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Design and Analysis of Snake Like Robot

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Abstract

The project presented in the paper have aim to mimic the movement of snake for gaining its advantages, both in theory and practice. The purpose is how the motion of biological snake can be used for robotic movement. The report consists of design, simulation and analysis of snake like robot. There are several types of movements in snakes. The most common movement lateral undulation is used for the design of the snake like robot. Analysis of the snake like robot is done with the help of ansys software. This work will lead to make a robot which will be having a real snake like movement.

Keywords— lateral, undulation, snake, robot, snake-like, design, movement.

1.INTRODUCTION

Snake is a reptile having no limbs known as limbless reptile. It is commonly noticed by its movement where its moves by different movements. The most common movement is lateral undulation.[1] According to Encyclopedia of Britannica[2] , the snake exists from way back to several million years, where oldest fossil of snake ever found has been 167 million years old. The evolution of snakes proves that its movement is somehow advantageous.

Lateral undulation is also known as serpentine crawling. It is the most common movement amongst all the snake species. The muscles around the spine of snakes make a wave like motion. The sides of body of snake pushes the roughness on the ground and exerts the force perpendicular to its present position. This motion is observed in figure 1.1 where arrows show force exerted to the sides and that force results in resulting force forward. [1]

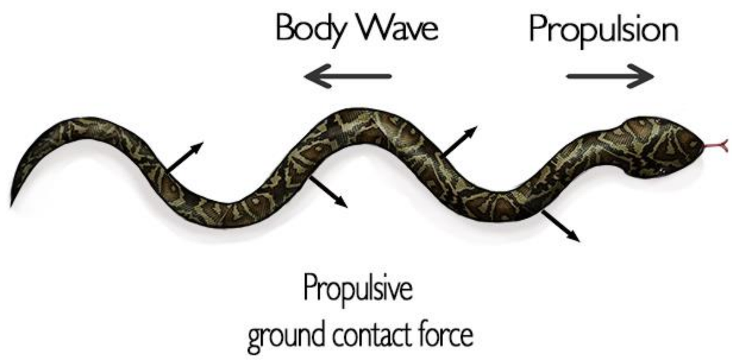

Fig 1.1 Propulsion generated by ground contact forces [1]

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2. SIMULATION

The general purpose of the simulation is to create understanding of how the lateral undulation works, how the motion forward is created and controlled. By creating a kinematic and dynamic model of the robot, complete simulations of the movement are possible and changes in the movement and properties of the robot can thoroughly be tested before the implementation.

2.1 Simulation Environment

The simulation is done with the help of ode solver ode 15s. When ode 15s is done with its calculations, it gives the result list of all state variables and torques during each time step. This results can be used to plot the movement and torques in matlab. The display tool was made in C++ as a supplement to matlab. The variables are saved in matlab in the file form and loaded by display tool. [4]

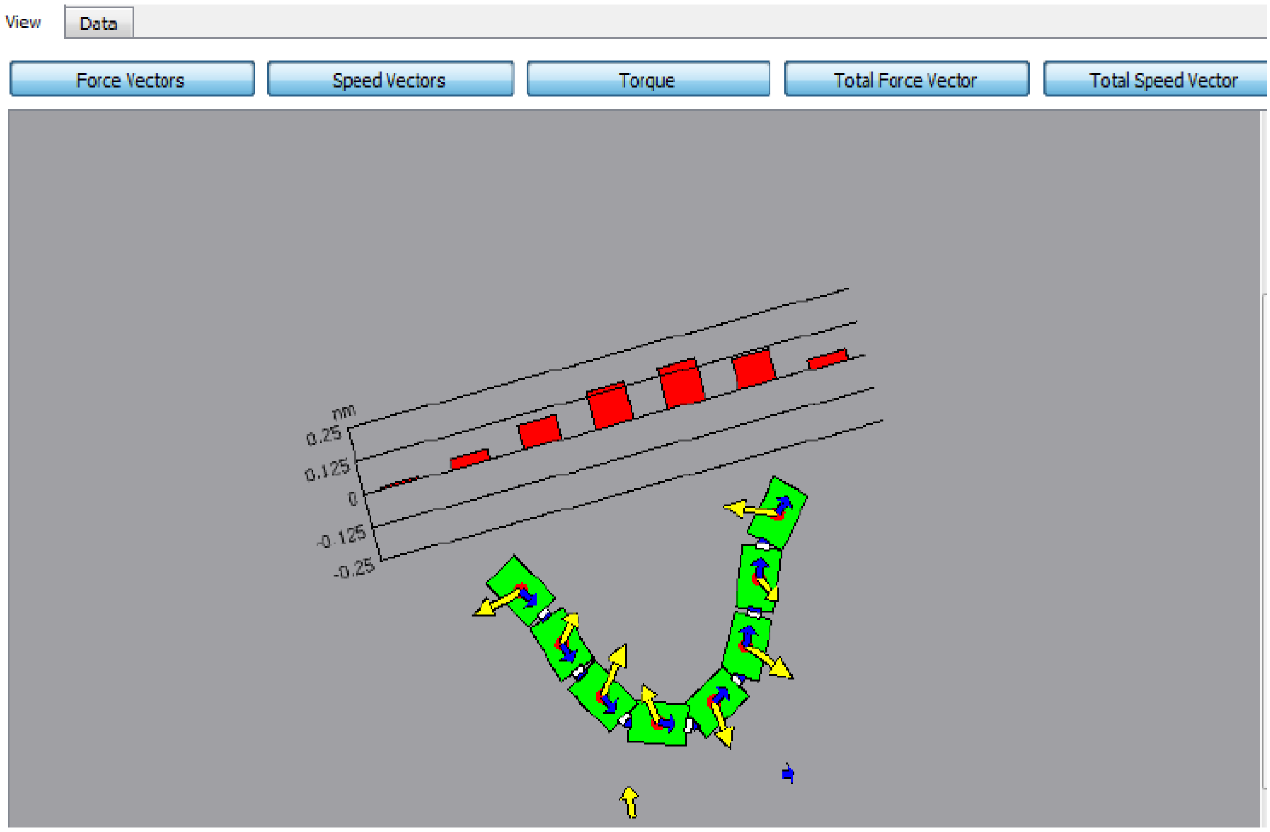

Fig. 2.1: A view of simulation of robot

2.2 Simulation Results

List of parameters used in the simulation:

Parameters	Value
L	55cm
M	100g
J	1/3ml2
μn	0.7
μt	0.1
Kp	50
Kd	10

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A	40degree
Ω	80degree s-1
N	8
Δ (360/N)	45degree

2.3 Notations

Symbol	Description
L	Half the length of links
M	Mass of links
J	Moment of inertia for each link
µn	Normal coefficient of friction
µt	Tangential coefficient of friction
Kp	Propotional gain in PID controller
Kd	Derivative control in PID controller
A	Amplitude of slithering
Ω	Joint angle frequency
N	No. Of links
Δ (360/N)	Phase shift

3. PROPOSED DESIGN

Design of snake like robot consists of three main parts :

- The modular segment
- Head
- Tail

Design of snake like robot require to convert muscle movement of snake into a robot. The design procedure consists of segments. The segments in the robot convert muscle movement into a robot with the help of the angular actuators. All the segments in the robot thus transfer the motion from one to another to appear like a wave like motion of robot.

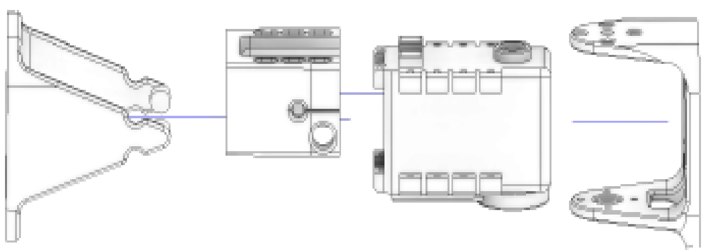

Fig 3.1 : Extended view of a segment of the robot [3]

3.1 The modular segment

The function of each segment is to produce a forward force so that the segments together can drive the robot. The segment consists of three designed parts and one servo.

- Base
- Flexible arm
- Propulsion arm

3.2Head

The head is the largest part of the assembly of robot. All the electronics are placed in the head part except the battery. It has an open design that has easy modifying of the electronics. It has 3 tracks for each circuit board that can fit and has 90 front. The IR sensors are positioned on each side of the 90 front and one on top known as three eyes. The back of the head has the flat flat side through which it is easy to attach and detach the head .

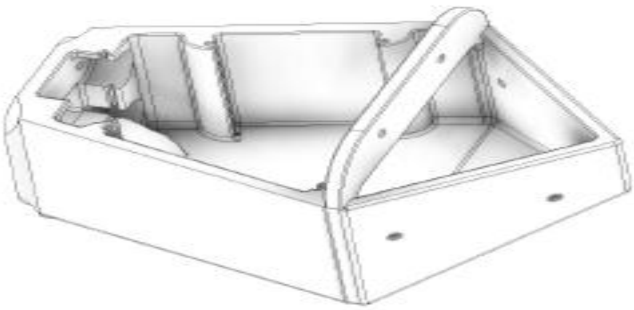

Fig 3.2: The Head [3]

3.3 Tail

The tail holds batteries and give the balanced weight to the last wheel. Then wheel is now capable for producing enough friction. The tail also improves the aesthetics of the robot. It has room for the lipo battery.

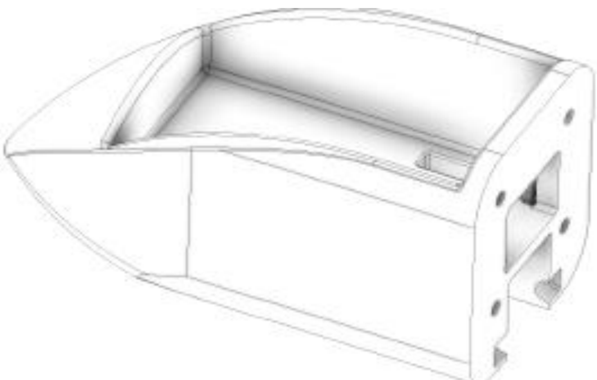

Fig. 3.3: The Tail [3]

3.4 Assembly of the whole robot

When all the seven segments are assembled one by one , the complete robot will be ready. In this , we have counted tail as first link and head as last link. Thus the complete robot design is obtained. For making its apperarance more like snake , all the parts of the robot are printed of black ABS plastic. [3]

Fig. 3.4: Assembly of the robot [3]

4. VIRTUAL VALIDATIONS ON PROPOSED DESIGN USING FINITE ELEMENT ANALYSIS (FEA)

4.1 Boundary Conditions & Calculations

1. Friction Force Acting B/w Wheel & ground; Ff=0.928*0.7=0.6496N.
2. Total Inertia acting on bot; It=0.928*A=0.02332N.
N(motor RPM)=60rpm
V=(pi*D*N)/60=0.05026 m/s
(Dia of spindle=16mm;Time of action=2s)
V=U+AT;
0.05026=0+A*2;
A=0.02513 m/s2
3. Tail Inertia; Irear=0.125*A=0.00314125N.
4. Head Inertia; Ih=0.089*A=0.002236N.
5. Inertia acting on each link; Il=0.102*A=0.002563N.
6. No. Of linkage = 8 (Head+Tail+Segments).
7. W=joint angle freq=1.3962 rad.
8. Ampl of each link = 0.6981 rad.
9. Total length; L=0.85m.
10. Joint angle differs from one in front & back = 0.7853 rad.
11. Torque due to motor; T=0.23Nm.
12. Motor Inretia; Im=53.5*9.81*10-3=0.5248N.
13. Weight can lift by the bot = 0.928*9.81*4=36.4147 N (4 Times the net weight of bot).

