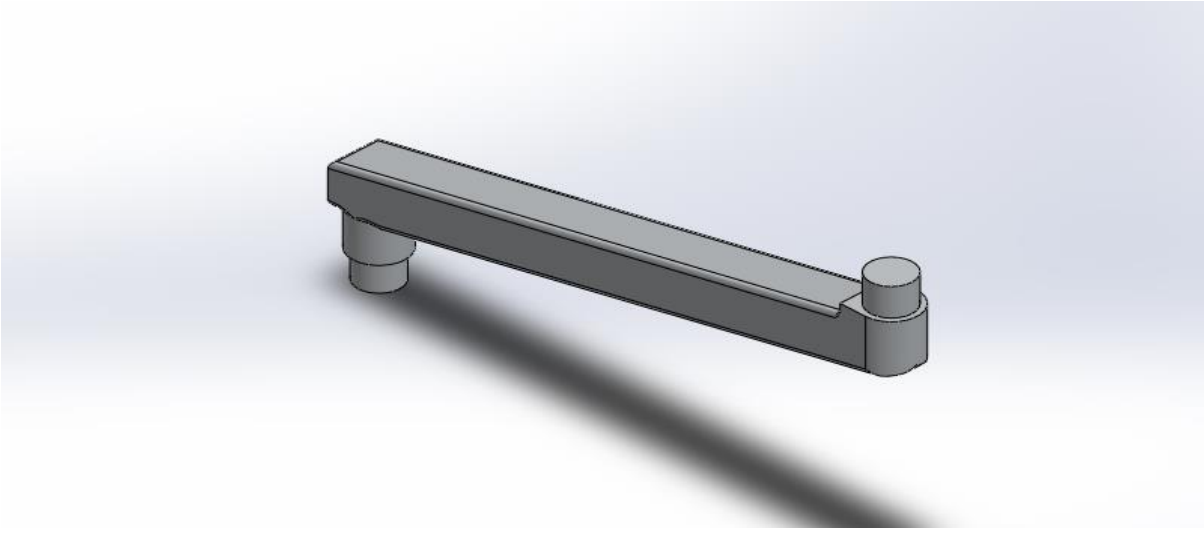

Fig 3.6: isometric view arm 1 (Solidworks 2015)

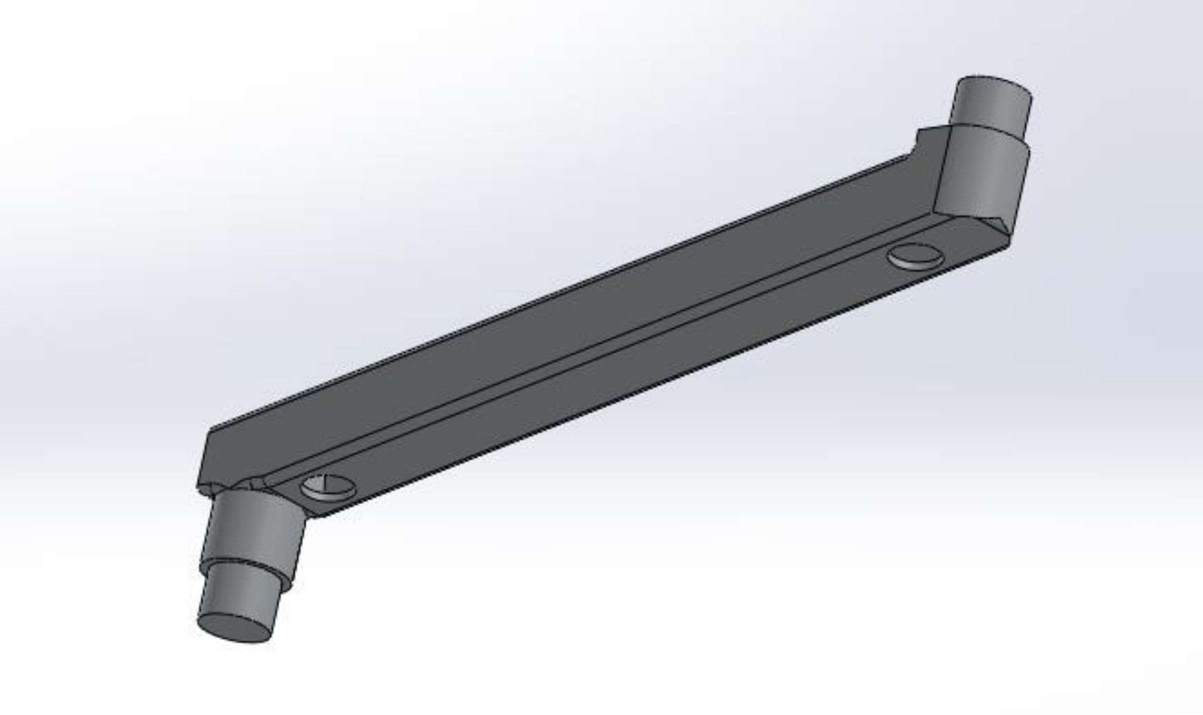

Fig 3.7: Design of arm 1 (Solidworks 2015)

Dimension of Arm 1:

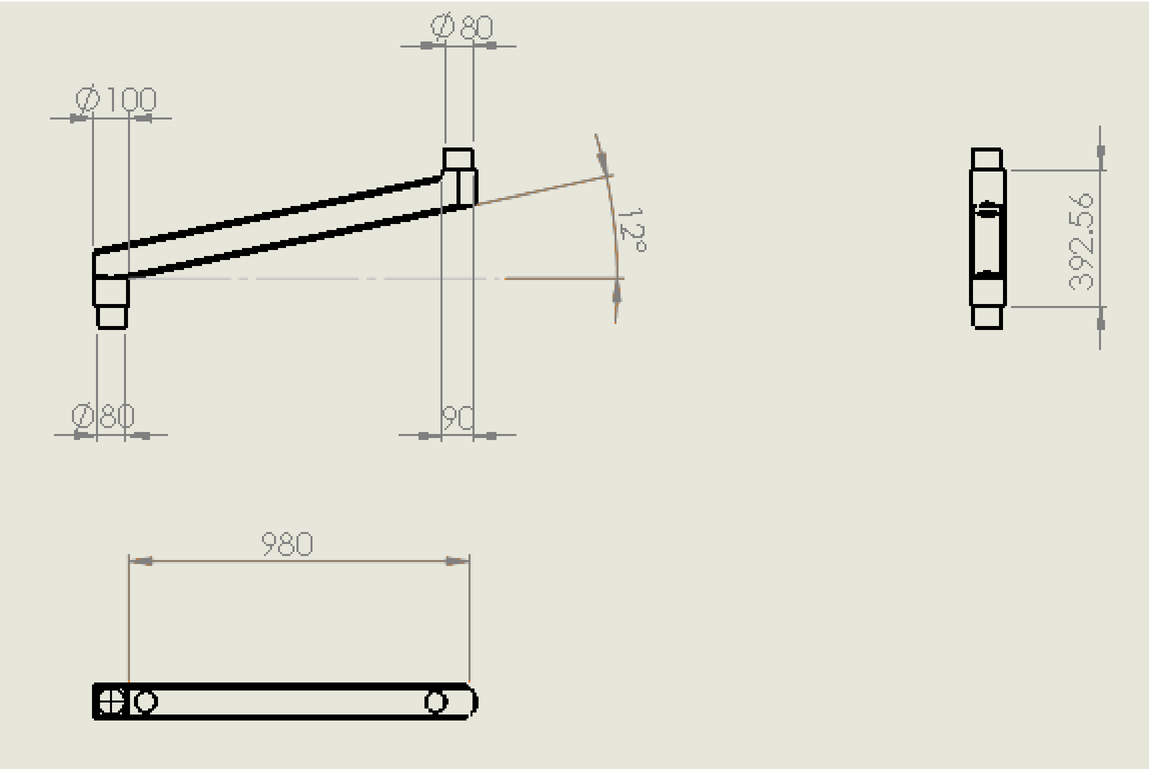

Fig 3.8: Dimension of arm 1

3.4 Base 2:

Link 3 is the part between arm one and arm two, link 3 has a revolute joints with arm 1, gas spring and arm 2.

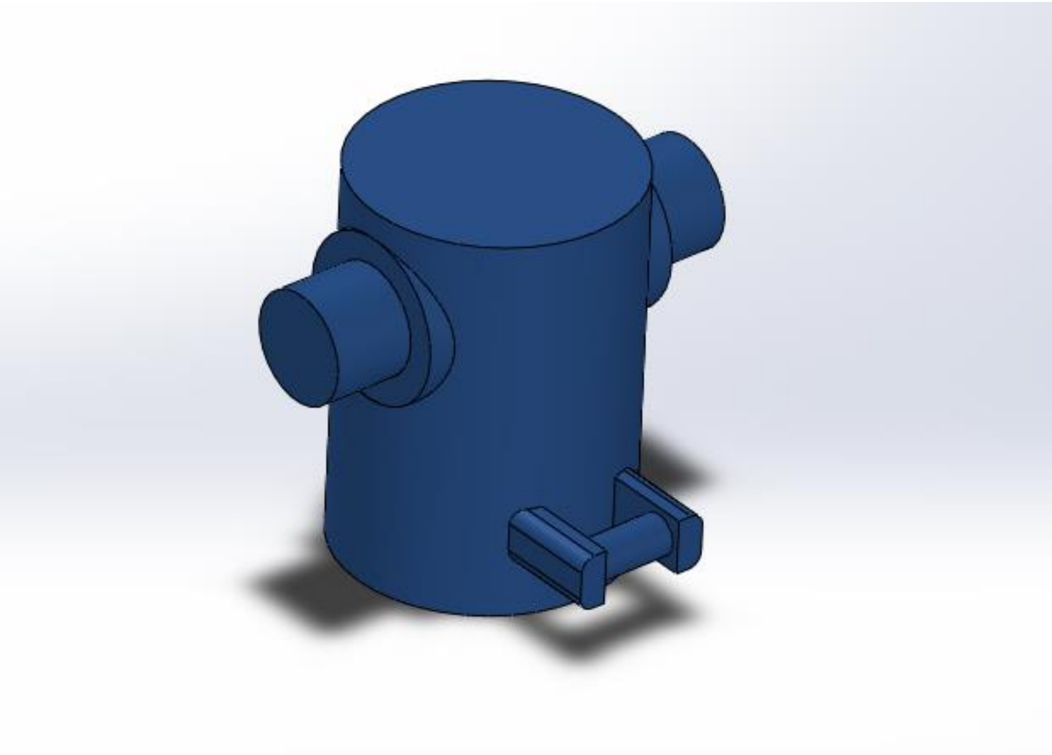

Fig 3.9: Base 2 design (Solidworks 2015)

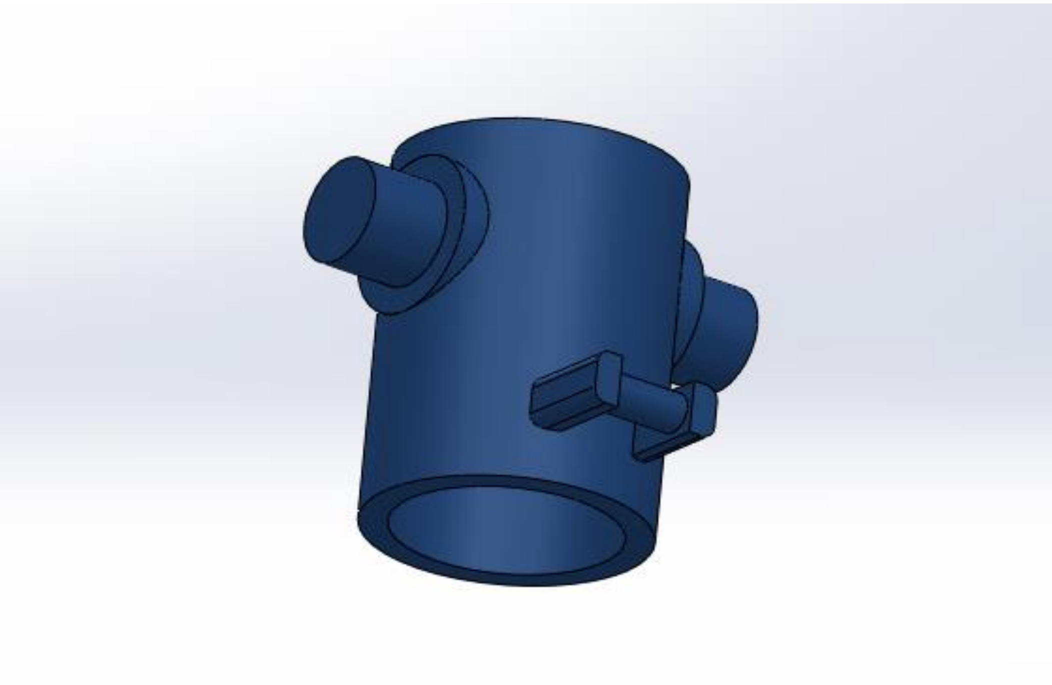

Fig 3.10: Design of base 2 (Solidworks 2015)

