ME 451: Final Evaluation

Design and Fabrication of Throat Surgery Holder and Retractor

BTP Group Number 23

Group Members:
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Sunil Kumar (13723)

Project Supervisors:
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DEPARTMENT OF MECHANICAL ENGINEERING
IIT KANPUR

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The Problem and the Solution

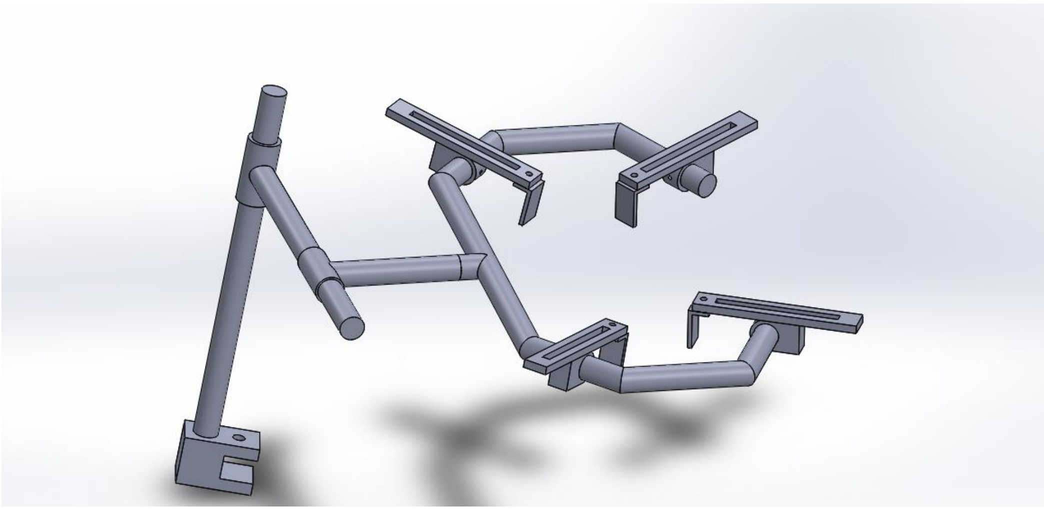
Problem:

Rural community health centres in India are facing **83 per cent shortage of surgeons** [1]**.** Moreover, currently at least two surgeons are required to perform a surgery where the second surgeon's job is mostly to hold the tissue and flesh at the incision using hand-held retractors.
In this project, our objective is to reduce the skilled man-power required during operations by designing a mechanical system with the capabilities of holding and retracting skin and tissue at the incision during surgeries and thereby providing a more efficient and obstruction-free surgical site for surgeons.

Proposed solution:

We propose a multitasking mechanical framework to assist the surgeon by holding and retracting skin and tissues at the incision without manual support. The whole system with multiple degrees of freedom will be mounted on a stand which will be fixed with the patient's bed providing stability. Retractor blades will be designed with the ability to adjust according to body profile appropriately during surgery and hold the skin at incision.

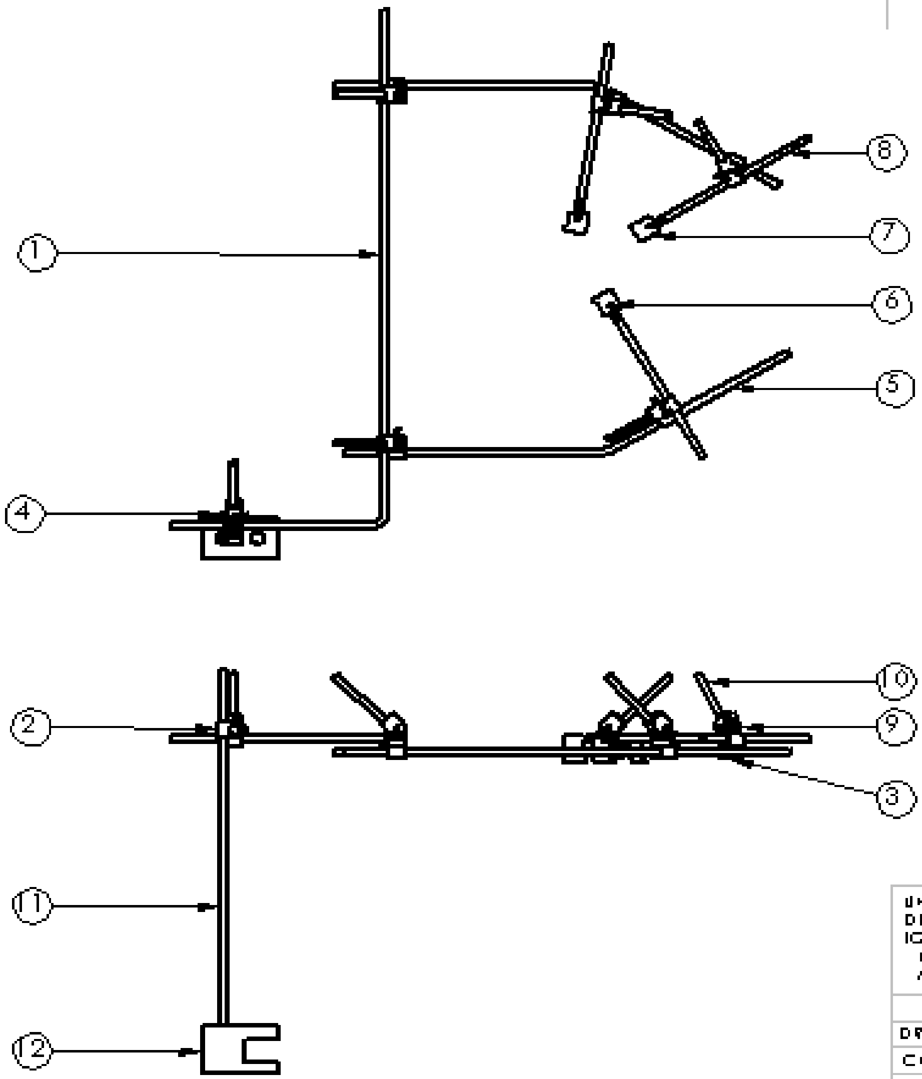
Conceptual Solution:



Deliverable:

At the end of the manufacturing, we will be present a working laboratory prototype of the complete retractor system. We will be display a simulation of the prototype which will be used by a single individual and thereby successfully reduce the man power required in the surgery**.**

[1] http://scroll.in/article/756973/indias-community-health-centres-are-in-dire-need-of-more-specialists



PART NO.	PART NAME	QTY.
1	rod1	1
2	connector	12
3	connector_pin	6
4	lever_pin	6
5	rod2	2
6	B18.6.7M - M2 x 0.4 x 6 Indented HHMS --6C	3
7	blade	3
8	bladerod	3
9	cam	6
10	lever	6
11	tablemount_shaft	1
12	tablemount_base	1

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETER
TOLERANCES:
LINEAR: ±1
ANGULAR: ±1°

	DATE	NAME	SIGNATURE
DRAWN	04/11/16	Group 23	
CHK'D			
APPV'D			
MFG			

MATERIAL:

TITLE:
ME451A Group 23
Design and Fabrication of Throat Surgery Holder and Retractor

GROUP MEMBERS:
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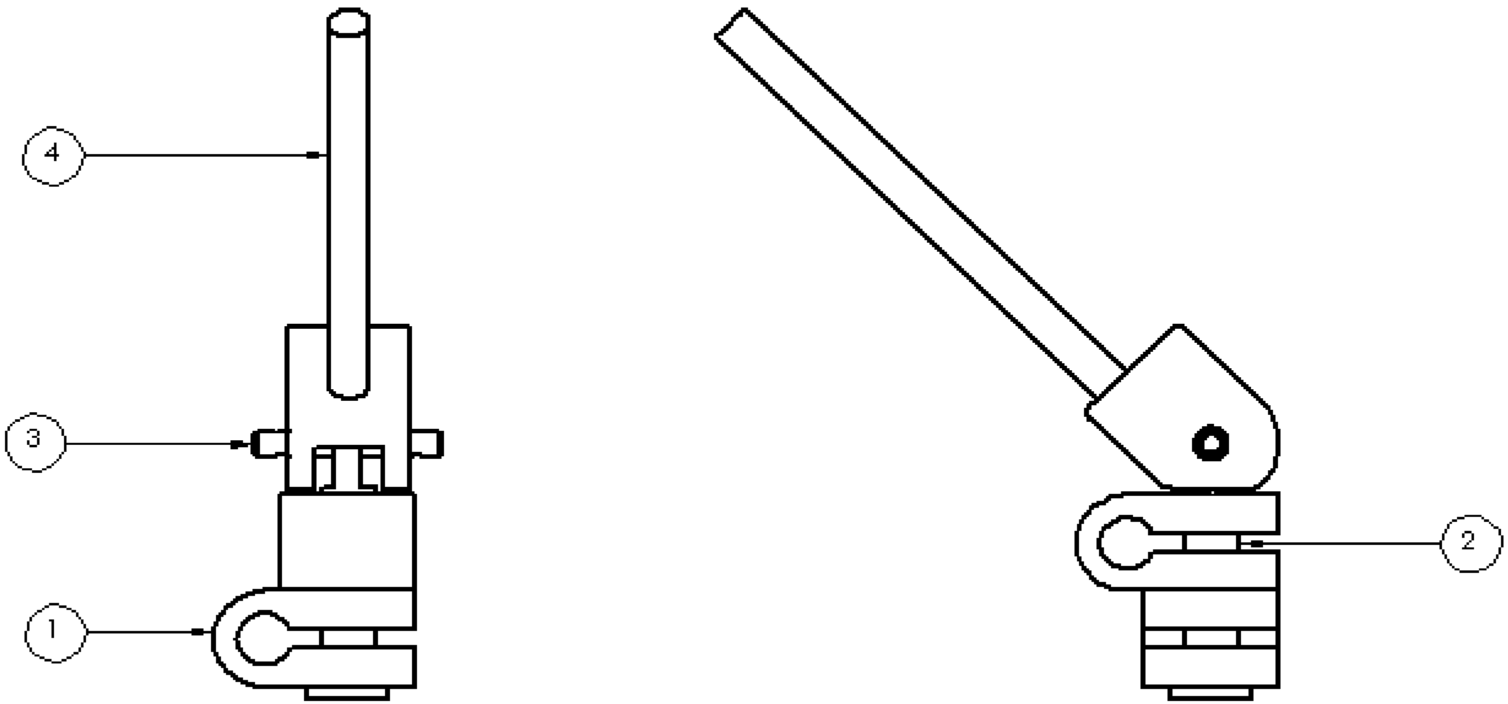
PROJECT ADVISORS: Dr. BISHAKH BHATTACHARYA
Dr. AMIT AGARWAL