4.2 Material Selections

After a number of iterations with different types of materials like Mild Steel, stainless steel, steel alloys etc. With taking cost of manufacturing strength characteristics and hardness values of the materials and We have selected the final material ABS (Acrylonitrile-Butadiene-Styrene).

Properties of ABS according to studies is appended below –

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Technical Data:

Property, Test Condition	Standard	Unit	values
Rheological Properties			
Melt flow index 220 °C/10 kg	ISO 1133	gms/10 min	35
Mould Shrinkage	D 955	%	0.4-0.6
Mechanical Properties			
Rockwell Hardness	ISO 2039/2	R-Scale	105
Tensile Strength at yield (50 mmm /min)	D 638	Kg/cm2	525
Tensile Modulus (50 mm /min)	D 638	Kg/cm2	27,000
Flexural strength (5mm/min)	D 790	Kg/cm2	750
Flexural modulus(5mm / min)	D 790	Kg/cm2	26,000
Izod notched impact strength (at 1/4" thickness)	D 256	Kg cm/cm	21
Izod notched impact strength (at 1/8" thickness)	D 256	Kg cm/cm	24
Thermal Properties			
Vicat Softening Temperature	D 1525	°C	97
Heat Deflection Temperature (annealed 80°C/ 4 Hrs , 1.80 MPA)	D 648	°C	92
Heat Deflection Temperature (annealed 80 °C/ 4Hrs; 0.45 MPa)	D 648	°C	96
Other Properties			
Specific gravity	D 792		1.04

Properties of Outline Row 4: ABS

	A	B	C
1	Property	Value	Unit
2	Density	1.53	g cm^-3
3	Isotropic Elasticity		
4	Derive from	Young's Mo...	
5	Young's Modulus	27000	Pa
6	Poisson's Ratio	0.29	
7	Bulk Modulus	21429	Pa
8	Shear Modulus	10465	Pa
9	Field Variables		
10	Temperature	Yes	
11	Shear Angle	No	
12	Degradation Factor	No	
13	Tensile Yield Strength	525	MPa
14	Compressive Yield Strength	525	MPa
15	Tensile Ultimate Strength	750	MPa
16	Compressive Ultimate Strength	750	MPa

Fig.4.1: Material Properties Input in Ansys Workbench version 16.0 Library

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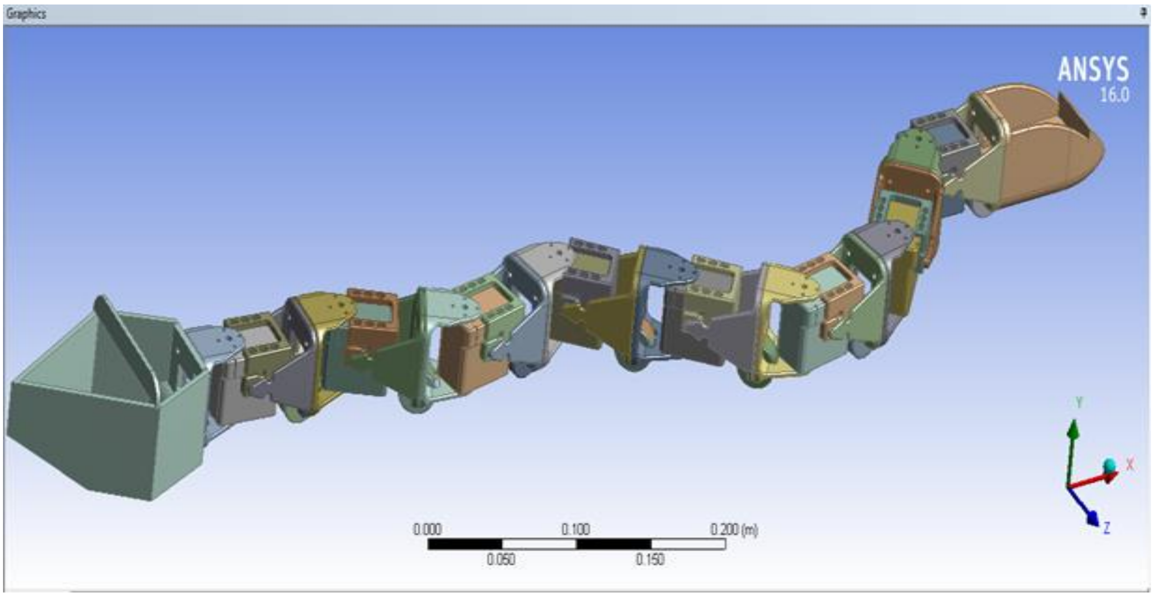

Fig.4.2: Proposed Snake robot Assembly

4.3Analysis of robot Tail

1. Geometry

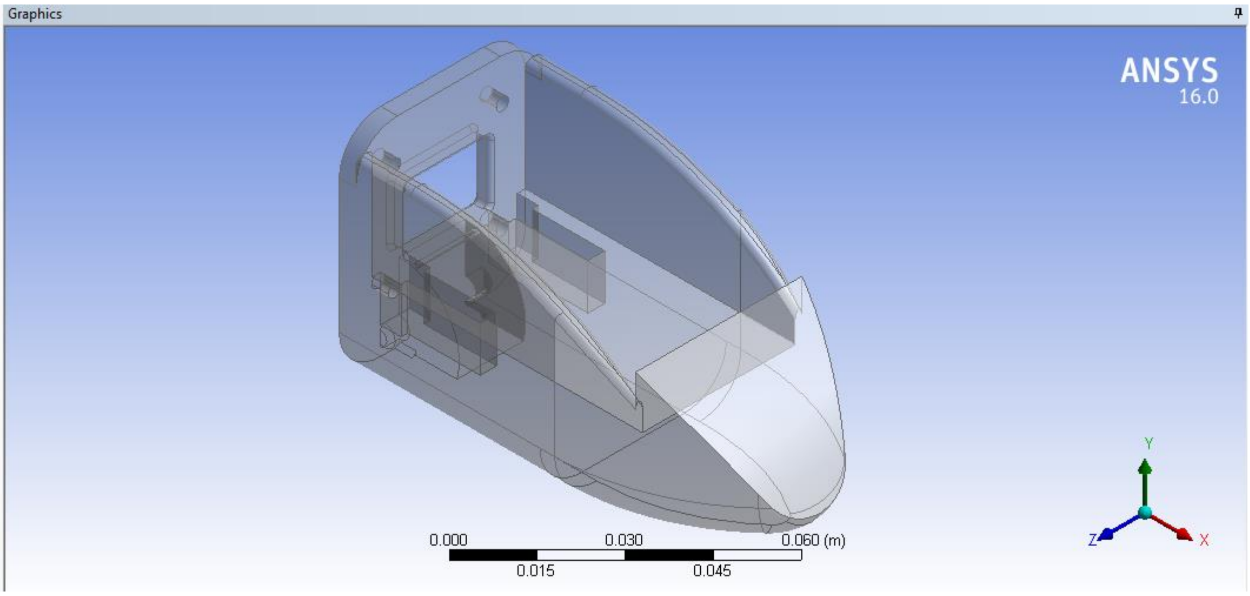

Fig.4.3 Geometry

2. Meshing

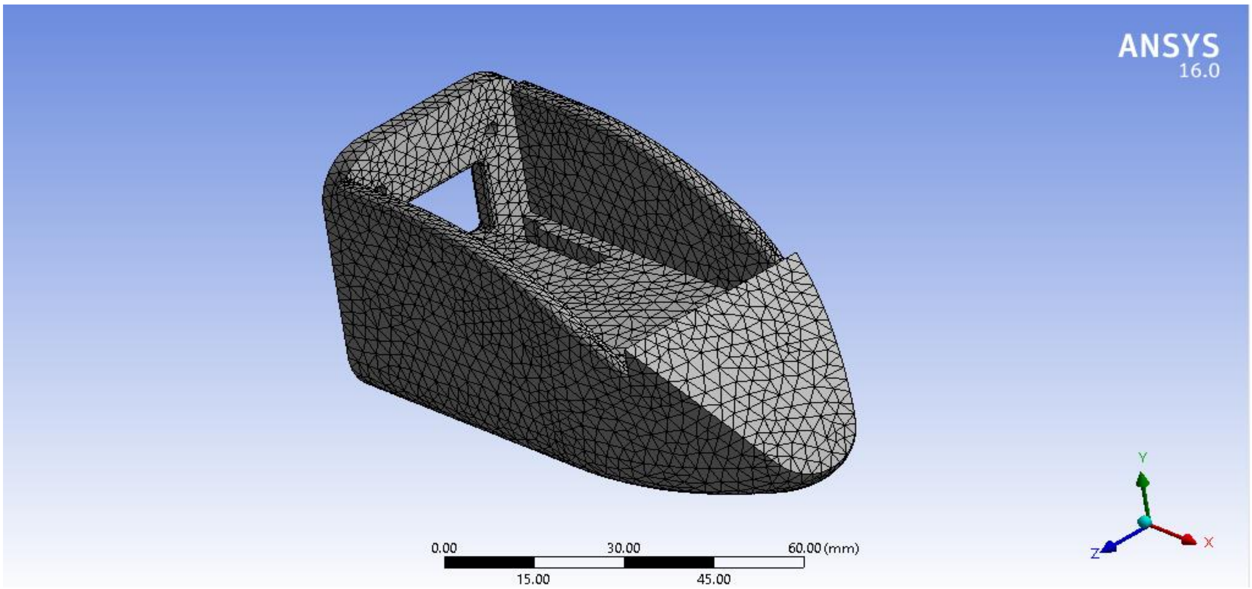

Fig.4.4: Meshed Elements

For meshing, CATPART file buoy is imported to ANSYS 16.0 Since all the dimensions of the sprocket are measurable, the best element for meshing is the tetrahedral element. Meshing tool in ANSYS workbench is used to create a very fine mesh

Meshing parameters-
Aspect Ratio =1.84 (avg)
Jacobian = 0.8
Element Quality = 0.88
Warping Factor = 0.00