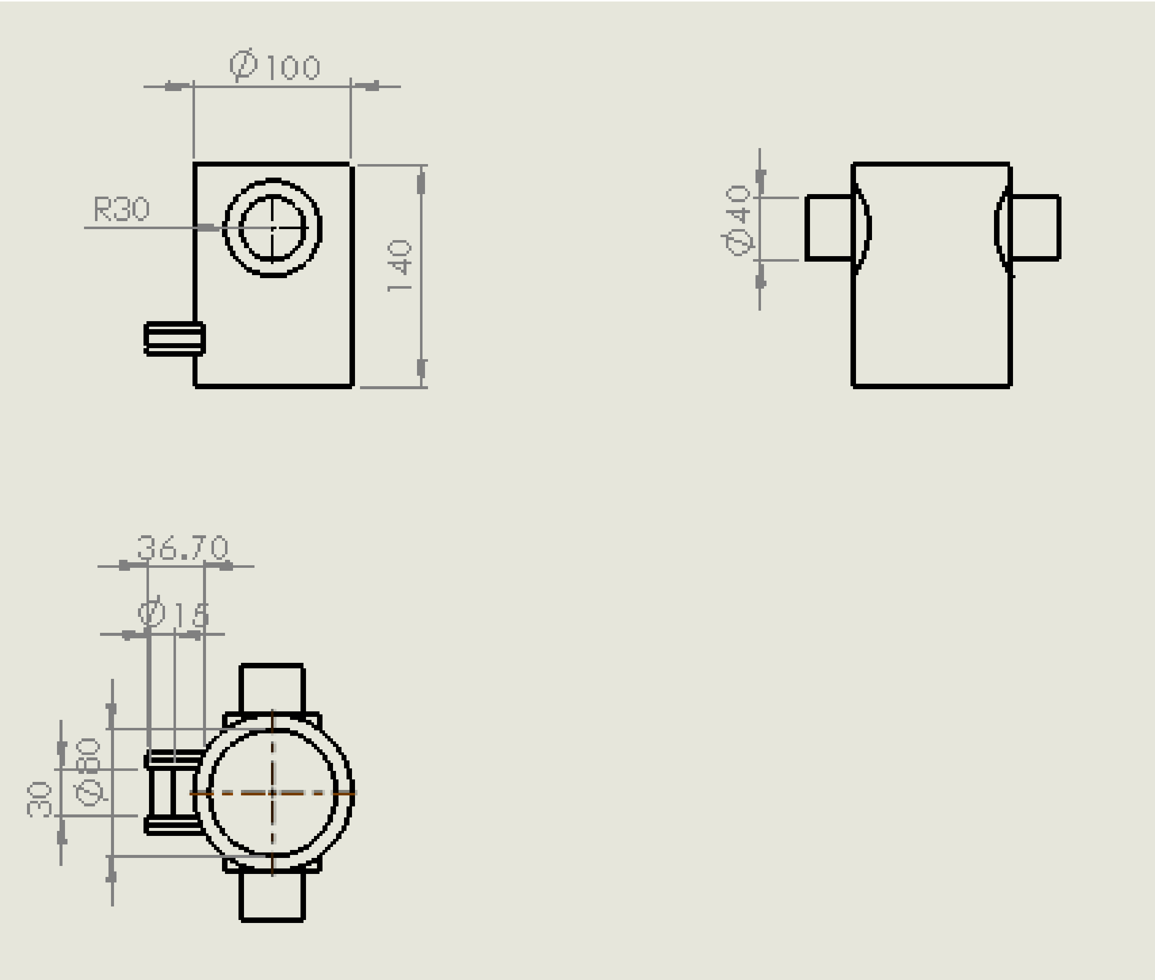

Fig 3.11: Dimensions of base 2 (Solidworks 2015)

3.5 Arm 2:

Arm 2 is the link in which force from the gas spring acts and can be lifted. Arm 2 is connected with bracket of monitor and link 3, with link 3, arm 2 has revolute joint and as the arm 2 moves, the piston in the gas spring move which restrict the movement with respect to the TDC and BDC. Arm 2 has a slot which is used to lock the cover, which helps to hide the wire connected to the monitor and also hide gas spring.

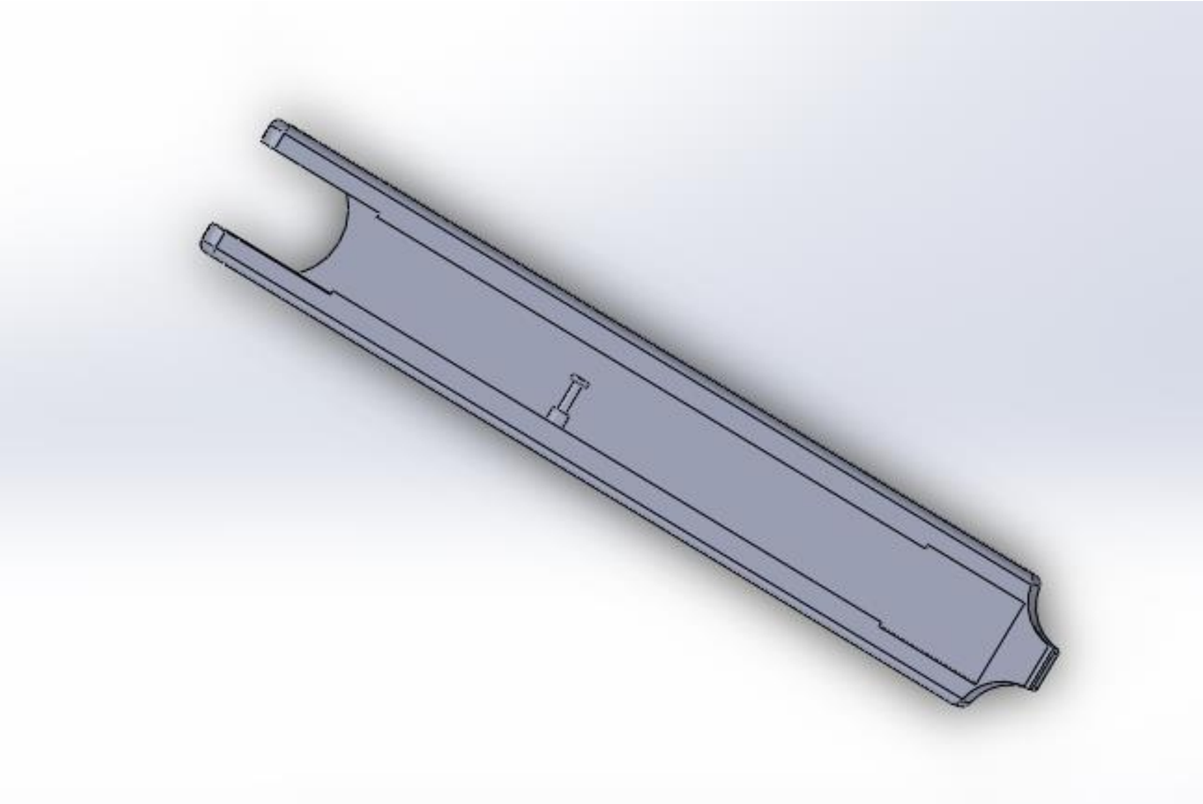

Fig 3.12: Design of Arm 2 (Solidworks 2015)

Dimensions for Arm 2:

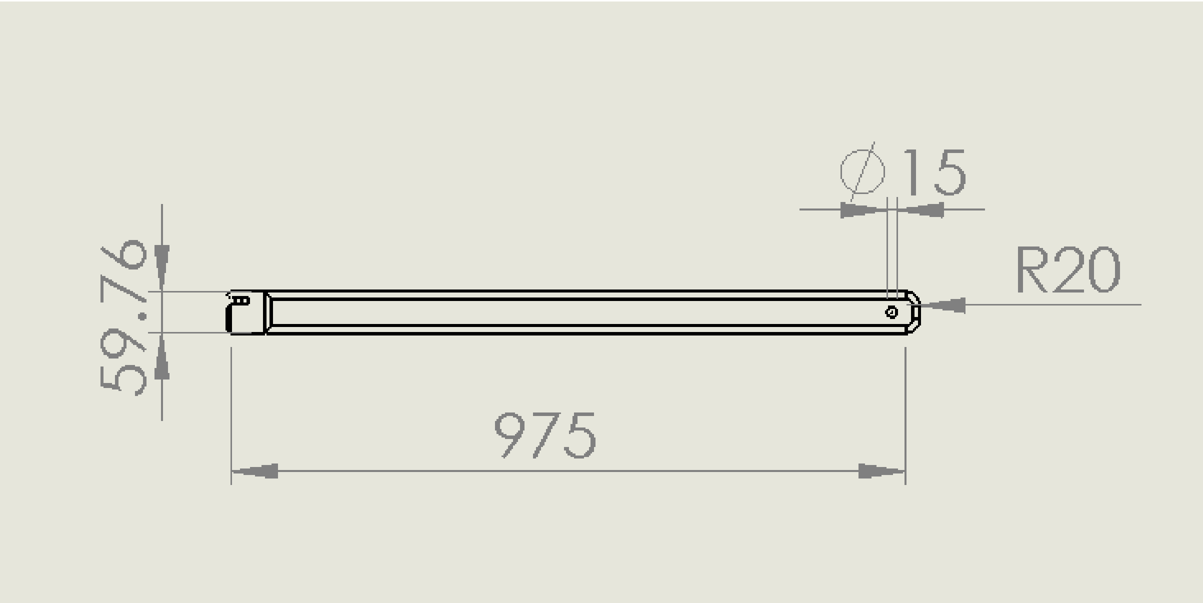

Fig 3.13: Dimensions for Arm 2 side

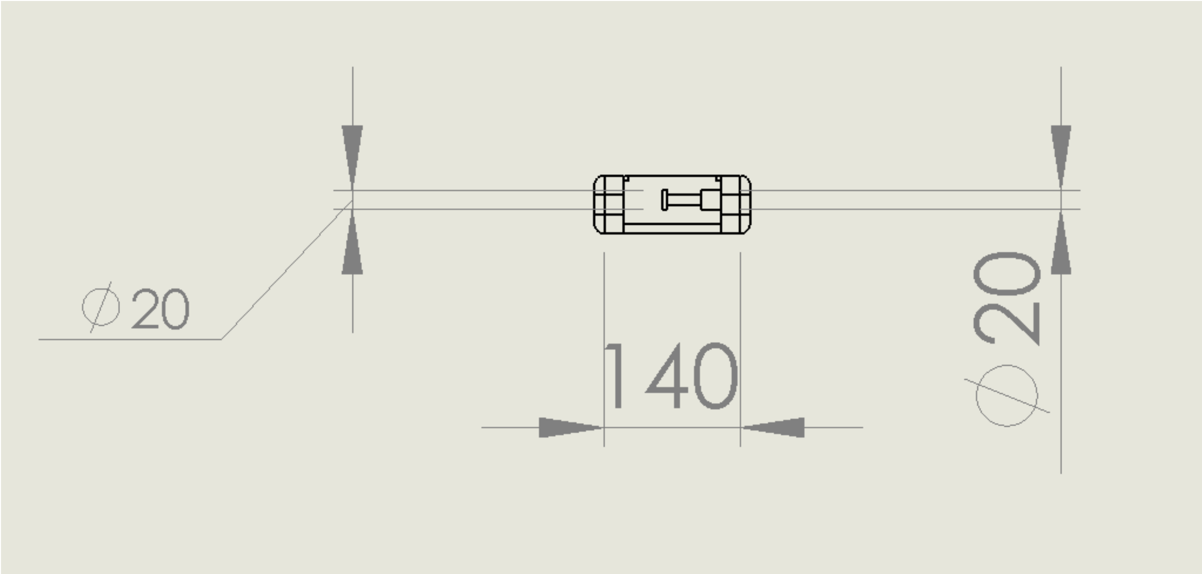

Fig 3.14: Dimensions for Arm 2 front

3.6 Gas spring:

Gas spring is a piston cylinder mechanism which uses nitrogen gas instead of mechanical spring, the pressure difference between the both sides of the piston head decides to move the piston. This pressure difference helps to easily lift the arm with monitor weight. There are ports in the piston head through which nitrogen gas moves to the other side of the piston.