DRAWING
Model assembly

SCALE:1:8 SHEET 1 OF 13



PART NO.	PART NAME	QTY.
1	connector	2
2	connector_pin	1
3	lever_pin	1
4	cam_joint	1

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
TOLERANCES:
LINEAR: ±1
ANGULAR: ±1°

	DATE	NAME	SIGNATURE
DRAWN	04/11/16	Group 23	
CHK'D			
APPV'D			
MFG			

MATERIAL: Aluminium

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DRAWING:
Cam lock sub-assembly

SCALE: 1:1

SHEET 2 OF 13

Group No.	23
Part No.	1
Part Name	rod1
Material	Aluminium
Quantity	1

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
TOLERANCES:
LINEAR: ±1
ANGULAR: ±1°

	DATE	NAME	SIGNATURE
DRAWN	06/11/16	Group 23	
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APPV'D			
MFG			

MATERIAL: Aluminium

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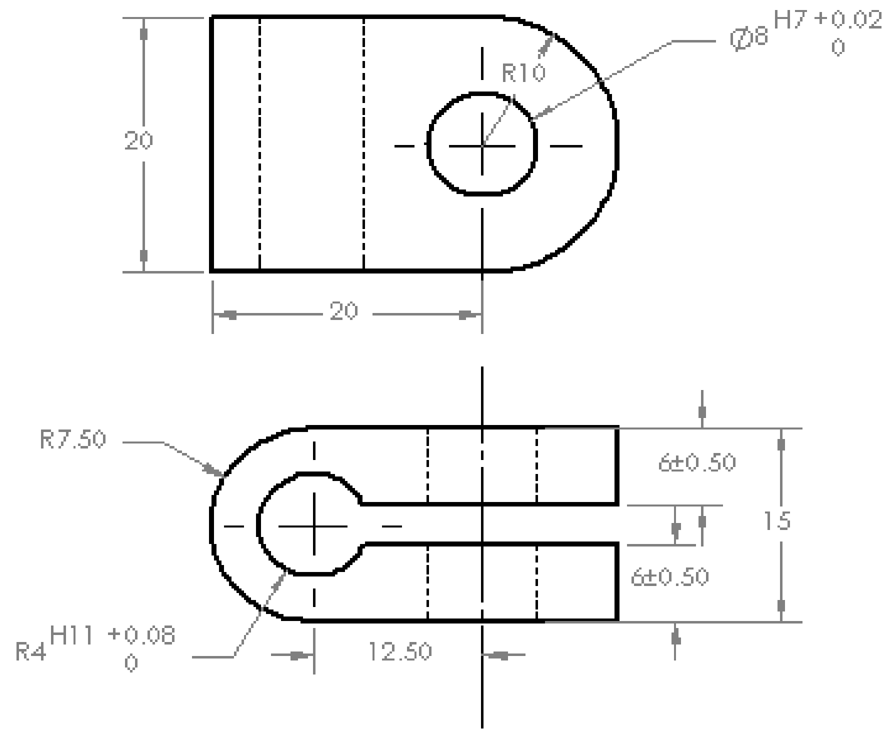
PART No. 1 Rod1