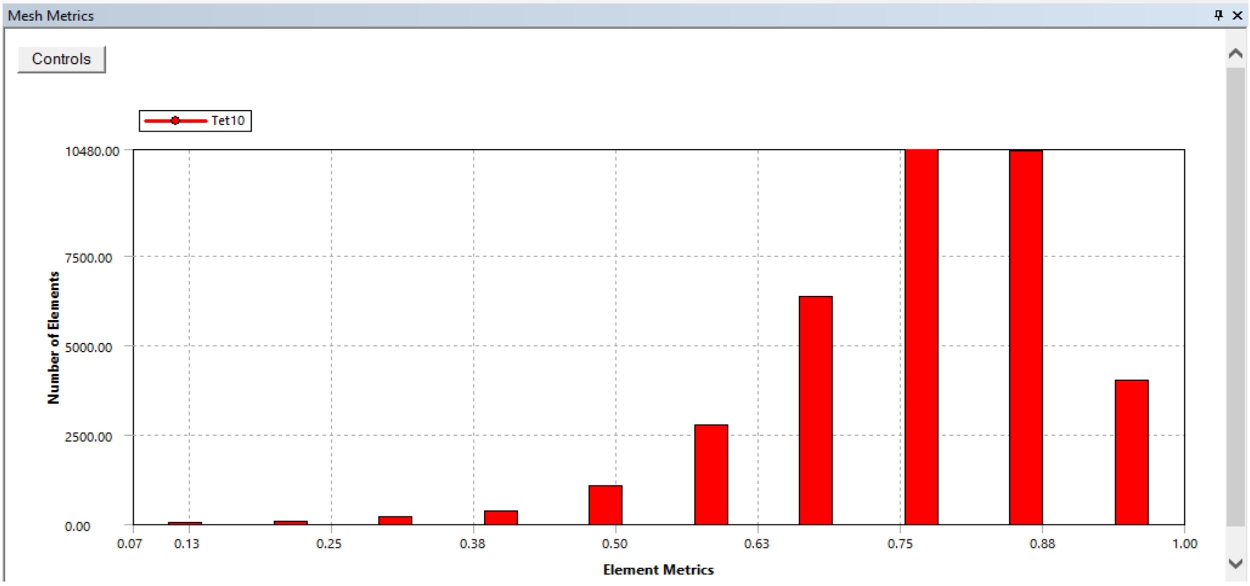

Fig.4.5: Bar Graph of Elemental mesh Metrics

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3. Boundary Conditions

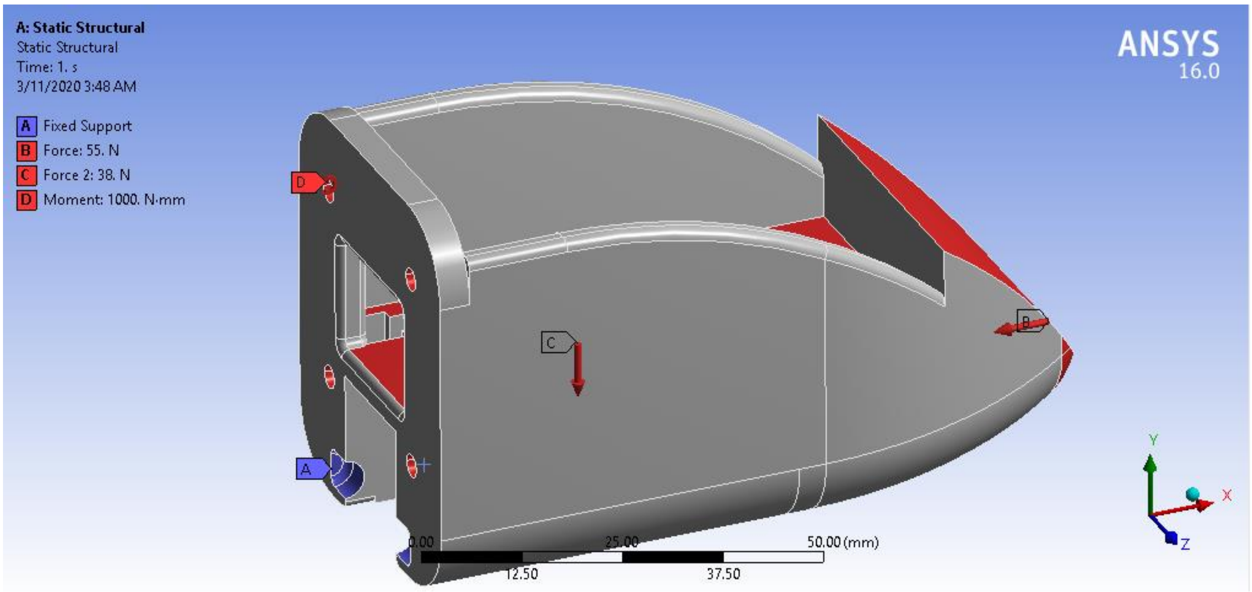

Fig.4.6: Force Applied on faces (Boundary conditions)