1 - Gas spring force:

The pressure required or the force needed to lift the arm and monitor can be calculated using the below formula

F1 = ((m x RH)/(2 x N x x2) + 5) x 9.81 = gas spring pressure expressed in Newton

- F1 = Force in the gas spring
- N = total no. of gas springs
- m = Total weight of the arm and monitor to be lifted
- RH = Length of the arm to be lifted.
- x2 = The distance between the arm 2 joint in base 2 and the cylinder joint in arm 2.

5 represents the pressure loosed due to the rubbing or friction in the piston and cylinder.

Dimensions of the gas spring:

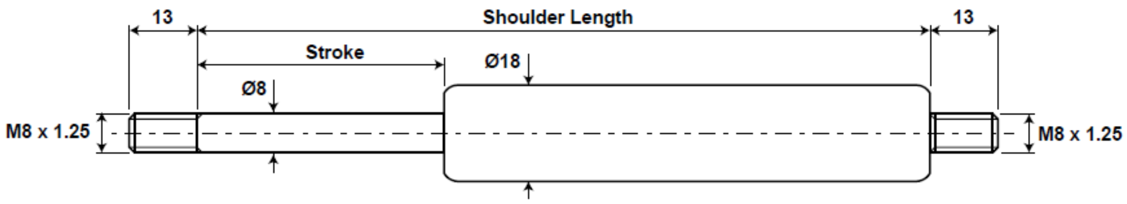

Fig 3.15: Design of gas spring with dimension

3.7 Bracket:

Bracket is used to hold the monitor and it is attached to the arm 2 with the help of small link. The link between bracket and arm 2 helps bracket to tilt at an angle. The monitor is connected to the bracket with the help of 4 screws.

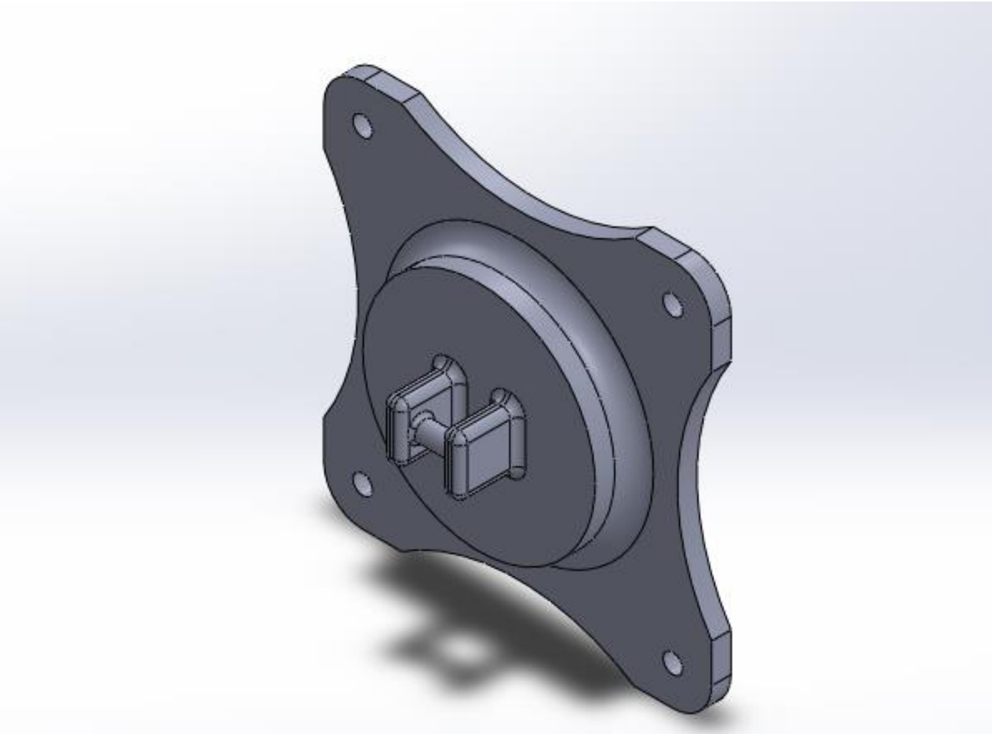

Fig 3.16: Design of bracket (Solidworks 2015)

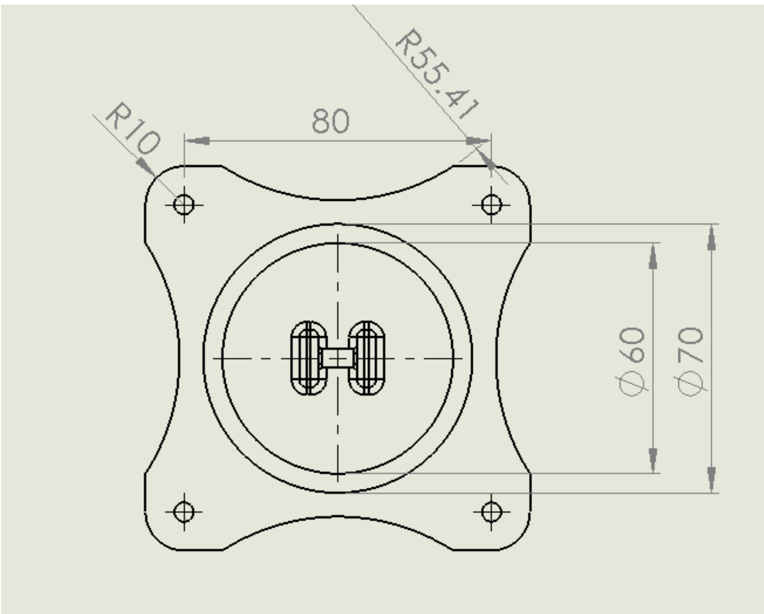

Fig 3.17: Dimension of brackets front

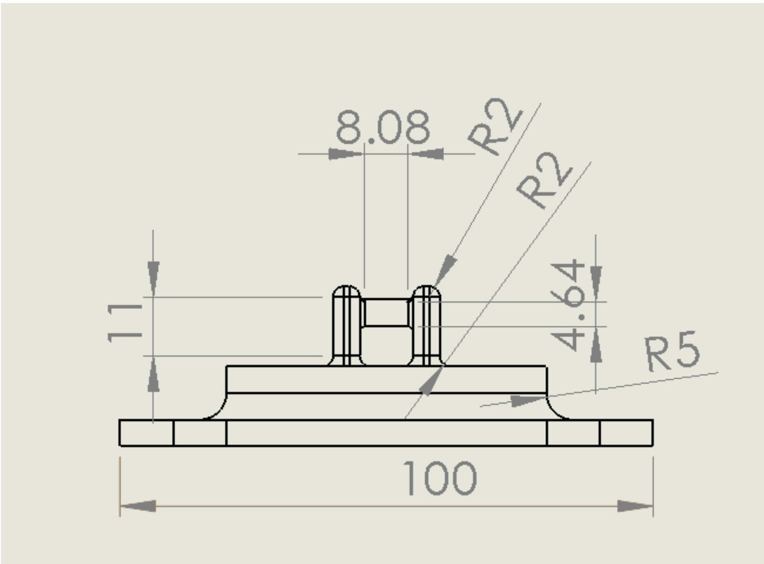

Fig 3.18: Dimension of brackets top

3.8 Assembly:

Assembly of all the part was done using Solidworks, as all the 5 joints are revolute. Every joint has certain degree of rotation, the assembly has 5 degree of freedom.

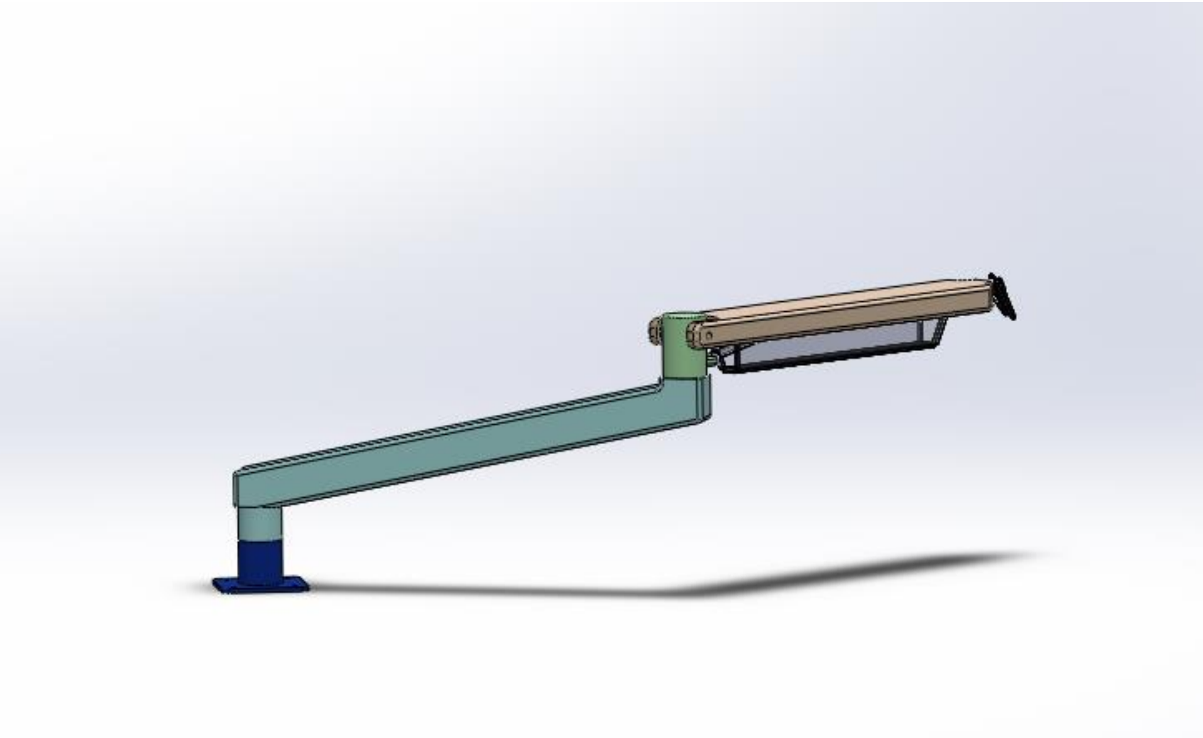

Fig 3.19: Assembled monitor arm (Solidworks 2015)

- The revolute joint between base and arm one gives 360 degree rotation to the arm one.
- The joint between arm one and link 3 is also revolute which gives the rotation of 360 degree for the arm 2, as the gas spring is also connected with the link 3 it also rotates when link 3 is rotated with the help of arm 2.
- The joint between gas spring and link 3 is revolute which allows the arm 2 to rotate at an angle decided by the movement of the piston head in the gas spring.
- The joint between arm 2 and link 3 is revolute joint which helps to rotate the arm two with respect to the movement of the gas spring piston.
- Link 6 between bracket and arm 2 gives bracket a swivel in the axis of arm 2.
- Last link 7 that is bracket connected with link 6 has revolute joint.

CHAPTER 4

MATERIAL SELECTION

Selection of material for the monitor arm is very crucial part as it decide different parameters like strength and weight of the system. There are various materials used in the design of arm and it depends on the environment and different physical requirement.

This chart gives the guidance for the selection of the material including various parameters like strength and cost of the design. For example robotic arm includes common materials for the construction. And the material selection also varies in various condition in which the product will be used. Lot of research was done to see the market for the construction of the monitor arm and the material used in most of the application was common that is Aluminium alloy. The important question was the availability of the material easily and construction of arm with that material, as most of the manufacturers are using the same material for the construction of the arm, it is suitable to select the same material. Ashby Charts give us the reason why to select the aluminium alloy and how the material properties varies with different condition and what kind of strength and cost it is required.