SCALE: 1:3 SHEET 3 OF 13



Group No.	23
Part No.	2
Part Name	connector
Material	Aluminium
Quantity	12

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
TOLERANCES:
LINEAR: ±1
ANGULAR: ±1°

	DATE	NAME	SIGNATURE
DRAWN	04/11/16	Group 23	
CHK'D			
APPV'D			
MFG			

MATERIAL: Aluminium

TITLE:
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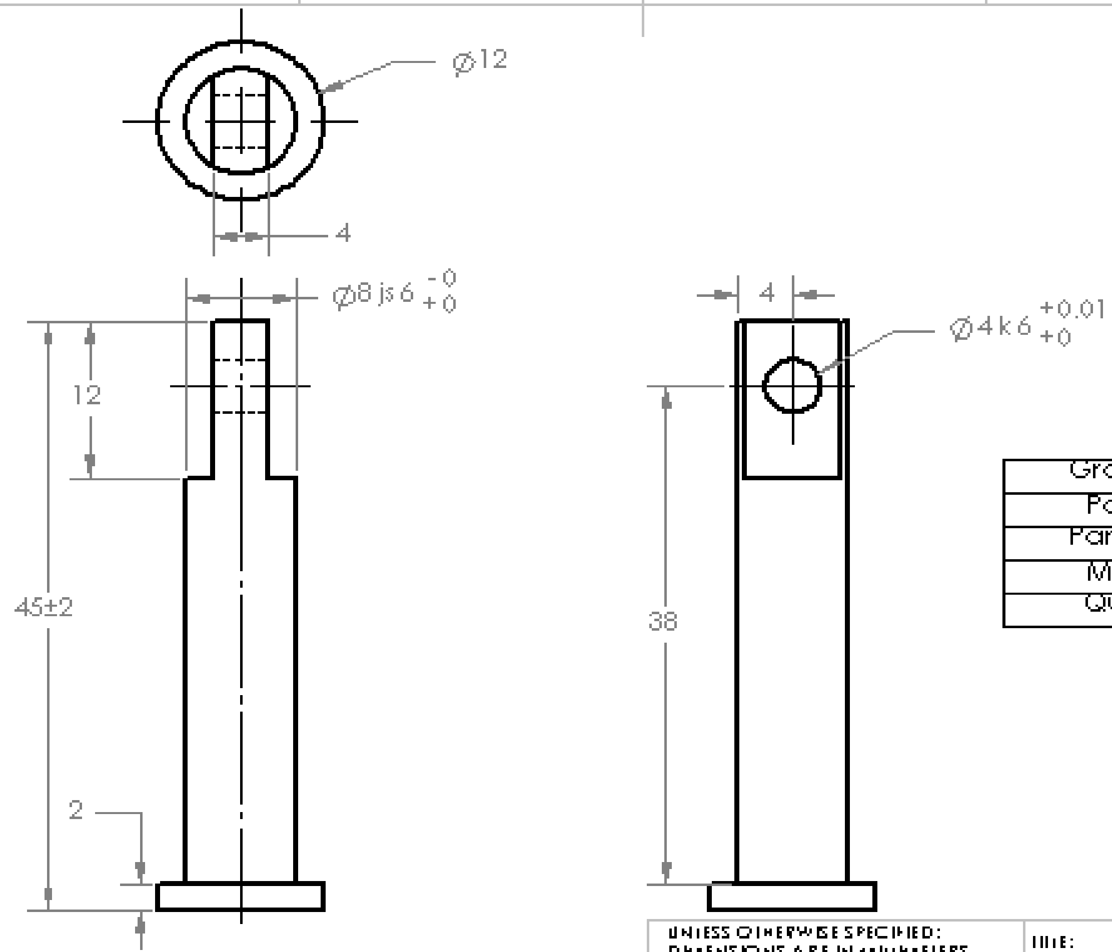
PART No. 2
Connector

SCALE 2:1
SHEET 4 OF 13



Group No.	23
Part No.	3
Part Name	connector_pin
Material	Aluminium
Quantity	6

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
TOLERANCES:
LINEAR: ±1
ANGULAR: ±1°