4. Results

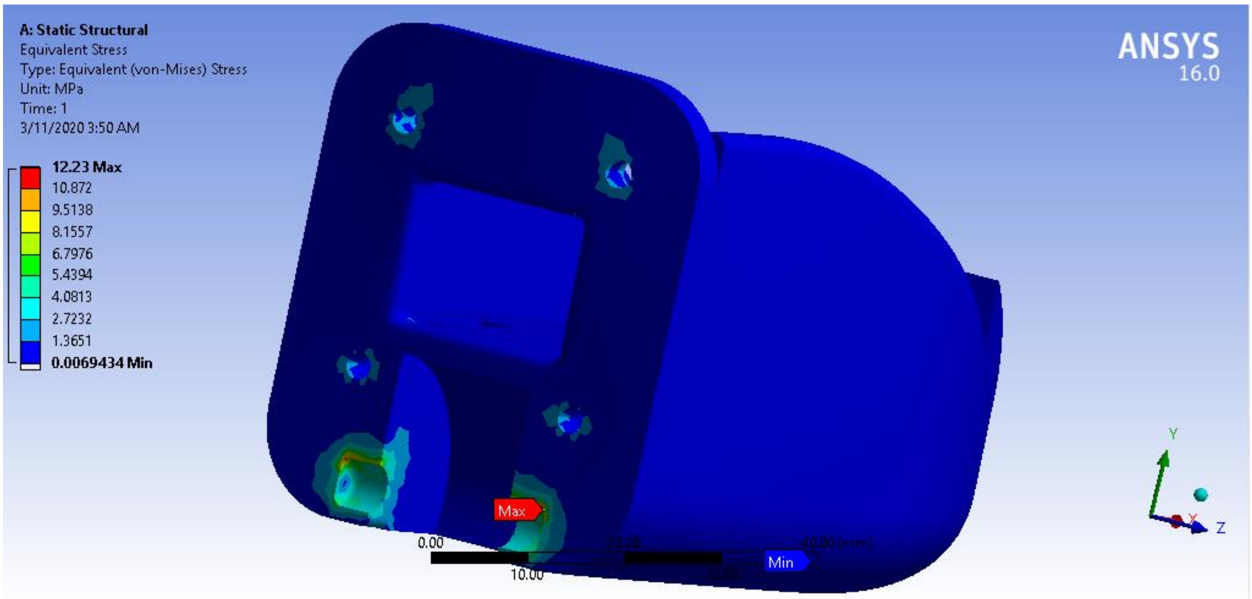

Fig.4.7: Equivalent Von Mises Stress

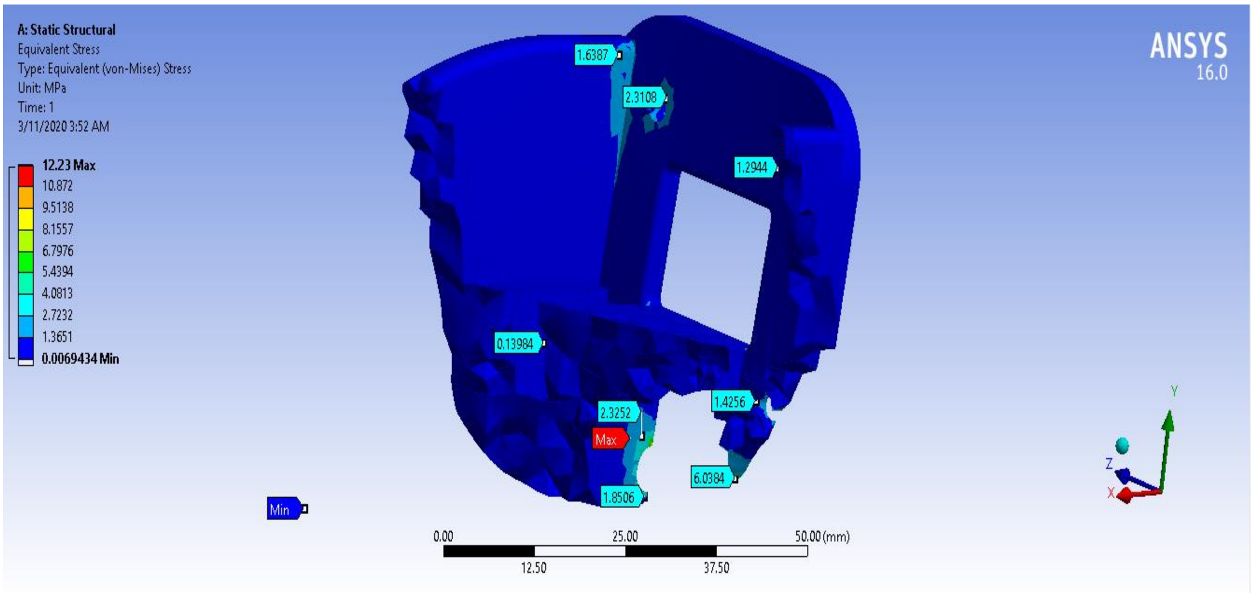

Fig.4.8: Cut Sections of most affected zone

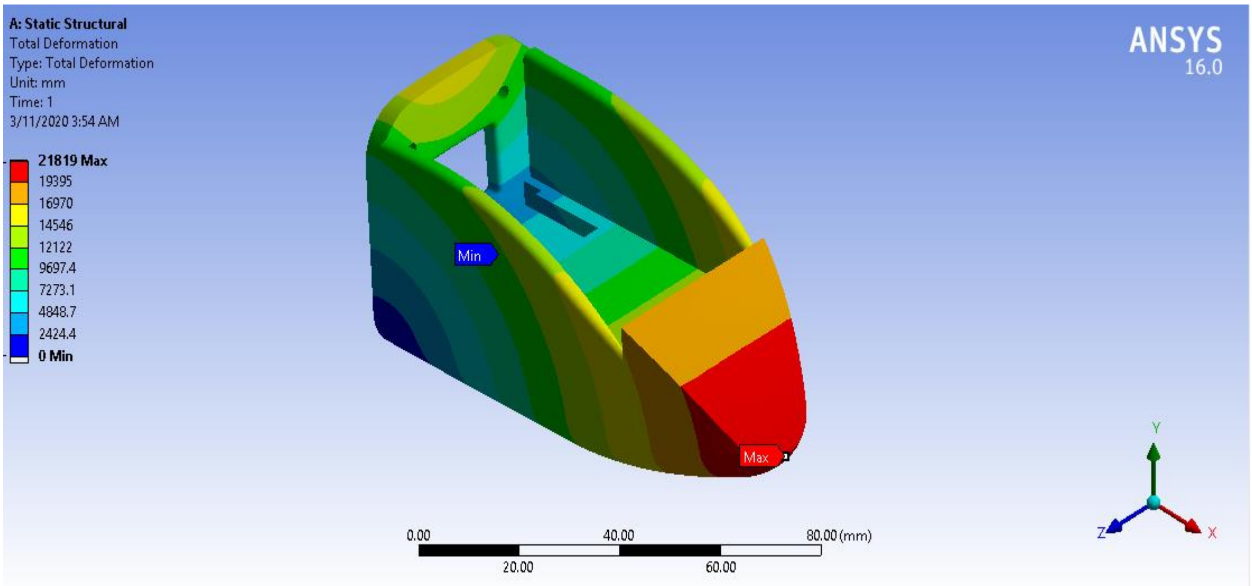

Fig.4.9 :Total Deformation in X – Direction

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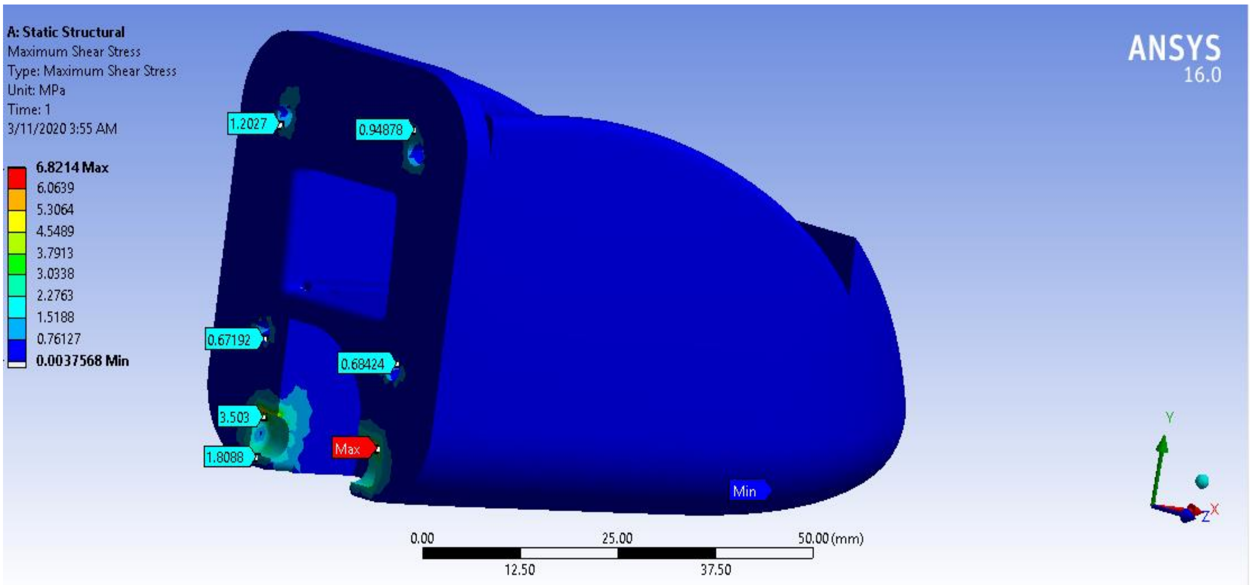

Fig.4.10: Maximum Shear stress Induced

Thus maximum Equivalent stress induced is 12.23 Mpa which is less than ABS ultimate tensile stress value and thus it is safe.

4.4.1Analysis of robot Base

1. Geometry-

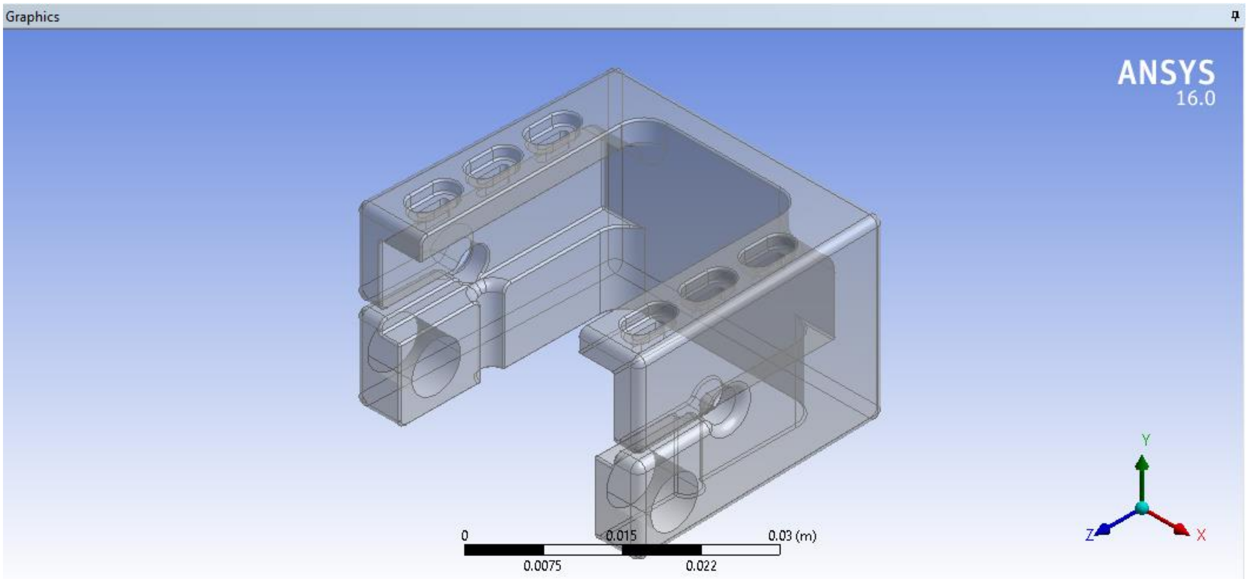

Fig.4 11 :Geometry

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2. Meshing-

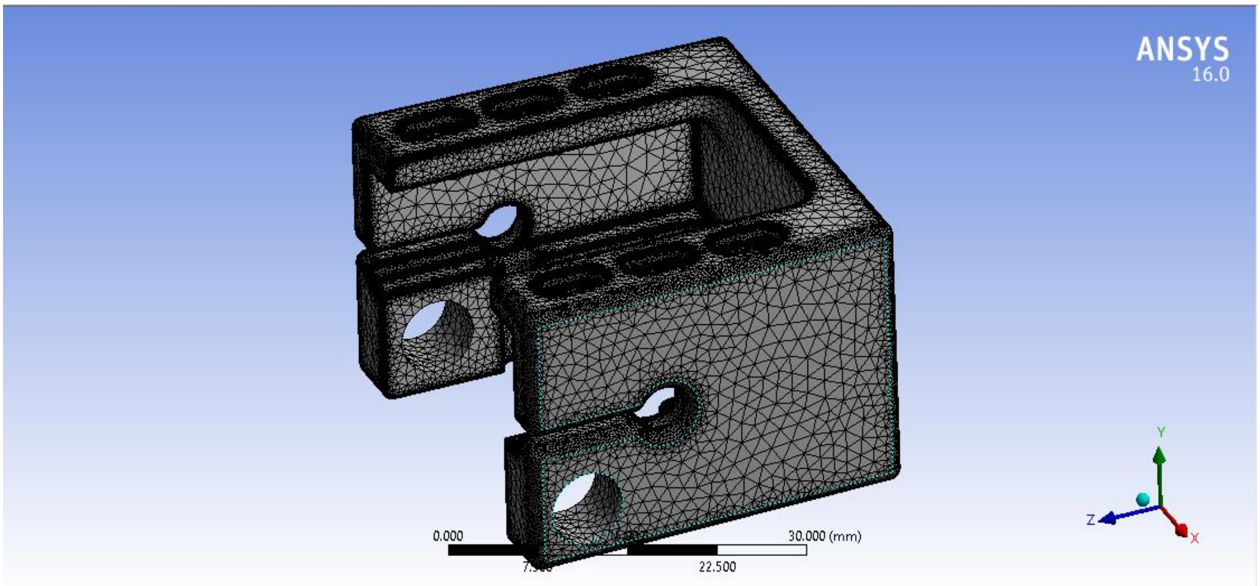

Fig.4.12: Meshed Elements

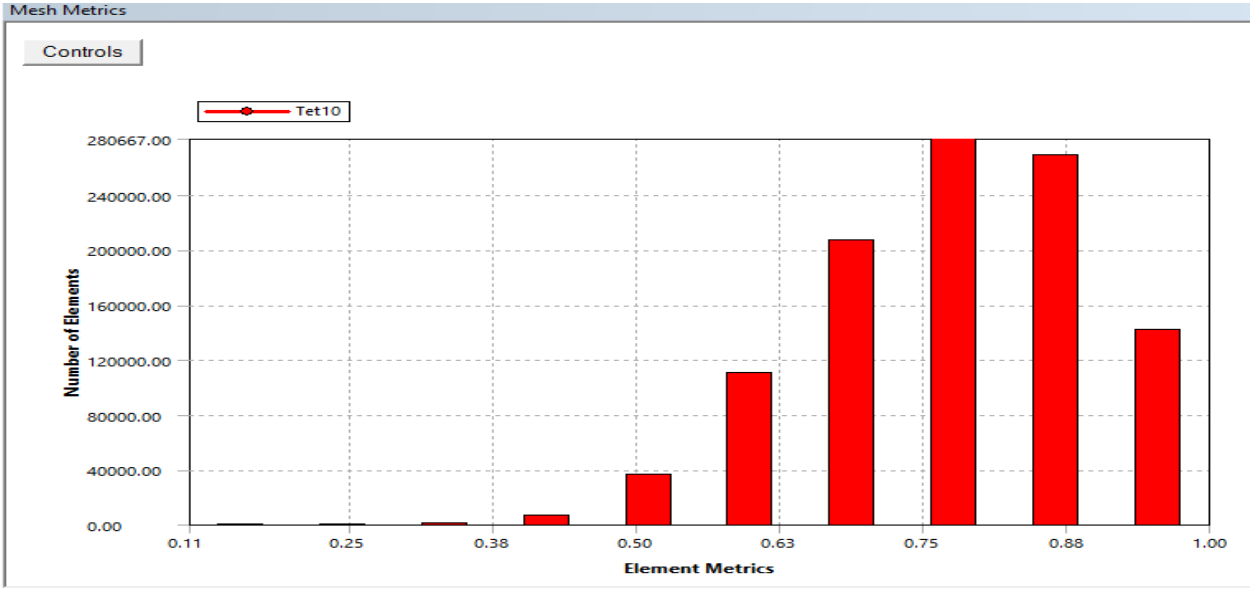

Fig.4.13: Bar Graph of Elemental mesh Metrics

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3. Boundary Conditions

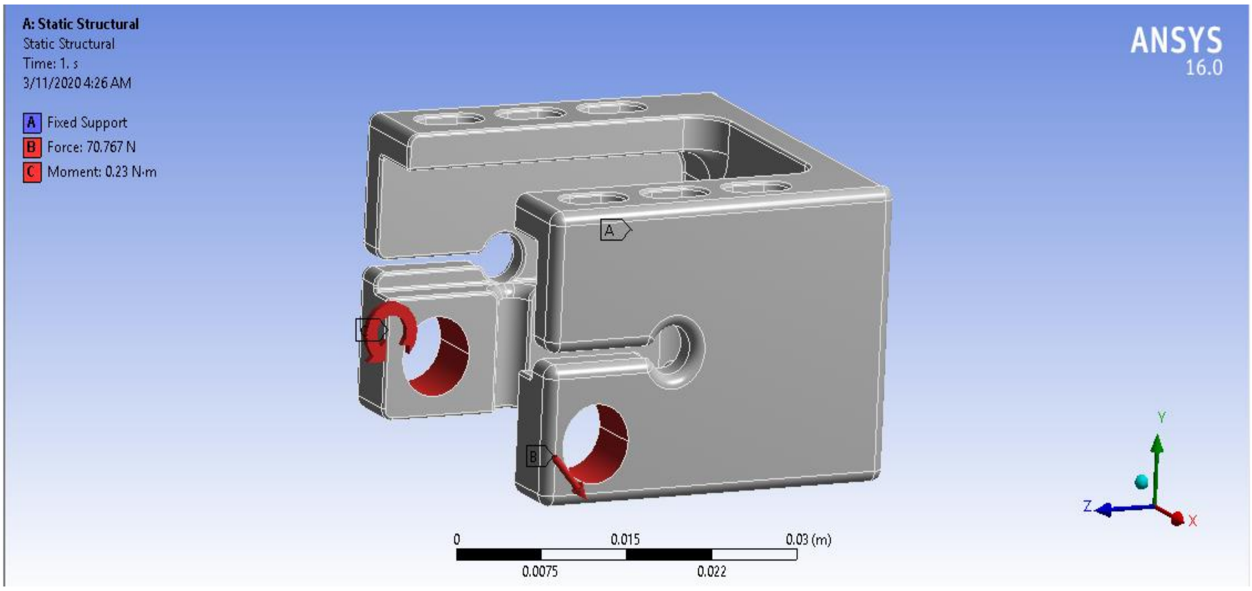

Fig.4.14: Force Applied on faces (Boundary conditions)