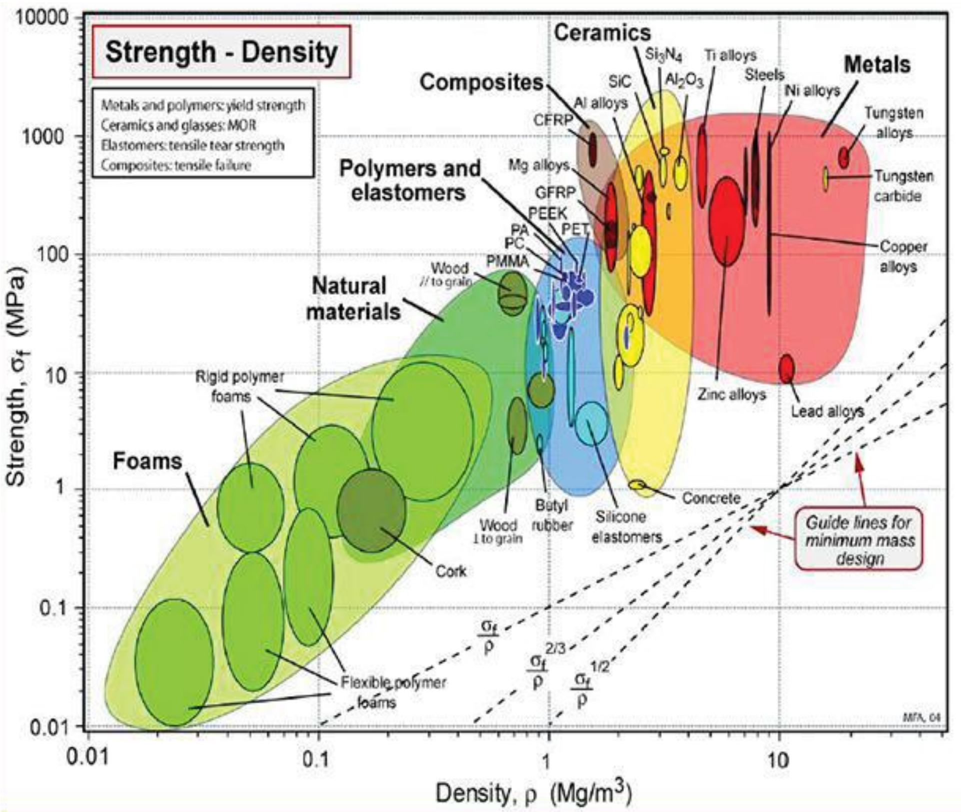

Fig 4.1: Strength vs density

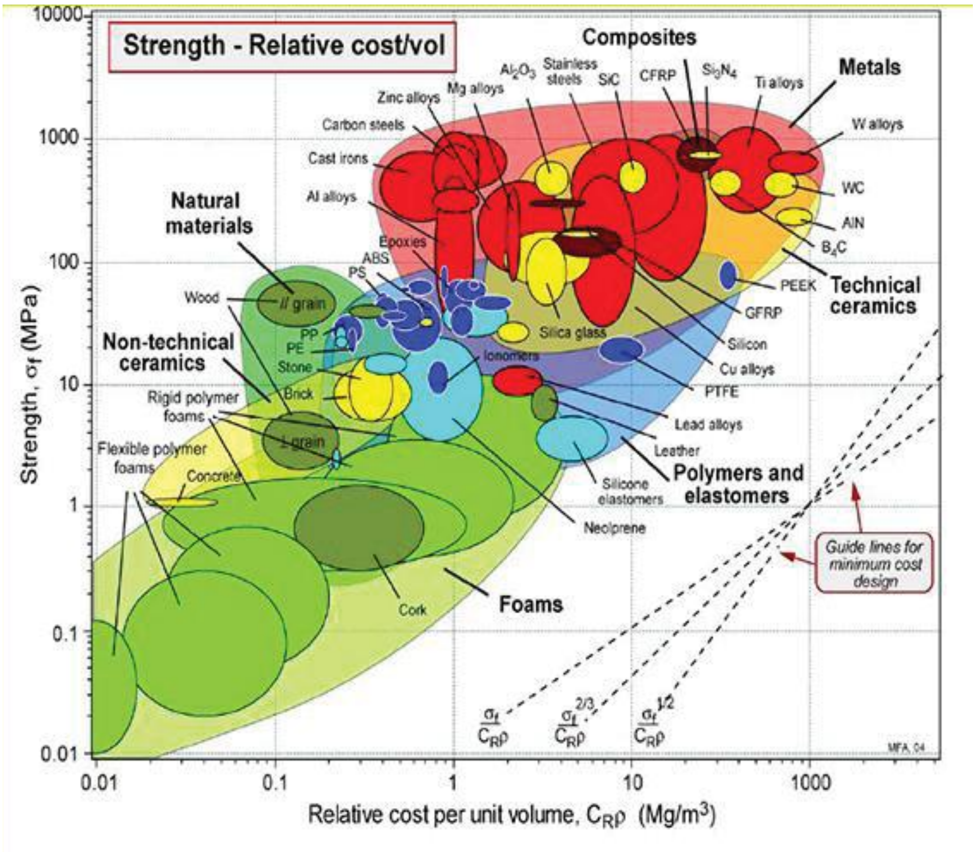

Fig 4.2: Strength vs cost

Above two figure show the relation of strength and density of the material and also the relation of strength and cost of the material used.

Material selection for the arm and base of the monitor arm is Aluminium 6061. The mechanical properties of the material are shown below:

Physical properties	
Density (ρ)	2.70 g/cm^3[1]
Mechanical properties	
Young's modulus (E)	68.9 GPa (9,990 ksi)
Tensile strength (σ_t)	124–290 MPa (18.0–42.1 ksi)

Elongation (ε) at break	12–25%
Poisson's ratio (ν)	0.33
Thermal properties	
Melting temperature (T_m)	585 °C (1,085 °F)
Thermal conductivity (k)	151–202 W/(m·K)
Linear thermal expansion coefficient (α)	2.32×10^{-5} K^{-1}
Specific heat capacity (c)	897 J/(kg·K)
Electrical properties	
Volume resistivity (ρ)	32.5–39.2 nOhm·m

CHAPTER 5

ANALYSIS OF MONITOR ARM

5.1 Stress Analysis:

Stress analysis is necessary of the better design of any system, it gives us the response of the system after applying loads and boundary condition on the system. The stress can be generated anywhere in the whole design because of the boundary condition. It can be a stresses in the joints of the arm. With respect to the weight of the monitor arm which will be fixed and the gravity, the stress in the monitor arm are calculated. For that, the model which was built in solidworks is transferred to the analysis software ANSYS, ANSYS is the most common software used for the simulation of the design. And for the finite element analysis of the system ANSYS is used. According to the assigned material properties of the system the stress are calculated of the monitor arm. According to the load applied on the monitor arm and boundary condition the stress in different location can be shown using ANSYS.

5.2 Boundary Conditions and the load applied:

The load applied on the monitor arm will be acting on the bracket which are used to hold the monitor, the load will be the weight of the monitor which will be a constant load. And to lift the weight of the monitor gas spring is used which will hold the monitor weight. The standard gravity force will also be acting in the arm so the gravitational effects are also considered in the analysis of the stress. The base of the monitor is fixed with the help of screws as you can see in the assembly. The figures for the visualization of the boundary conditions and load applied on the monitor arm are shown below. And the boundary condition and the size of the monitor used are also shown below.

Base (Link 1)	Fixed on the screw hole
Arm 1 (Link 2)	Revolute joint between base and arm 1 (360 degree)
Link 3	Revolute joint between arm 1 and link 3 (360 degree)
Piston	Revolute joint between link 3 and piston (90 degree), pressure of 1-4 Mpa on the piston varying with time.
Arm 2	Revolute joint between link 3 and arm 2 (90 degree)
Cylinder	Revolute joint between arm 2 and cylinder (90 degree)

Holder	Revolute joint between arm 2 and holder (90 degree)
Bracket	Revolute joint between bracket and holder (60 degree) force of 100 N is applied on the bracket holes

Table 5.1: Boundary conditions and requirements

5.3 Finite element Analysis of the monitor arm:

Finite element analysis is a simulation technique used to solve the numerical problem using Finite element method, to reduce the complex equation that is of partial deferential equation into simpler one finite element method is used. Finite element method convert the infinite degree of freedom of any system or component into finite number called elements. For any arm it can be treated as beam and to solve or analysis the structure Euler beam equation is used.

$$EI\frac{d^4w}{dx^4} = \frac{q}{L}(x) \quad \text{.... Equation 5.1}$$

Static structural analysis of robotic arm was performed using the ANSYS workbench. To perform the simulation double click on the Ansys workbench and Drag the Static structural analysis from the toolbox to project schematic.

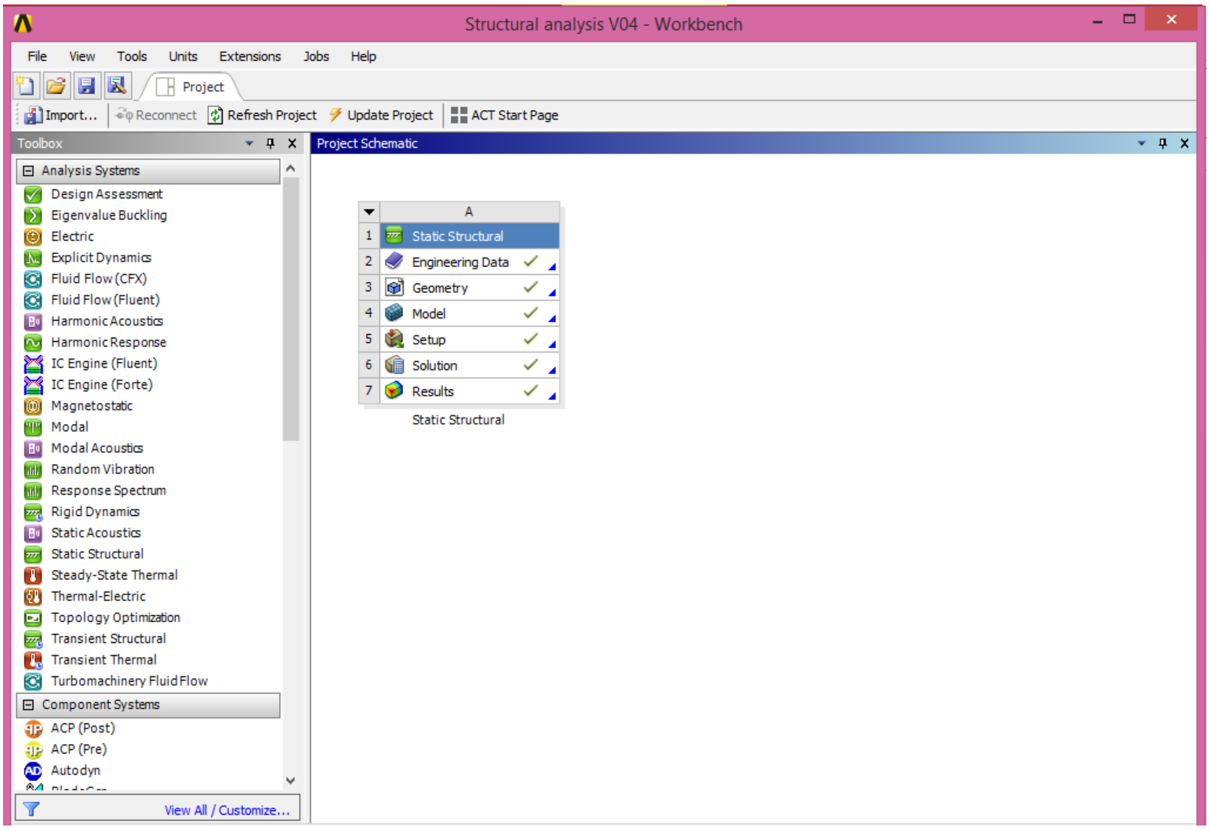

Fig 5.1: ANSYS workbench

Material Selection: Selection of Aluminium Alloy for the arms of the monitor product design.

To select the material to be used for the monitor arm we have to go to the Engineering data where we will select the materials from “General material”. Aluminium alloy and structural steel will be selected from engineering data.