Results

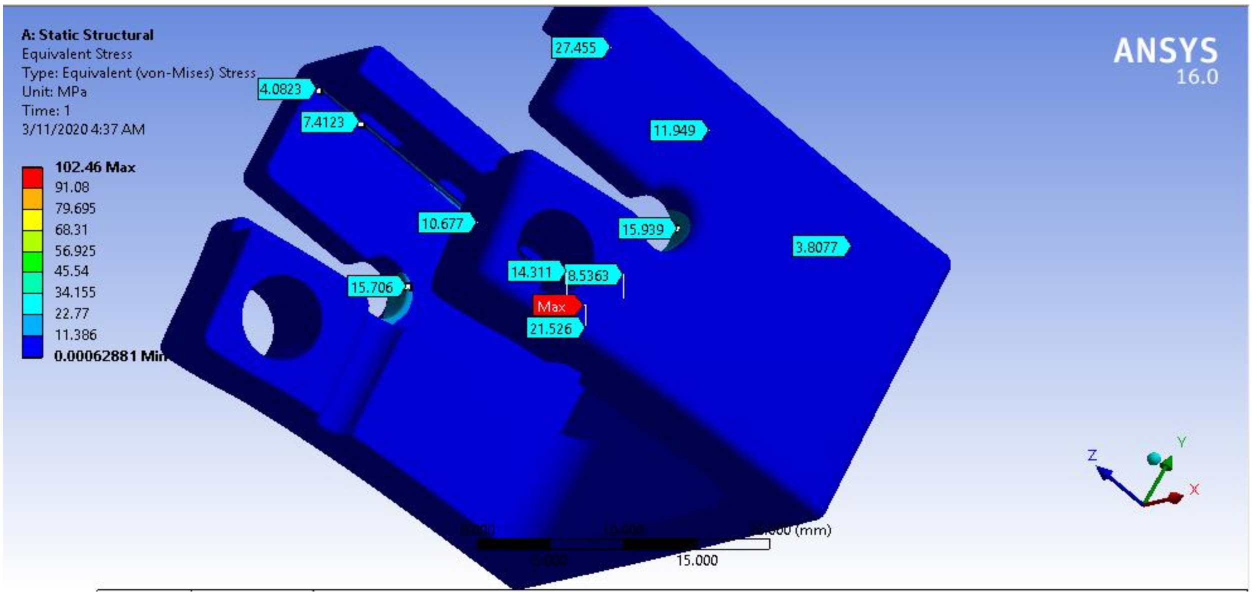

Fig.4.15: Von mises stress

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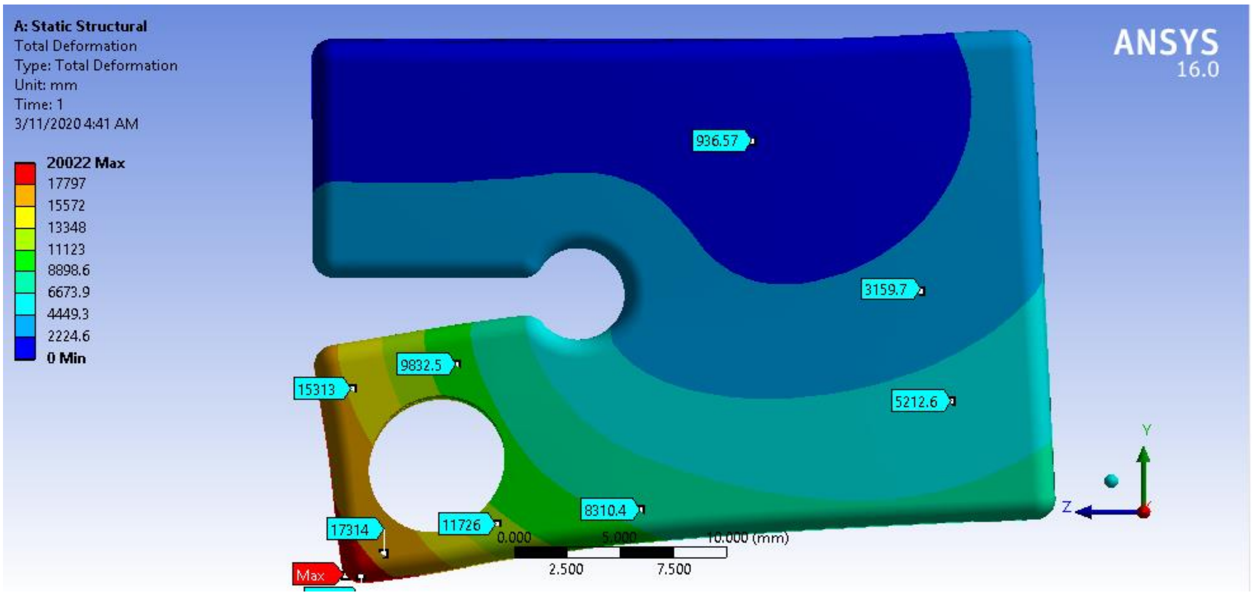

Fig.4.16: Total Deformation in X - Direction

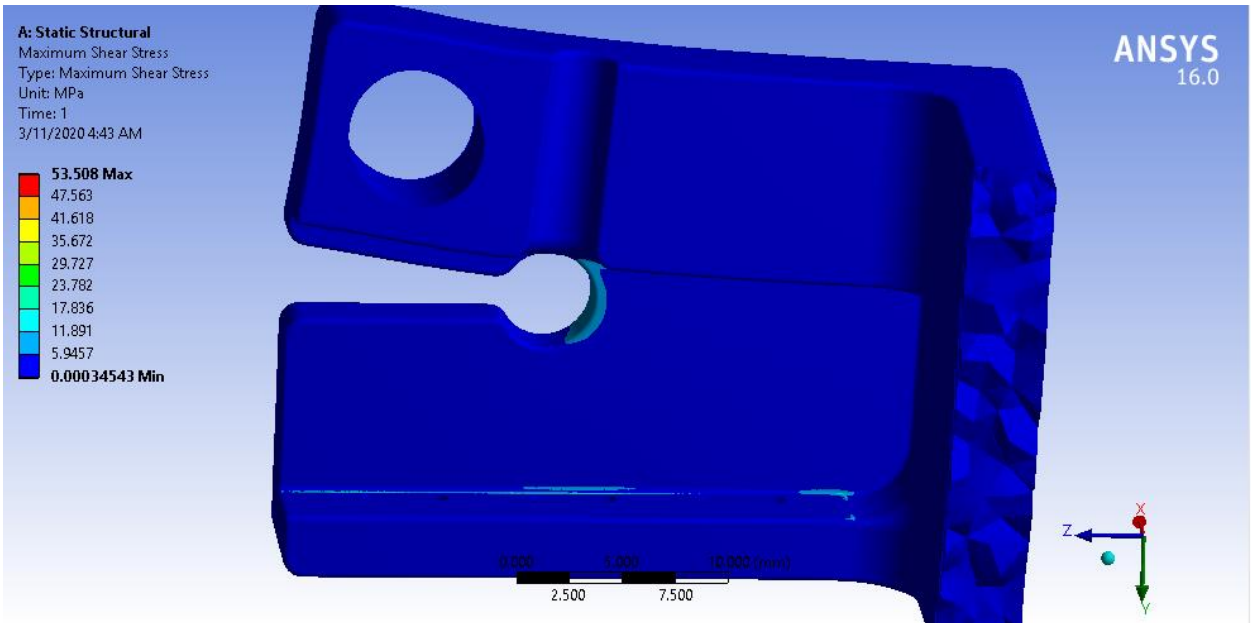

Fig.4.17: Maximum Shear Stress

Thus maximum Equivalent stress induced is 102.00 Mpa which is less than ABS ultimate tensile stress value and thus it is safe.

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4.4.2 Analysis of robot Link 01