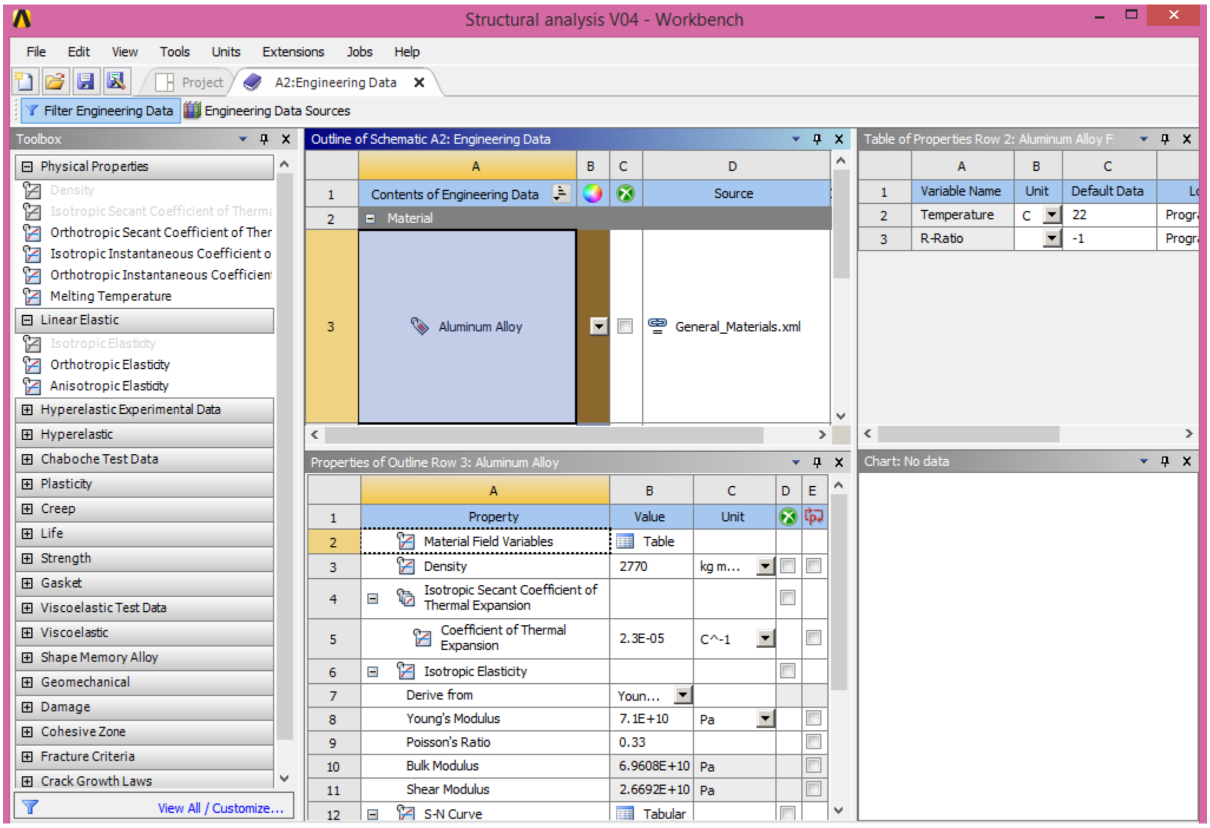

Fig 5.2: Engineering data

Importing the geometry of the monitor arm into the ANSYS workbench. Assigning the material properties of aluminium to the base, arms and bracket. Gas spring is given the properties of steel. To assign a material to the part, select the part and in the details assign the material to the part.

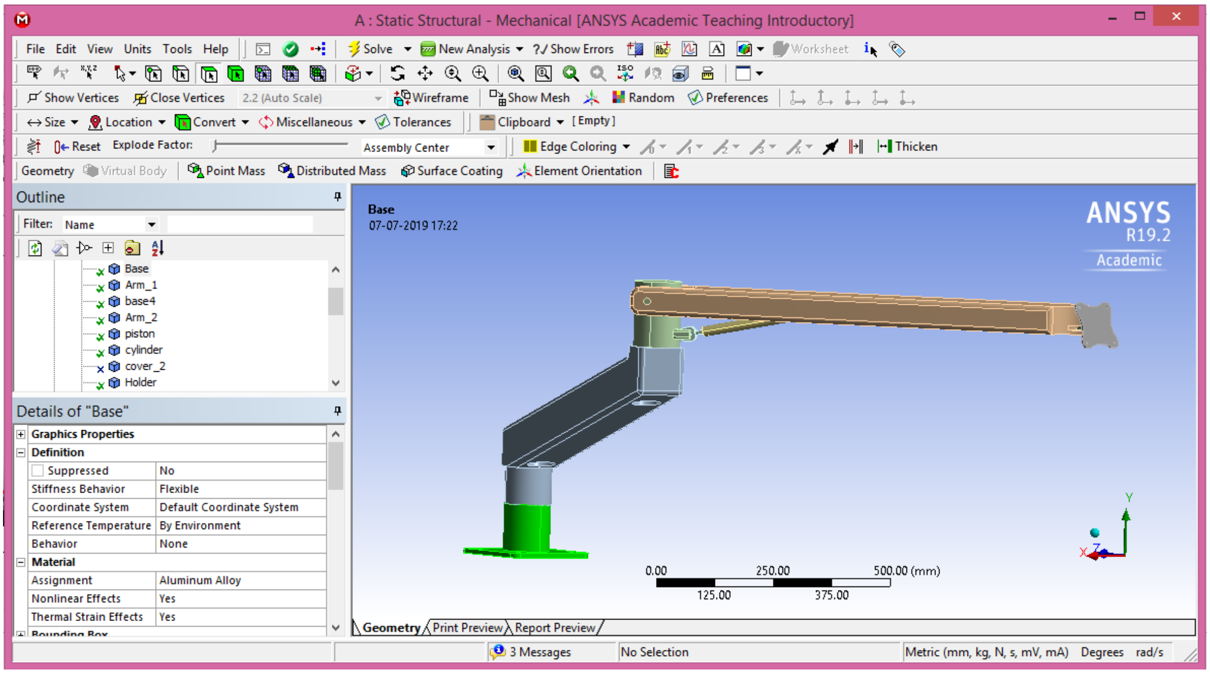

Fig 5.3: Material properties to parts

In next steps we defined the contact of the joints for the analysis. And to do so, select the connection tab on the tree and select the contact. The contact between all the joints are selected to be revolute. And the contact type to be assigned as frictionless for the parts in which the forces are acting. The reference and the target of the contact can be selected so that the movement of the arm can be defined. All the figures below shows the contact between the joints. To assign the contact select the reference faces and the select the target faces and select the reference frame of the joint with respect to the axis.

Contact between Base and arm 1:

Base and the arm 1 is bounded using 3 faces on the base shown in red and the 3 faces on arm 1 in blue. To find the stresses induced in the monitor arm at particular location the joints are bonded.

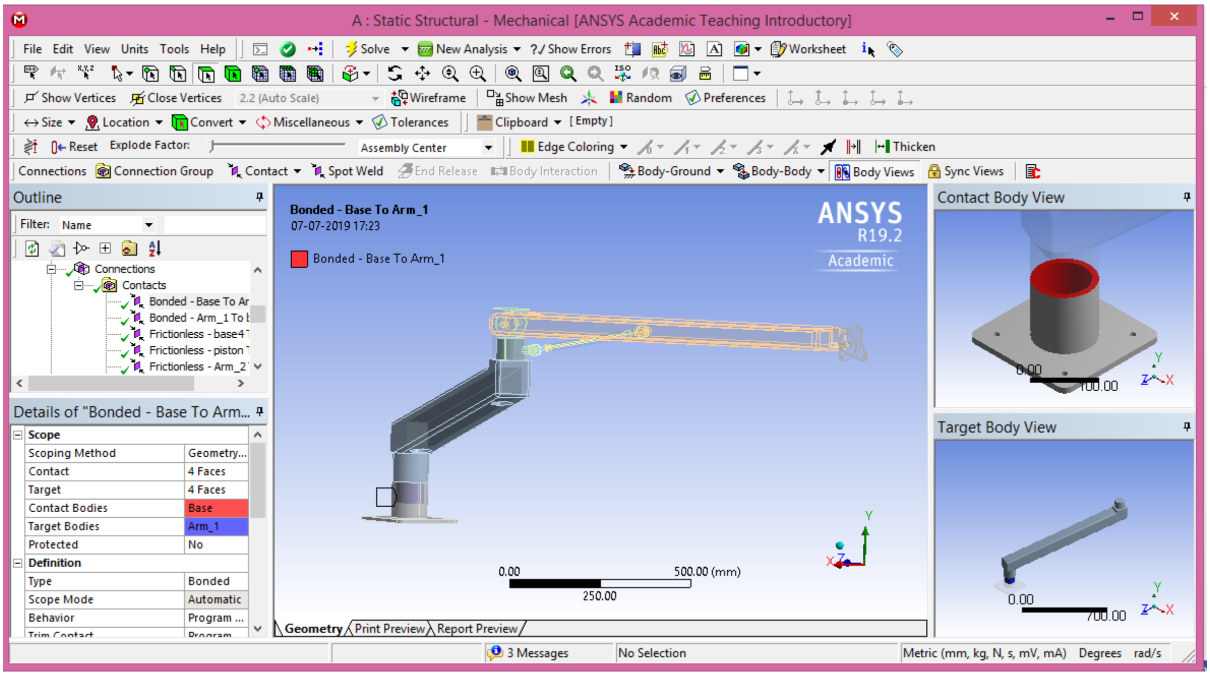

Fig 5.4: Contact between Base and arm

Frictionless contact was chosen for the analysis of force acting on arm 2. But at a particular point when the monitor is positioned at a particular location the type of joint chosen between is bonded.

Contact between base 2 and piston:

To assign the contact between the Base 2 and piston select the contact in the tree and select the faces in the Base 2 as contact bodies and faces from piston to target bodies. Type of the joint is frictionless and for the static structural analysis the contact type between the joints can be selected as bonded.

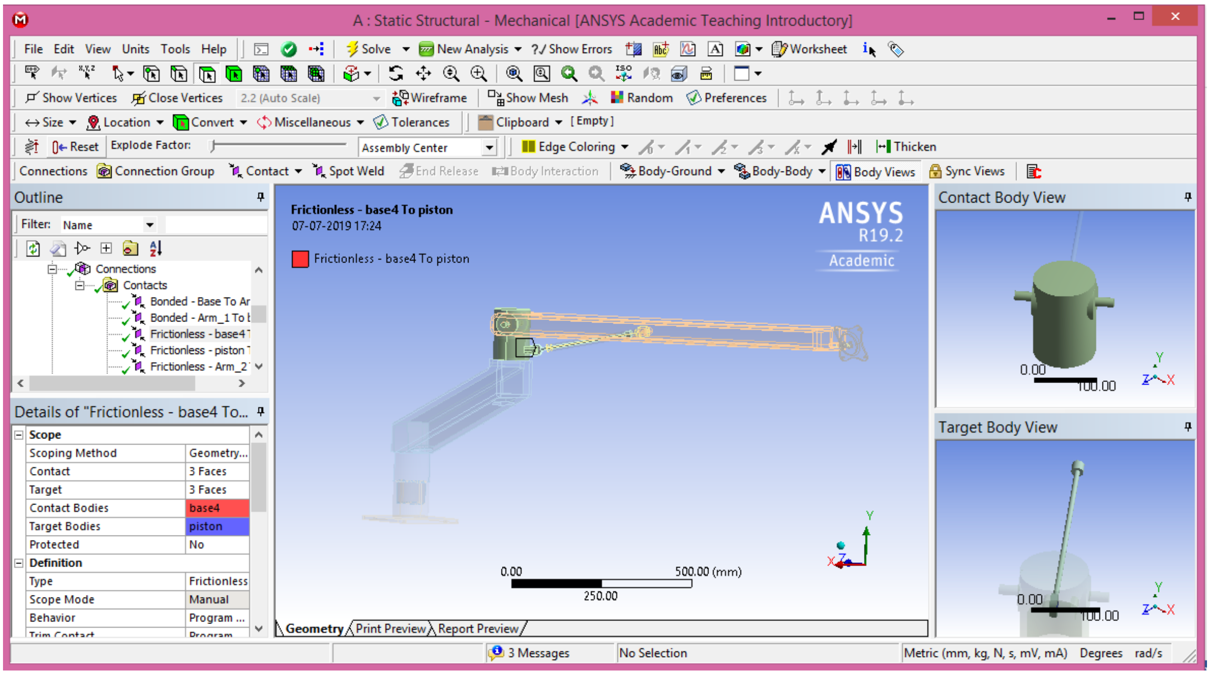

Fig 5.5: Contact between base 2 and piston

Contact between piston and cylinder:

At a particular moment the contact can be treated as bonded, after the gas inside the gas spring performs its function. The pressure applied by the gas in the piston move the monitor arm to a particular position and then the structural analysis at that particular position is performed. To select the contact between the piston and cylinder go to the contact in the tree and right click. Use the manual contact. In details select the contact bodies as piston and target bodies as cylinder.