1. Geometry

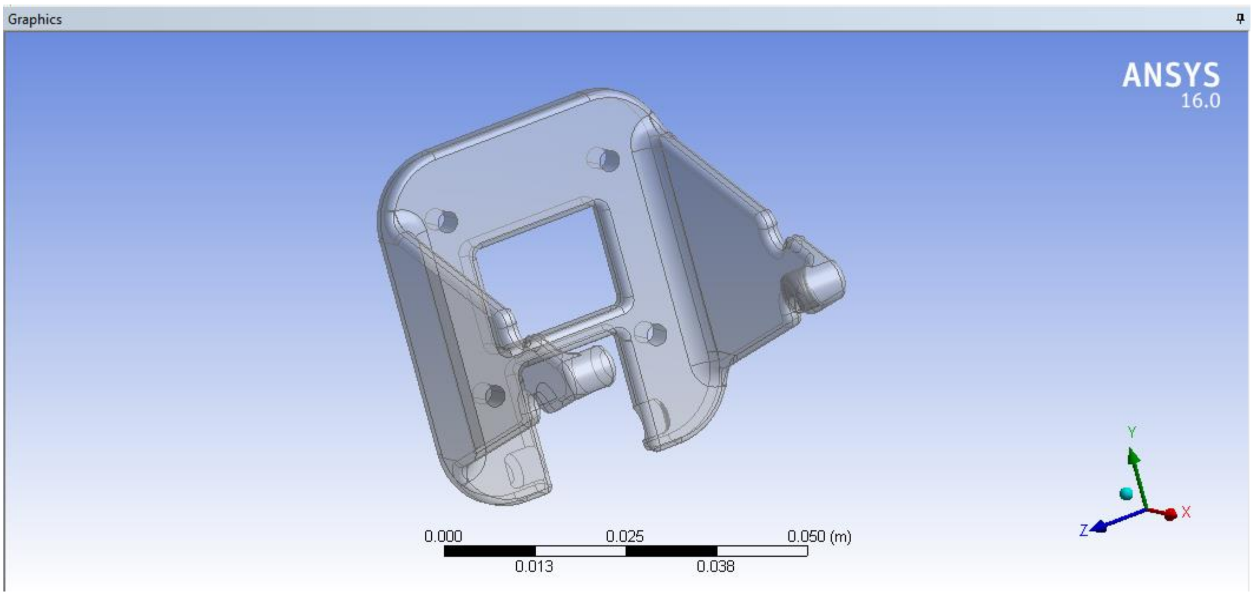

Fig.4.18: Geometry

2. Meshing

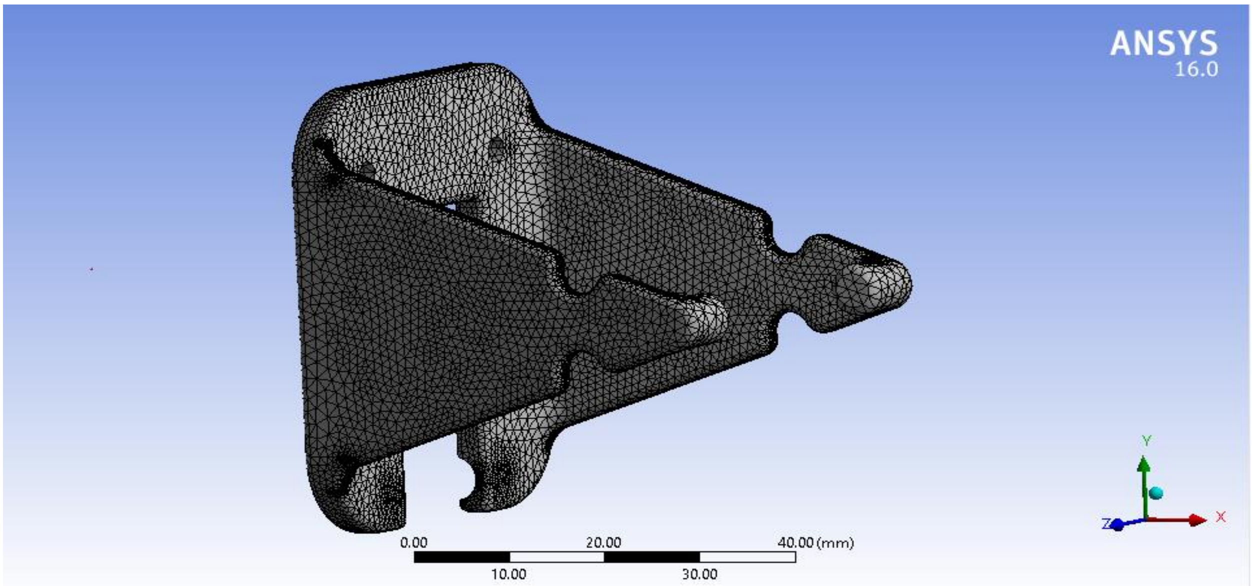

Fig.4.19: Meshed Elements

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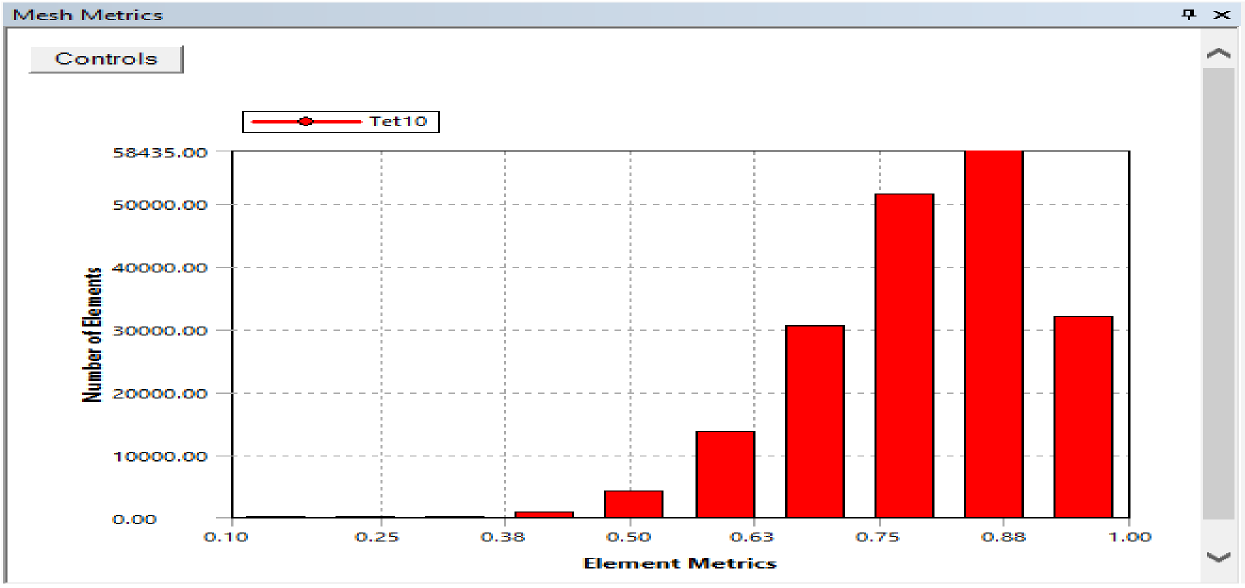

Fig.4.20: Bar Graph of Elemental mesh Metrics

3. Results

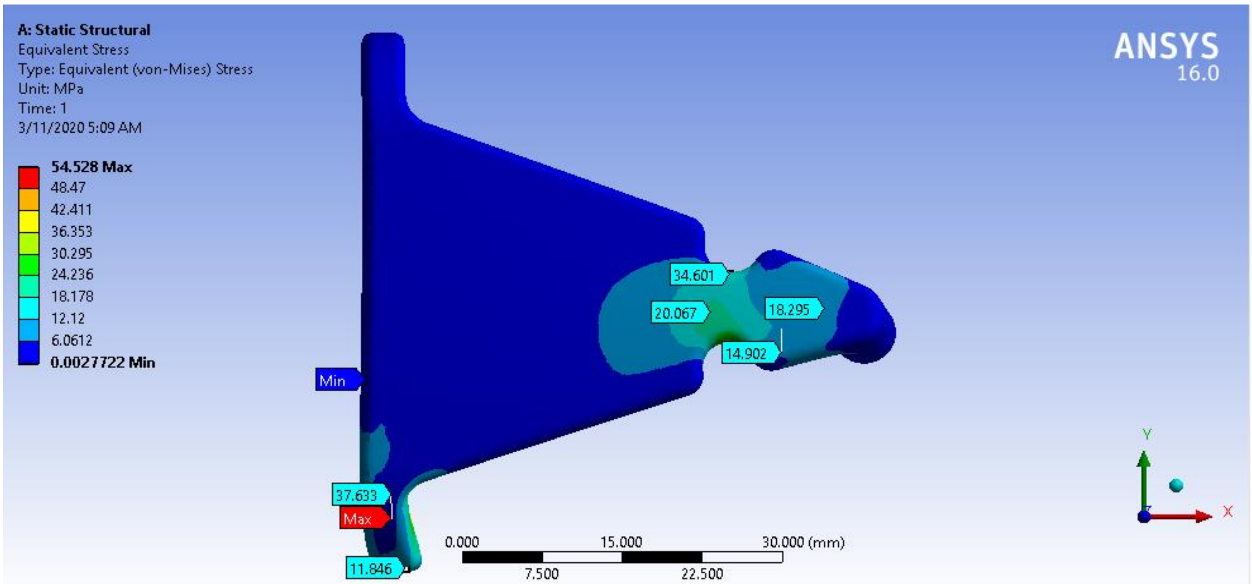

Fig.4.21: Von mises stress (Size View)

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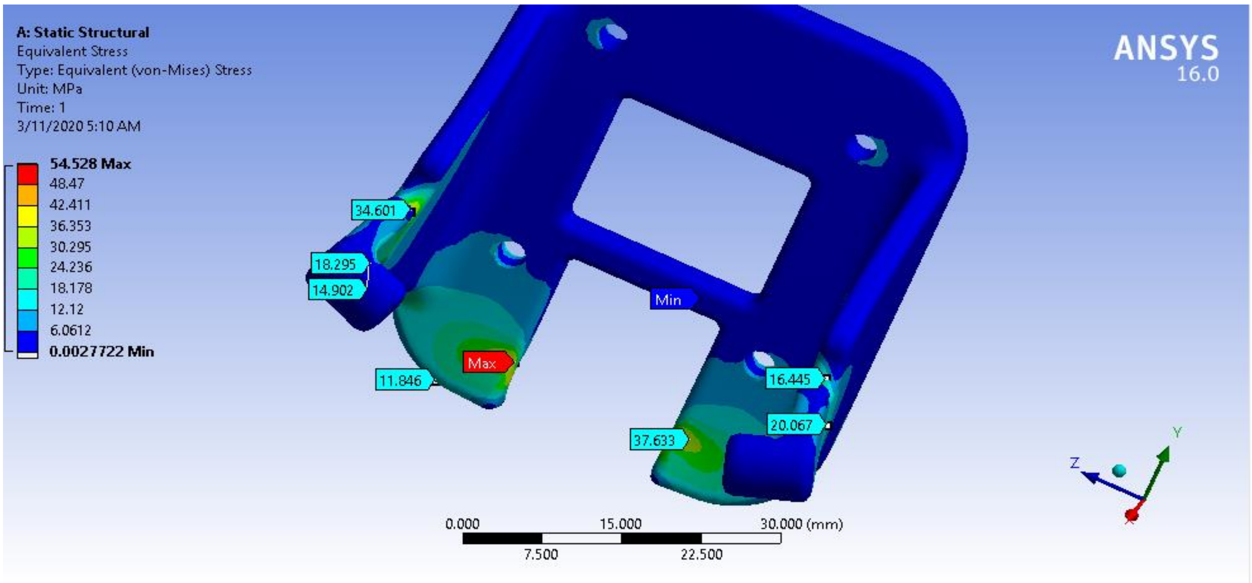

Fig.4.22: Von mises stress (isometric view)

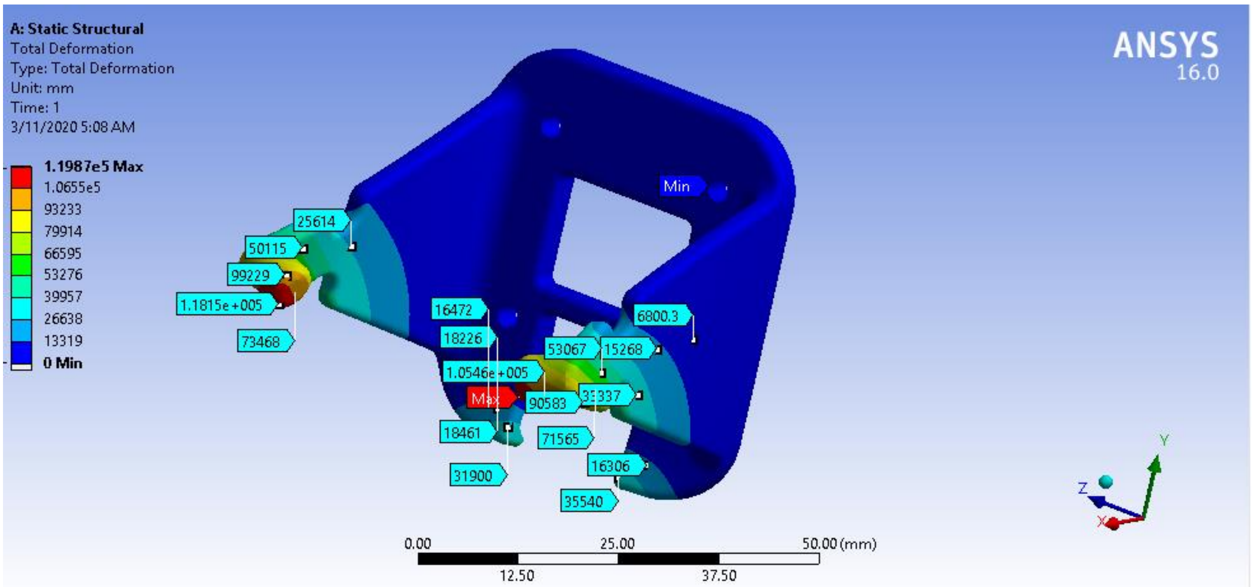

Fig4.23: Total Deformation (isometric view)