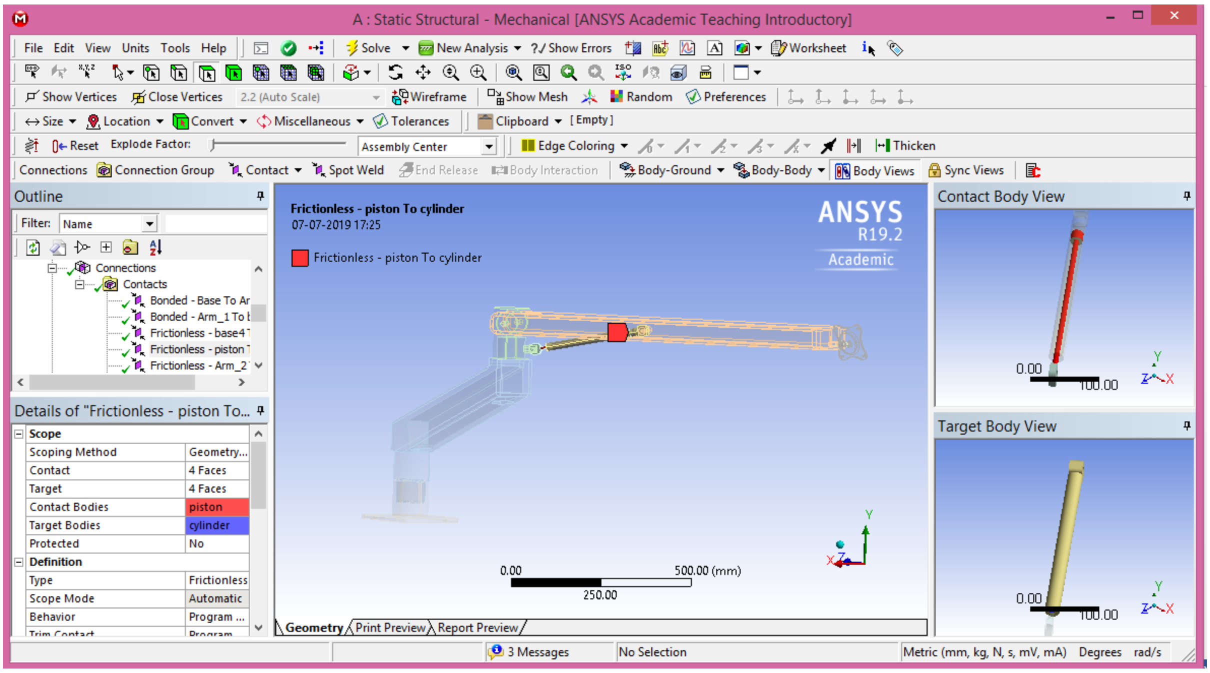

Fig 5.6: Contact between piston and cylinder

Contact between Cylinder and arm 2 (Frictionless):

Similarly to make contact between cylinder and arm 2, go to the contact tab in the tree and select the manual contact, in the details select the type as bonded and arm 2 as contact bodies also cylinder as target bodies.

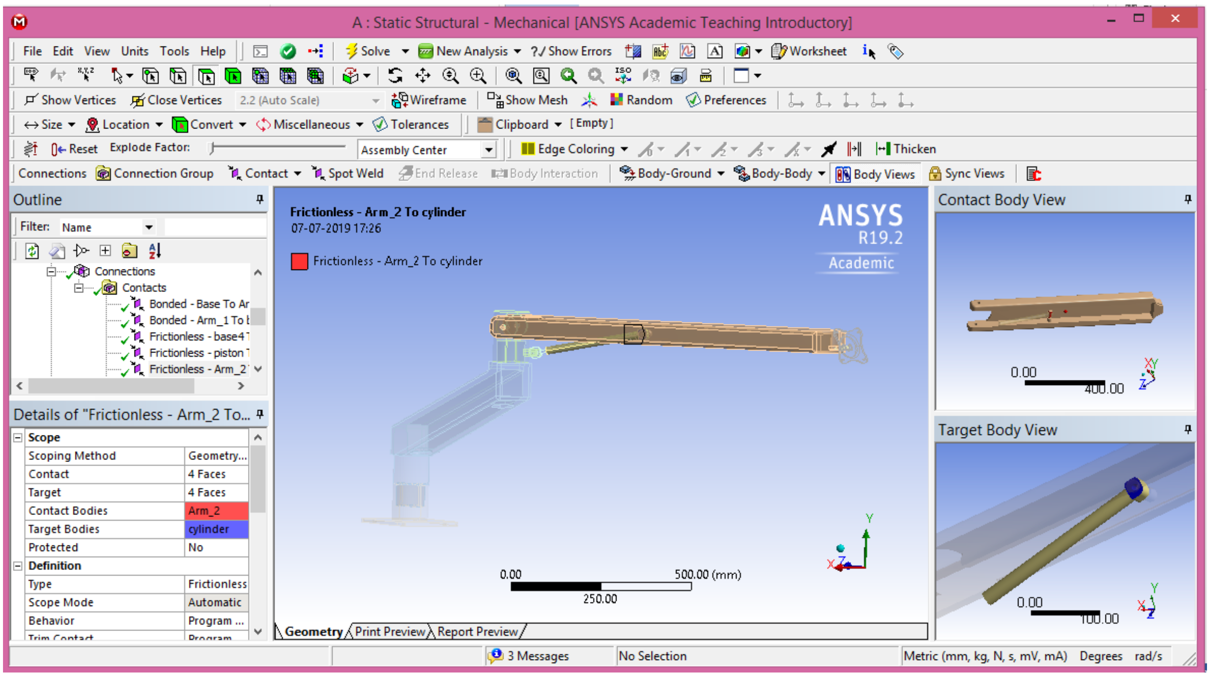

Fig 5.7: Contact between Cylinder and arm 2

Contact between arm 2 and base 2:

Similarly, to make contact between the arm 2 and base 2, right click the contact tab in the tree and select the manual contact. In the details select the contact type as bonded, and arm 2 as contact bodies with base 2 as target bodies.

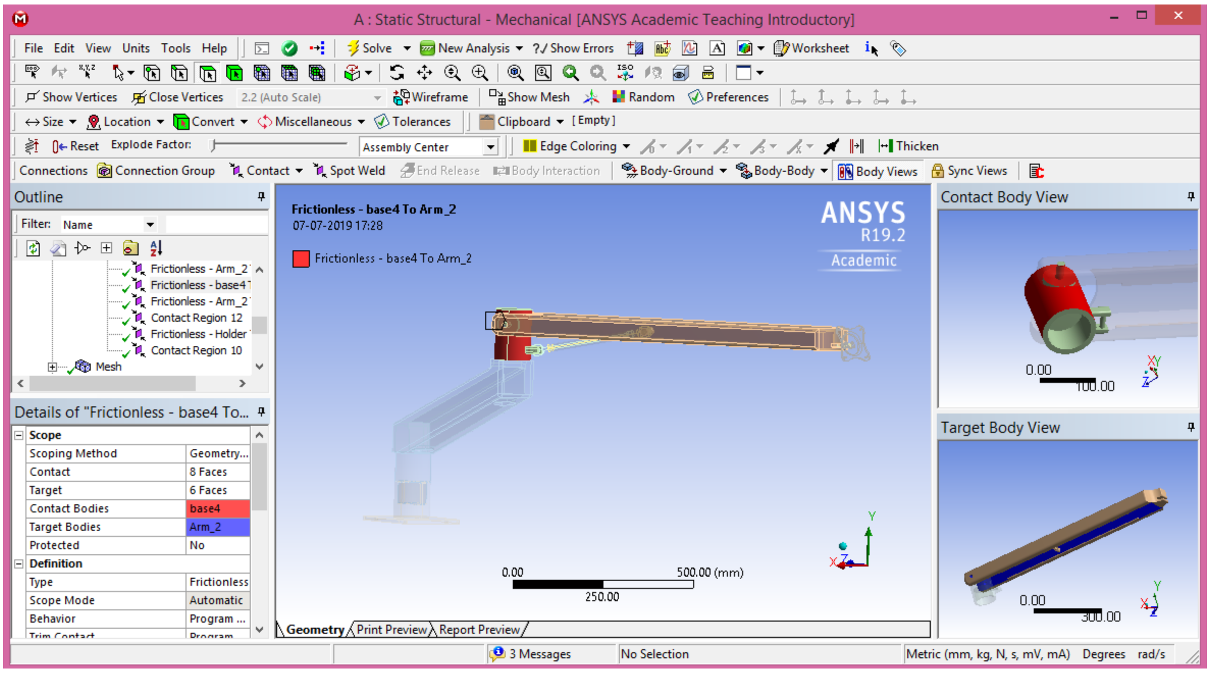

Fig 5.8: Contact between arm 2 and base 2

Contact between arm 2 and holder:

Similarly the contact between the arm 2 and holder which is revolute when the arm is moved. In here the contact type is bonded which helps in static structural analysis. To select the contact between the arm 2 and holder go to the contact and click right and select the manual contact. In details select arm 2 as contact bodies and holder as target bodies.

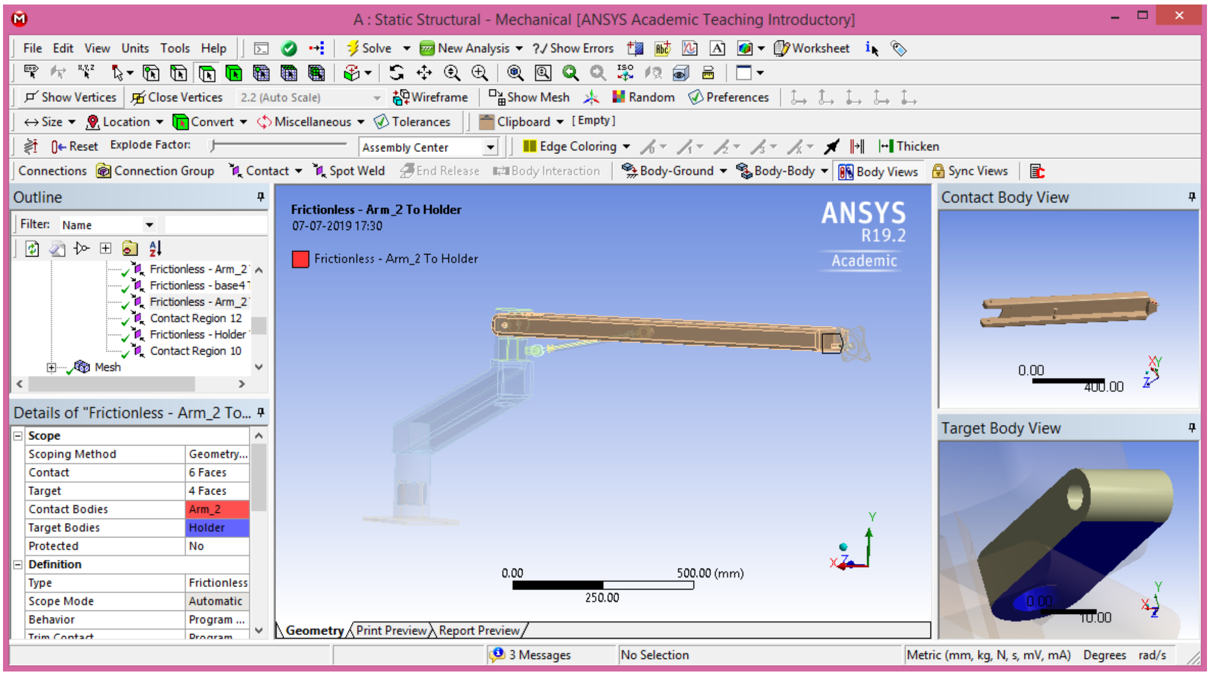

Fig 5.9: Contact between arm 2 and holder

Contact between holder and bracket:

The contact between the holder and bracket is also revolute but for the structural analysis the contact type chosen is bonded. To select the contact between the holder and bracket right click the contact on the tree after selecting the manual contact, in details select holder as contact bodies and bracket as target bodies.

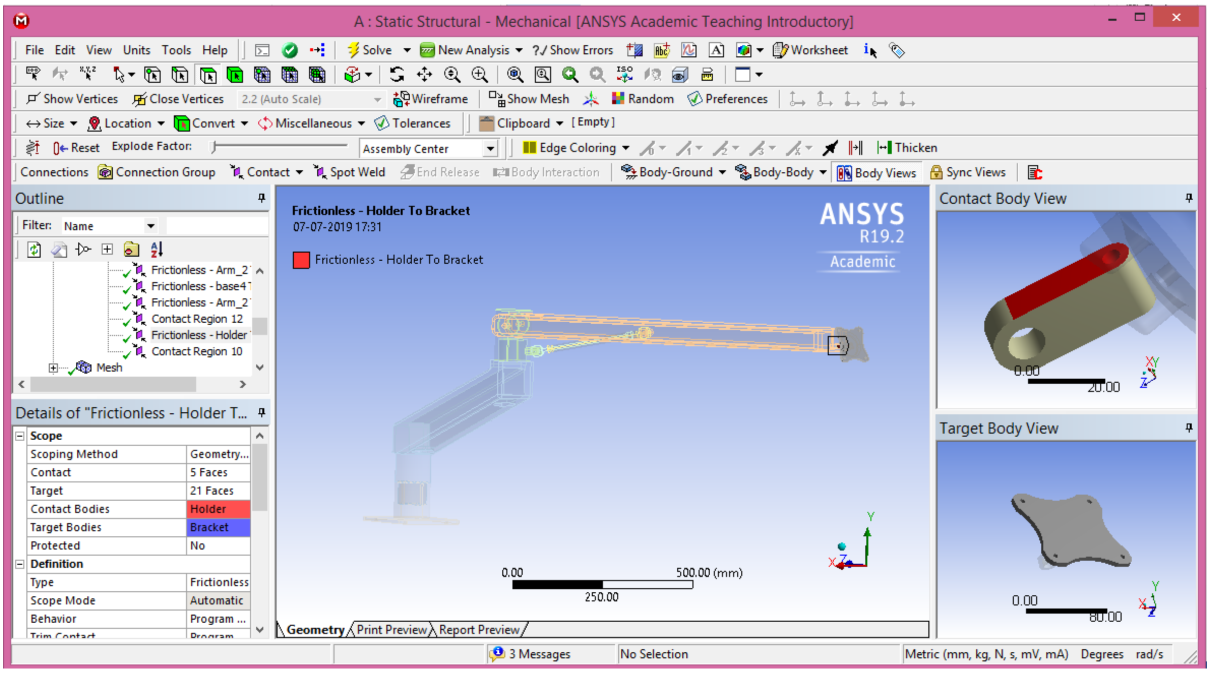

Fig 5.10: Contact between holder and bracket

5.4 Meshing:

To do the meshing select the mesh tab in the tree, right click on the mesh and import sizing for the mesh on the part. In below every part is assigned with the different size of the mesh. To decrease the degree of freedom of a component finite element uses discretization method that is meshing. Which divides the components into small element of specific size which finites the degree of freedom of the components and helps to solve the complex equations easily.

No. of nodes: 31425

No. of elements: 16690

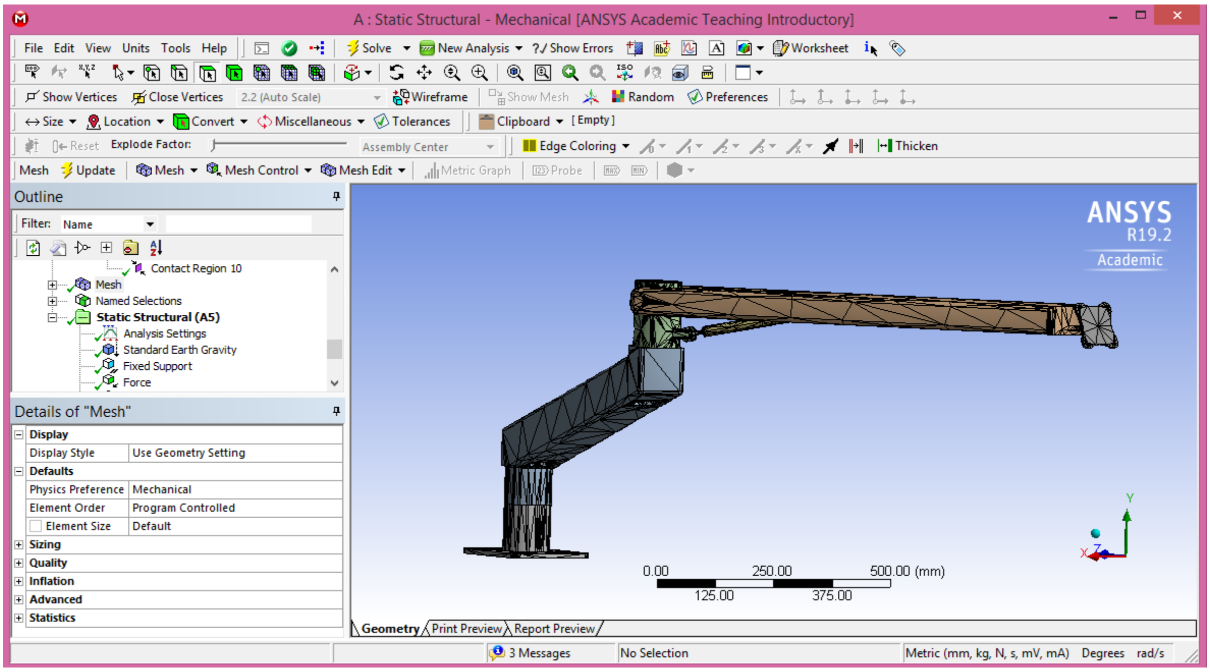

Fig 5.11: Meshing of the design

5.5 Static Structural Analysis:

Analysis Setting:

Analysis setting is the major part of the analysis of problem it define the number of steps and time taken by the solution and the solver type used for solving the required problem. To do the analysis setting go to the Static structural tab on the tree and select analysis setting. In that, in the details number of steps and time for each steps could be changed and solver type also.

In our analysis we have chosen the below setting as shown in the figure.

Step Controls	
Number Of Steps	3.
Current Step Number	3.
Step End Time	3. s
Auto Time Stepping	On
Define By	Time
Carry Over Time Step	On
Minimum Time Step	0.1 s
Maximum Time Step	1. s
Solver Controls	
Solver Type	Direct
Weak Springs	Off
Solver Pivot Checking	Program Controlled
Large Deflection	Off

Fig 5.12: Analysis setting for solution

Forces and boundary conditions:

Boundary condition as mention above are to be given in the Static structural tab. To define the boundary conditions, right click the static structural and select the fixed support in it. In the details of the fixed support select the geometry as the base and holes in it for the screws.

After assigning the fixed support right click the static structural and select the force, In details select the holes in the bracket where the monitor will be attached and assign the force of 100 N in –y axis direction.

Force for the gas spring will be varying with the time steps so do the above procedure to select the force and then select the face of the piston head to assign the force. This force with respect to the area will be the pressure applied be the nitrogen gas in the cylinder to lift the monitor arm.

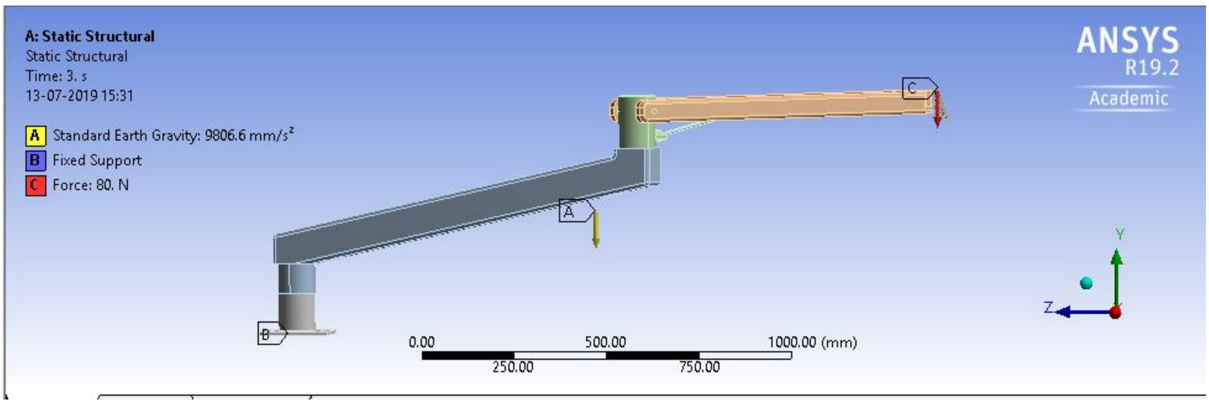

Fig 5.13: Boundary conditions on arm

In the further process for the solution of the problem three behaviours were considered that is the equivalent stress, total deformation and Life in the fatigue analysis. The result for the problem are shown in further section.

CHAPTER 6

KINEMATICS ANALYSIS

To know about the position of the monitor arm there is a need to do the kinematic analysis. In this project forward kinematic analysis was done so that the position of the monitor can be known with respect to the angles given to the joints. To visualize that a graphic user interface was made in MATLAB using the peter corke robotic tool box. MATLAB is the most comfortable method used for the analysis of the robotic arm. So in this project also MATLAB was used to perform the kinematic analysis.

Below shows the code for the MATLAB to perform the forward kinematic analysis. For doing the forward kinematic analysis we have used the DH representation of the arm. DH representation show the parameters of the arm that is the frames of the joint and angle of each and every joint to be assigned.

In the DH representation there are following things that should be known for the forward kinematic analysis:

Theta: Theta is the angle to the joint. It is the angle between x (0) and x (1) measure in plane perpendicular to z (0).

Length of the link (a): This can be got by measuring the distance along x (1) of z (0) and z (1).

Twist angle (alpha): It is measured along x (1), angle between z (0) and z (1).

Offset of link (d): Measured along z (0), Distance between x (1) and z (0) intersection to origin.

The equations used for the calculation of the end position of monitor is give below:

$$\mathbf{A_i} = (\mathrm{ROT}, z, \Theta_i)(\mathrm{Trans}, z, a_i)(\mathrm{Trans}, x, a_i)(\mathrm{ROT}, x, \alpha_i). \quad \text{....Equation 1}$$

$\mathbf{A_i}$ =

$$\begin{bmatrix} C\theta_{n+1} & -S\theta_{n+1}C\alpha_{n+1} & S\theta_{n+1}S\alpha_{n+1} & a_{n+1}C\theta_{n+1} \\ S\theta_{n+1} & C\theta_{n+1}C\alpha_{n+1} & -C\theta_{n+1}S\alpha_{n+1} & a_{n+1}S\theta_{n+1} \\ 0 & S\alpha_{n+1} & C\alpha_{n+1} & d_{n+1} \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

...Equation 2

Below is the code made for the forward kinematic analysis using peter corke robotic toolbox.

```
>> dh = [
0 0.313 1 0
0 0.1 0 pi/2
0 0 1 -pi/2
0 0 0.044 pi/2 ]

dh =

         0    0.3130    1.0000         0
         0    0.1000         0    1.5708
         0         0    1.0000   -1.5708
         0         0    0.0440    1.5708
```

```
>> r = SerialLink(dh)

r =

noname:: 4 axis, RRRR, stdDH, slowRNE
+---+-----------+-----------+-----------+-----------+-----------+
| j |     theta |         d |         a |     alpha |    offset |
+---+-----------+-----------+-----------+-----------+-----------+
|  1|         q1|      0.313|          1|          0|          0|
|  2|         q2|        0.1|          0|     1.5708|          0|
|  3|         q3|          0|          1|    -1.5708|          0|
|  4|         q4|          0|      0.044|     1.5708|          0|
+---+-----------+-----------+-----------+-----------+-----------+
```

```
>> r.fkine([0.2 0.1 0.3 0.1])


ans =
    0.8786   -0.2823    0.3852     1.931
    0.3763   -0.0873   -0.9224    0.4975
    0.2940    0.9553    0.0295    0.7215
         0         0         0         1

>> r.plot([0.2 0.1 0.3 0.1])

>> r.teach
```

CHAPTER 7

RESULTS

In this project design of monitor arm was made with the help of solidworks and two different analysis were done. First was the stress analysis using ANSYS and second was the kinematic analysis using MATLAB. The results obtained from the analysis are shown below:

Equivalent stresses:

After assigning the boundary condition select the solution tab and right click in it add von misses stress and total deformation for the solution. After selection of the above two solve the problem by clicking solve button. The results will appear after solving the problem.