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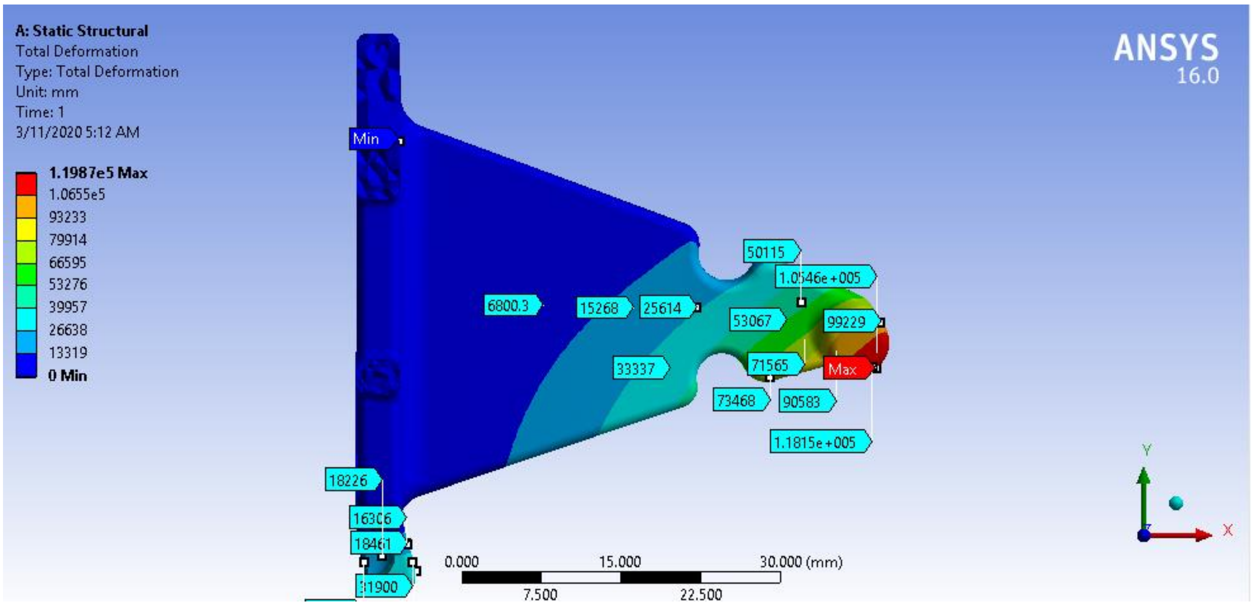

Fig.4.24: Total Deformation (Size View)

Thus maximum Equivalent stress induced is 54.28 Mpa which is less than ABS ultimate tensile stress value and thus it is safe.

4.4.3 Analysis of robot Link 02

1. Geometry

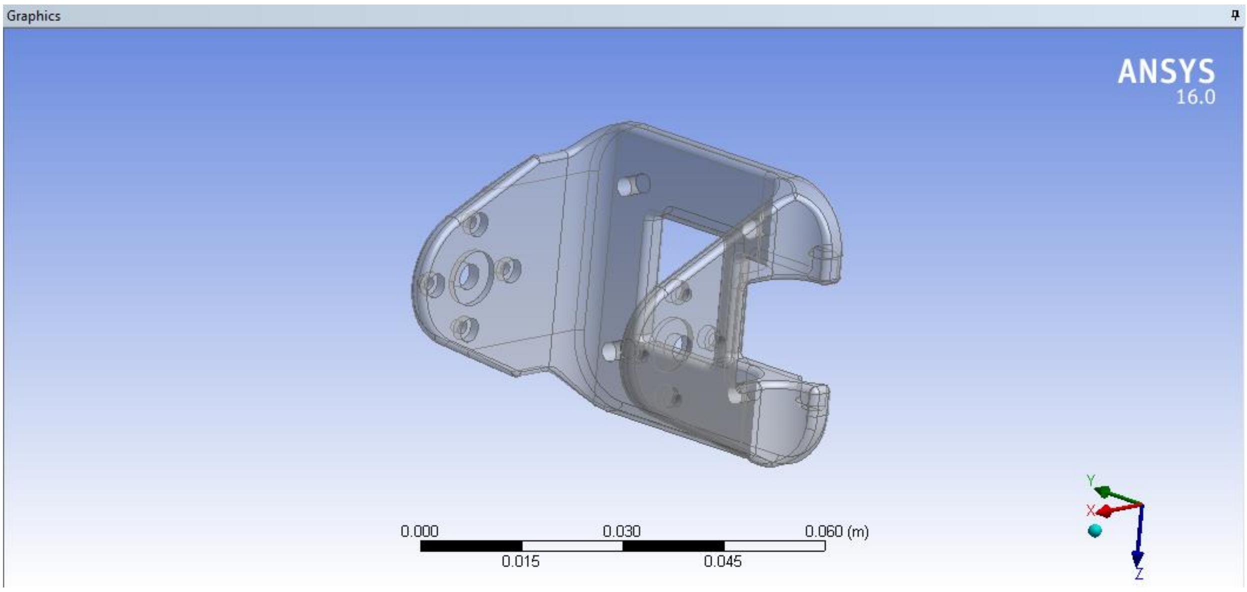

Fig.4.25: Geometry

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2. Meshing

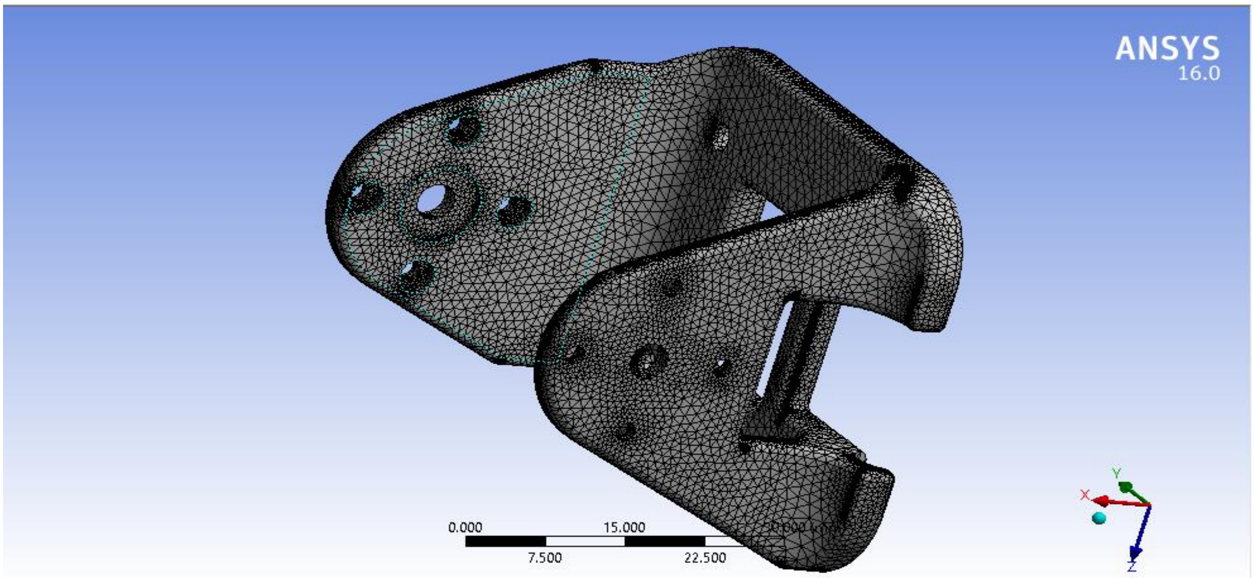

Fig4.26: Meshed Element

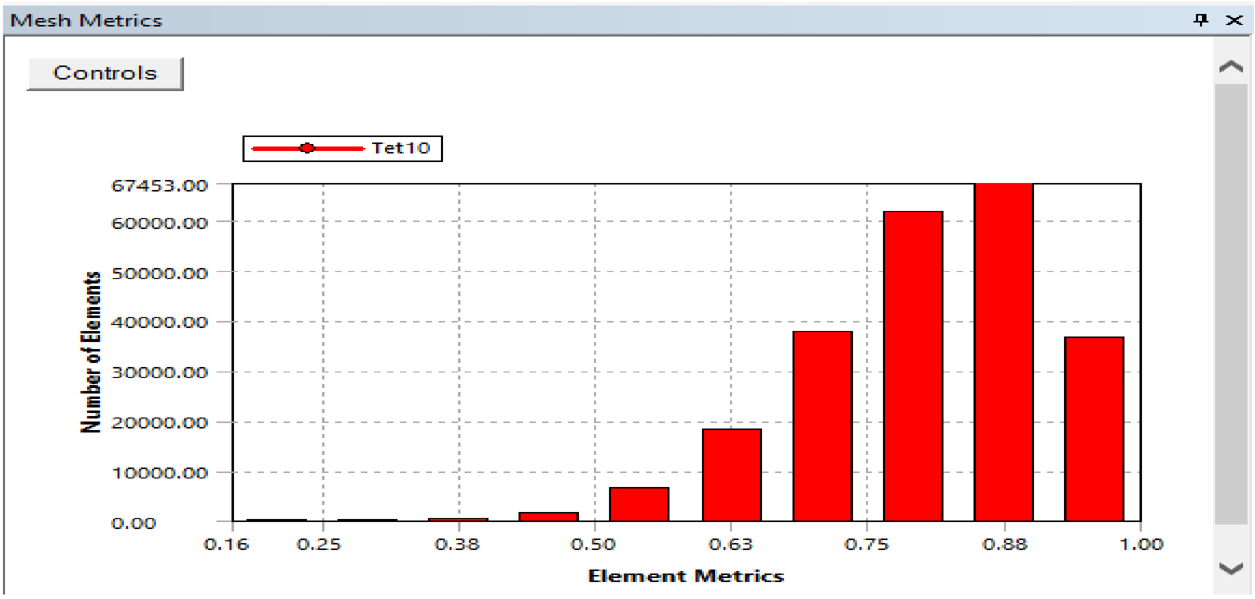

Fig.4.27: Bar Graph of Elemental mesh Metrics

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3. Boundary Conditions

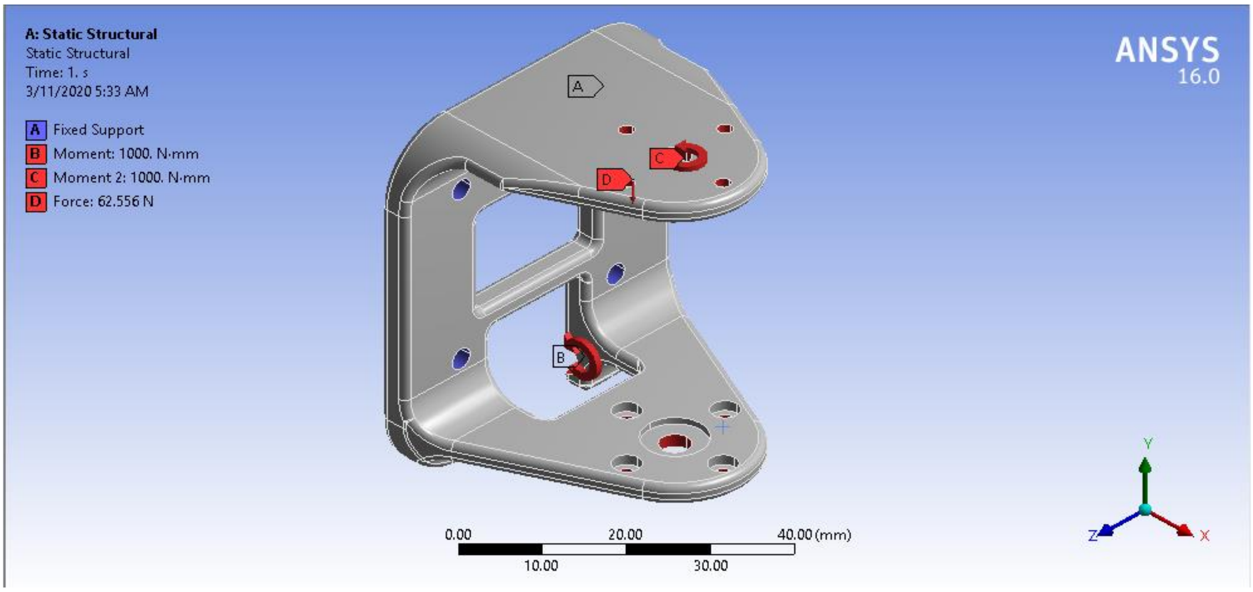

Fig.4.28: Force Applied on faces (Boundary conditions)