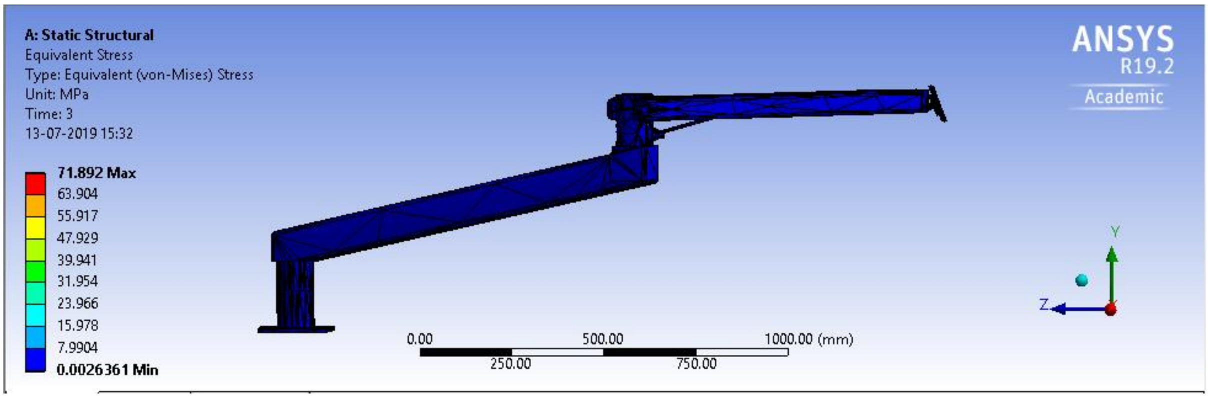

Fig 7.1: Equivalent stress

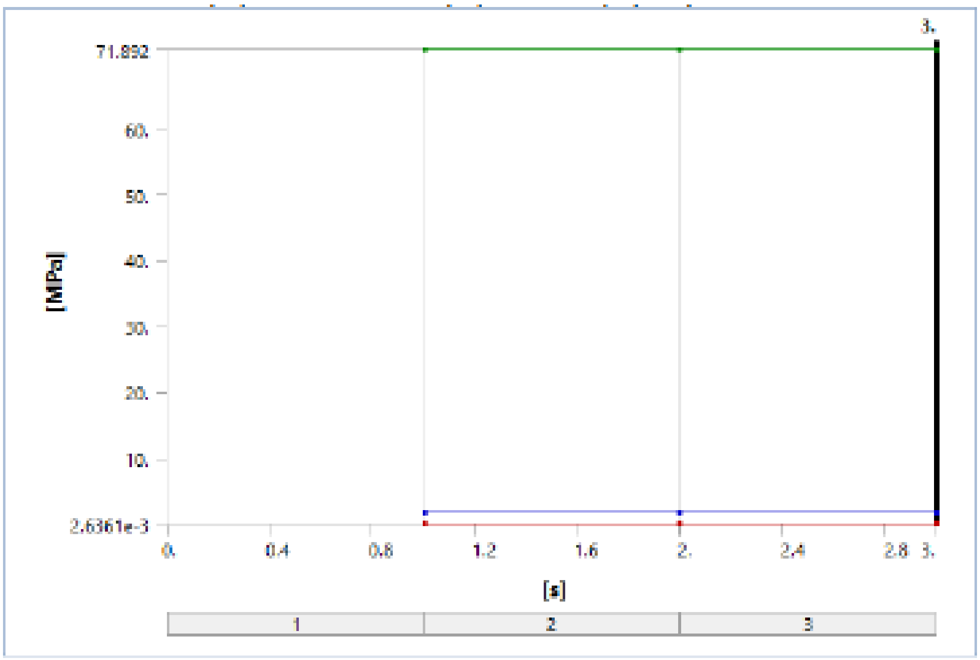

Fig 7.2: Stress in the arm graph

Total deformation:

Total deformation shows the bending of the arms due to the weight of the monitor and due to the gravitational force acting on it. The deformation of the body after applying the forces due to gravity and monitor on the bracket is 1.717 mm.

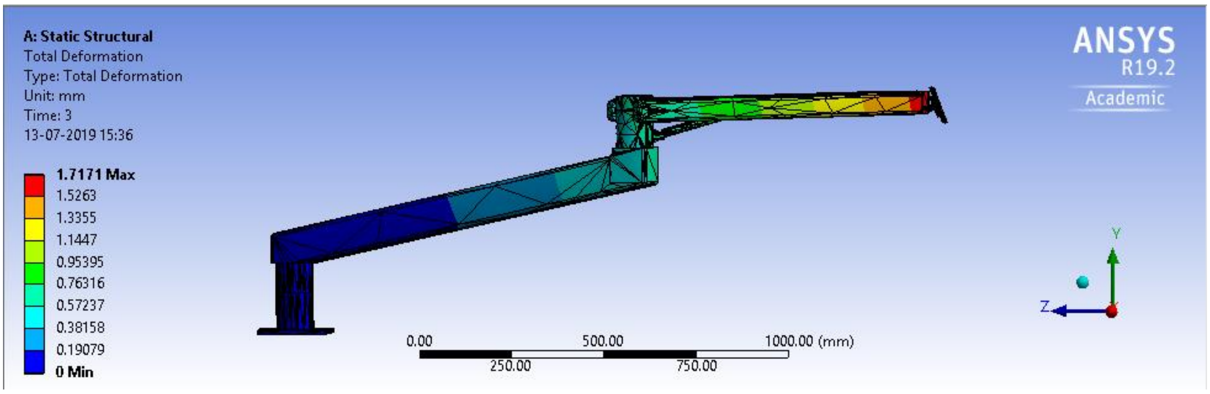

Fig 7.3: Deformation of arm

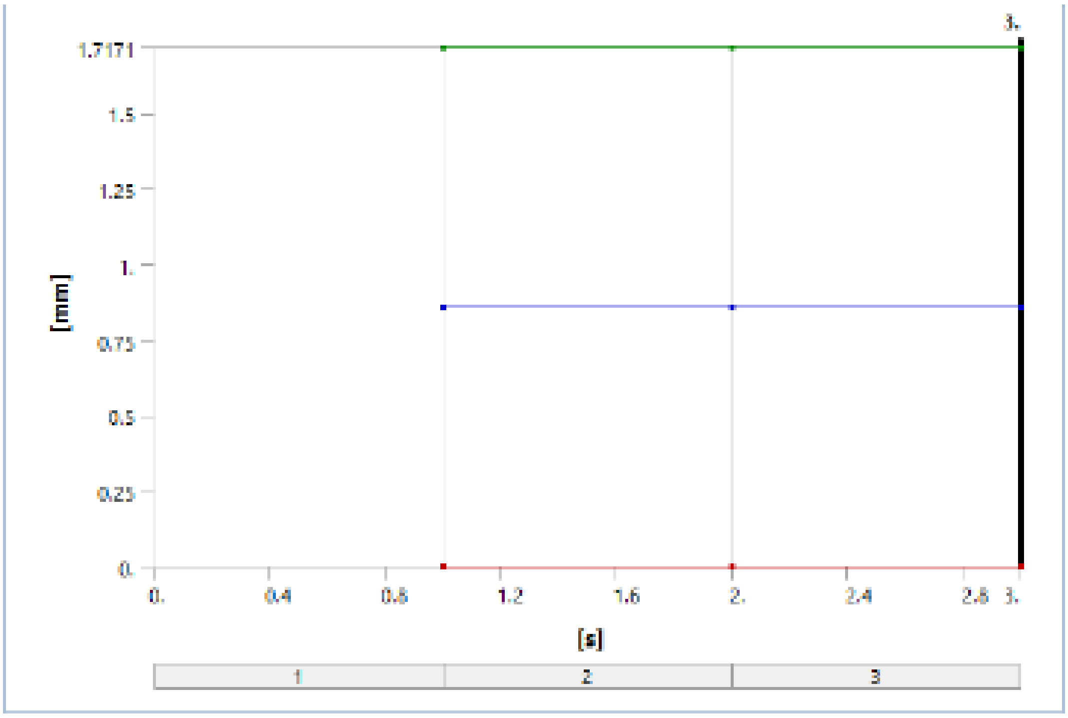

Fig 7.4: Deformation of arm graph

Life of the Arm:

With the help of fatigue analysis we can figure out the life of the monitor arm. The below figure shows the life of the arms

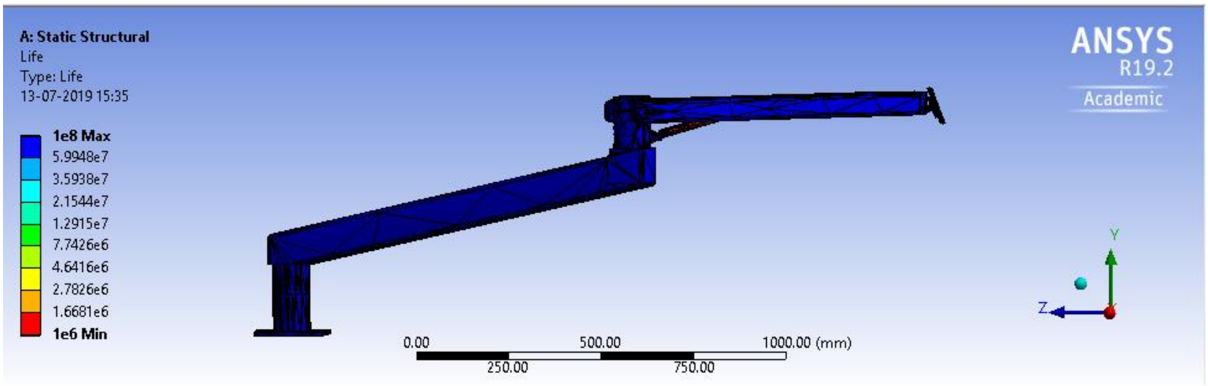

Fig 7.5: Life in number of revolution

The maximum life of the arm found was 1e8 revolution and minimum is found to be 1e6 which is of the piston of the gas spring.

The GUI for the kinematic analysis of the monitor arm.

The diagram show the outline of the arms in blue colour and joints in red colour. The theta value can be manipulated using the scroll bar (q1, q2, q3, q4).Here we will be able to see that when we are changing the value of theta the end effector position is changing. X, Y, Z show the position of the monitor in the space. R, P, Y show the roll pitch yaw of the monitor attached to the bracket.

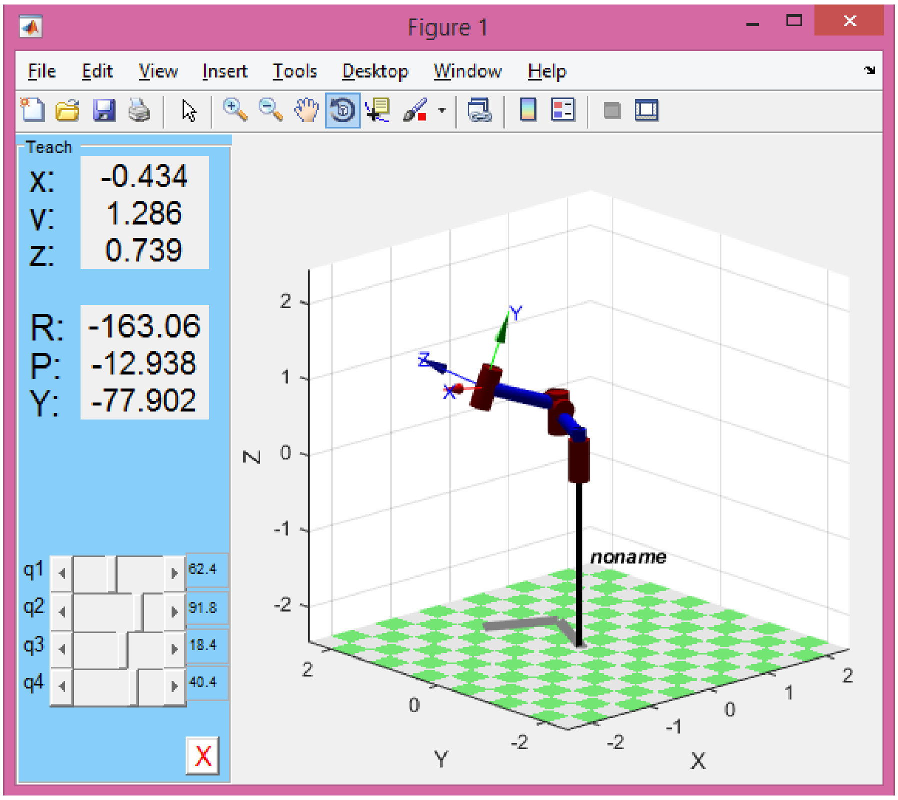

Fig 7.6: The GUI showing the position of monitor in space

CHAPTER 8

VALIDATION

Validation is very important criteria that should be considered to analysis and decide the design made is different and better than the design present currently. With respect to healthcare sector and the monitor arm which can be mounted behind the C arm does not has the design shown above and the benefits of the design. The research made with respect to the design available show that the design currently present does not fulfil the requirements of the doctors. So the design made in this thesis has different factor which shows the monitor arm design is valid. The features of the design with respect to the requirements are: The use of gas spring which helps to lift the arm and the monitor weight easily was not used in any of the C arm. The length of the arm gives the coverage of two meters as the position of the monitor was required to reach till 2m from the base which can be seen in the MATLAB Forward kinematic analysis that the design is capable of this requirement, which brings technicians comfortable view and handling of the monitor. The stresses induced are very less and the deformation in the design can be neglected. The life of the design which can be seen in the result section is valid. The patent shown in the literature review section is the design patent which is used as a design for many monitor arm. Which is not that flexible as the design made in this thesis project. There is no use of gas spring in the design and also the degree of freedom of the design shown in the patent is not sufficient as per requirements of the doctors and technicians.

CHAPTER 9

CONCLUSION

The monitor arm design which consist of two arms with gas spring, arms are made of Aluminium alloy and gas spring is made of steel. The design gives the flexibility using revolute joints and appropriate degree of freedom. The monitor arm can be easily handled and lifted without making much efforts. The coverage of the monitor arm gives the comfortable view of the monitor to the technician or doctor while performing procedure. Monitor arm can withstand the weight of the monitor of size 27 inches giving negligible amount of stress and deformation. The use of this monitor arm reduces lot of space in the cath lab by mounting the arm behind the C arm. The Siemens Cios select with FD which contains two systems that is the C arm and the monitor system can be integrated using this monitor arm.

CHAPTER 10

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