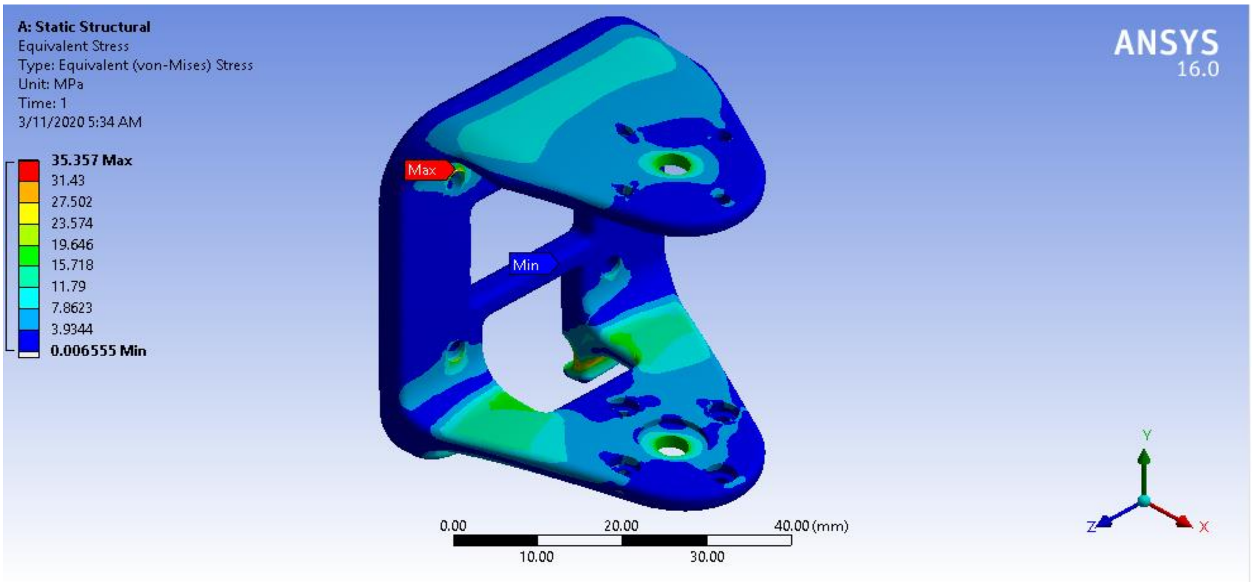

Fig.4.29: Von mises stress (isometric view)

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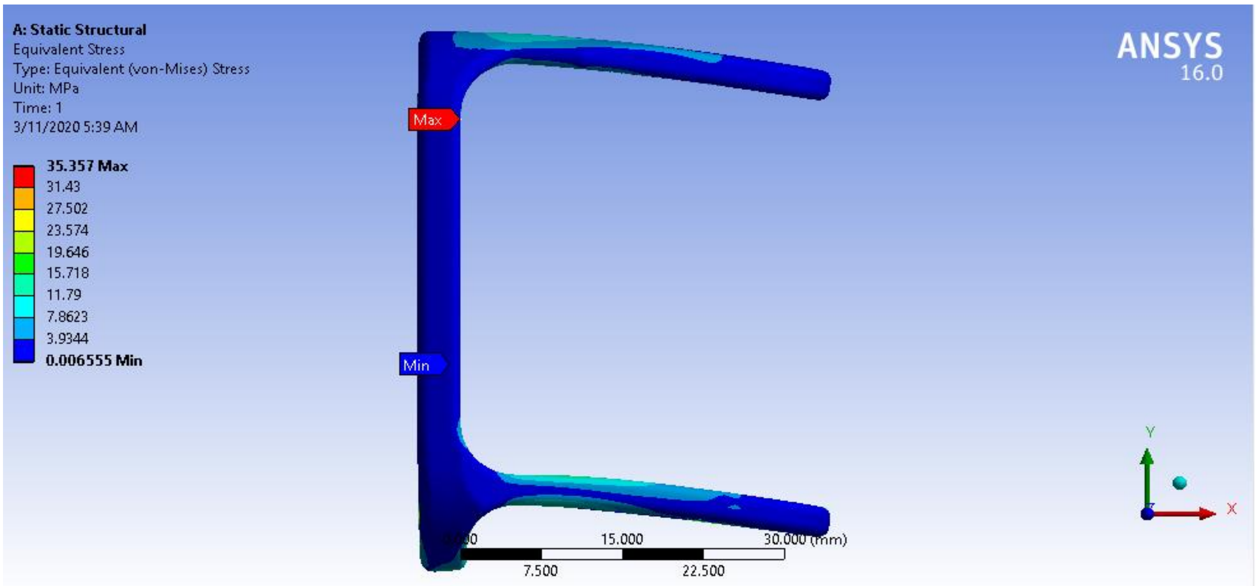

Fig.30: Von mises stress (Top view)

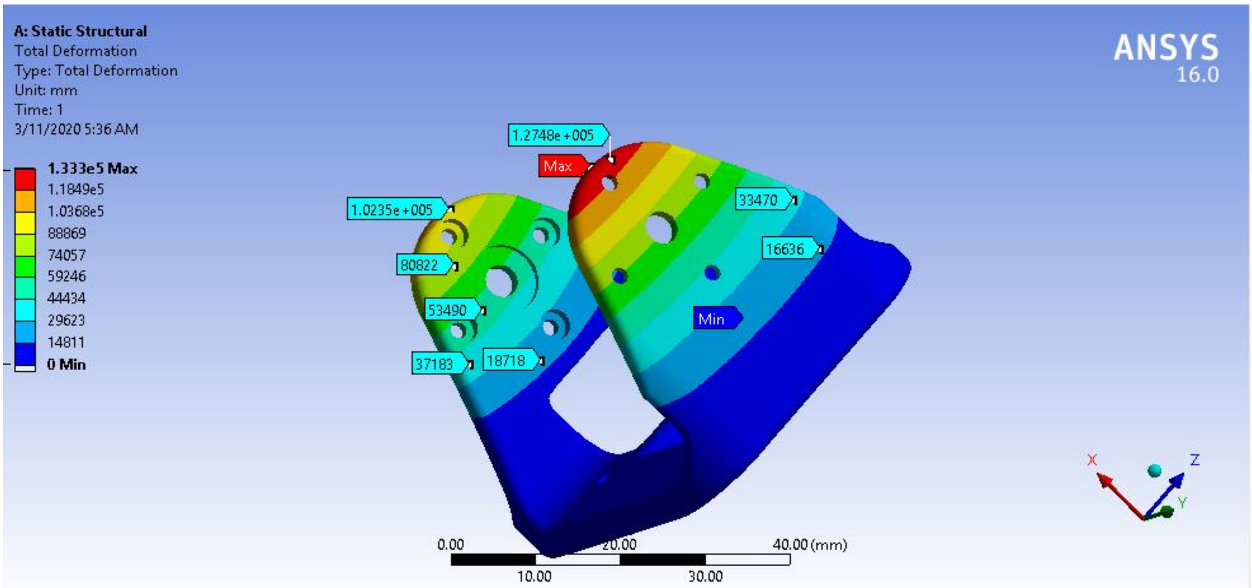

Fig.4.31: Total Deformation

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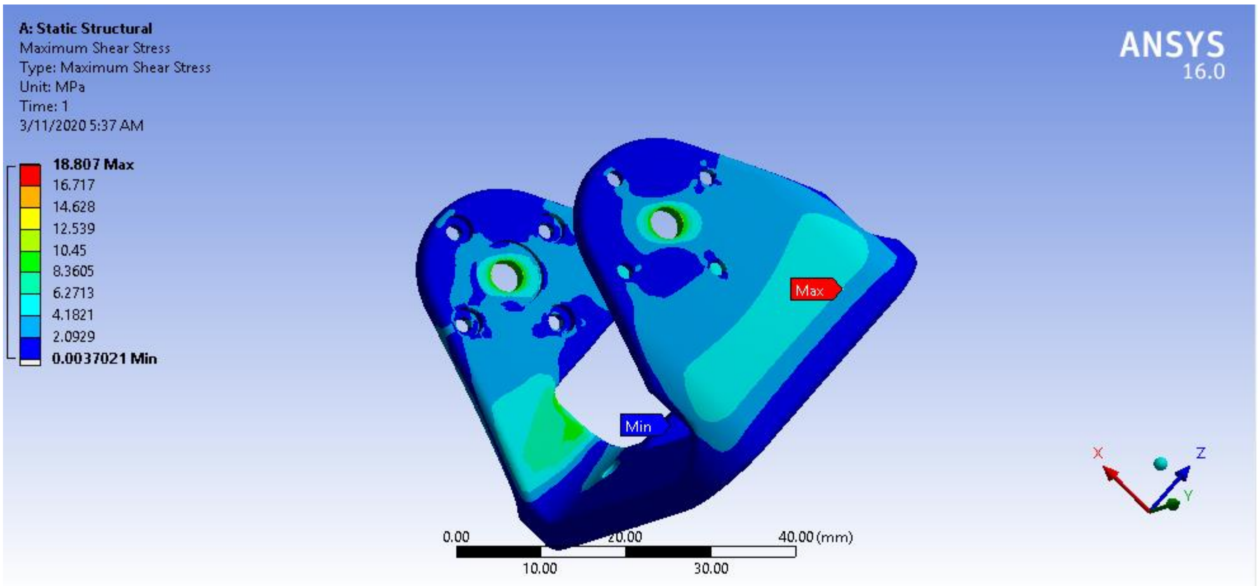

Fig.4.32: Maximum Shear Stress

Thus maximum Equivalent stress induced is 35.3 Mpa which is less than ABS ultimate tensile stress value and thus it is safe.

CONCLUSION

To summaries, design, simulation and analysis of snake-like robot was made. The design of robot had the ability of moving forward using the movement lateral undulation and succeeded to meet almost all of the demands.

The final product of design, simulation and analysis emulated the movement and appearance of a biological snake in a satisfactory way. In order to make the snakes movement lateral undulation meaningful and suitable, a different source of friction other than wheels would be necessary to make the robot handle uneven terrain in a more efficient way. Thus this design and analysis of the robot will result in the robot which will mimic the lateral undulation .The resulting robot is however a great step in the right direction and has lot of room for further development.

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