	DATE	NAME	SIGNATURE
DRAWN	06/11/16	Group 23	
CHK'D			
APPV'D			
MFG			

MATERIAL: Aluminium

TITLE:
ME451A Group 23
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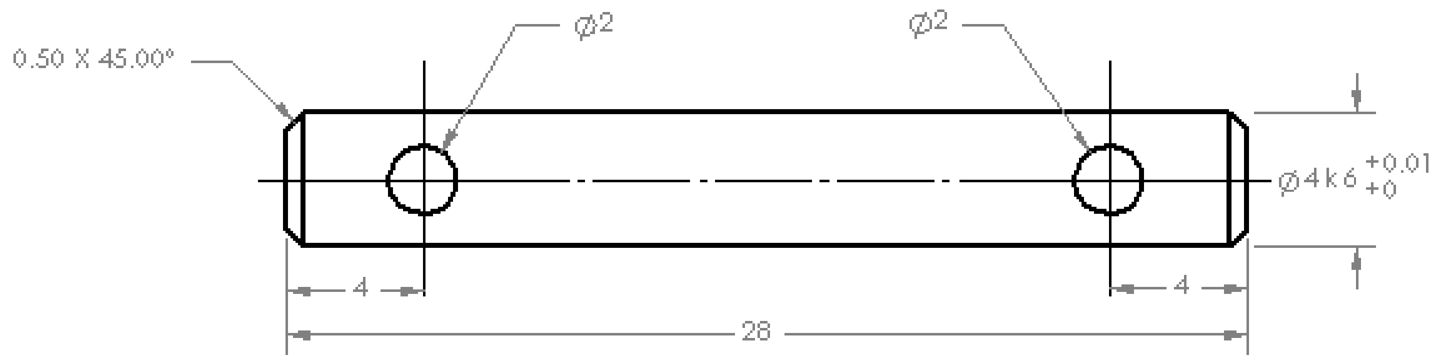
PART No.3
Connector pin

SCALE 2:1
SHEET 3 OF 13



Group No.	23
Part No.	4
Part Name	lever_pin
Material	Aluminium
Quantity	6

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
TOLERANCES:
LINEAR: ±1
ANGULAR: ±1°

	DATE	NAME	SIGNATURE
DRAWN	04/11/16	Group 23	
CHK'D			
APPV'D			
MFG			

MATERIAL: Aluminium

TITLE:
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PART No. 4
lever_pin

SCALE:1

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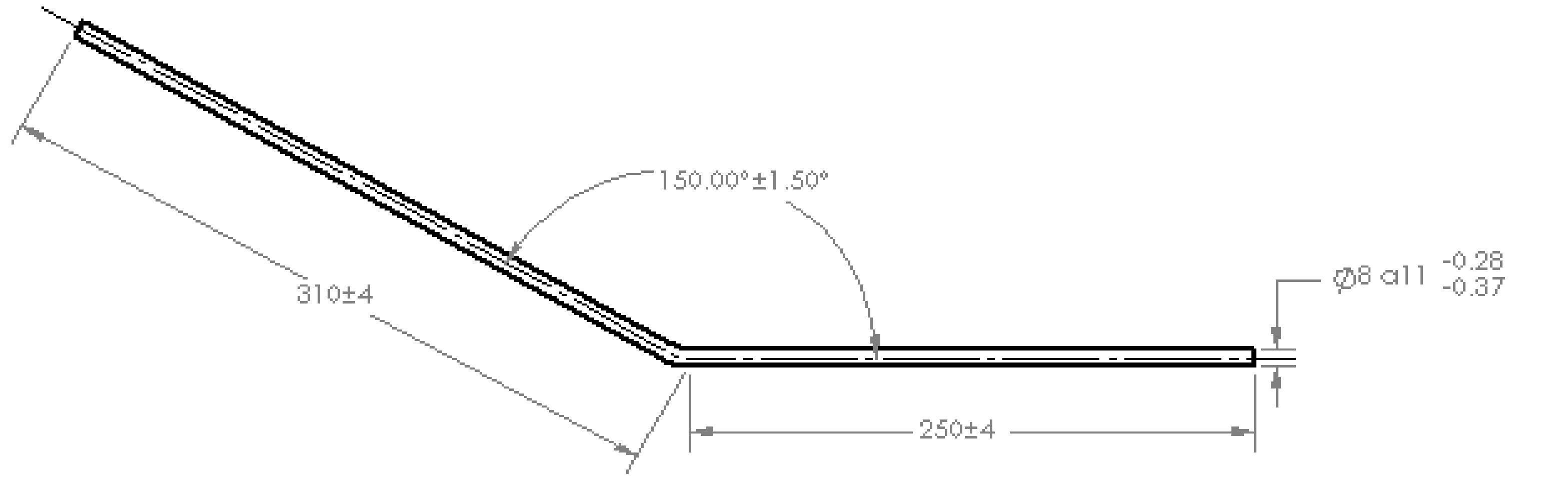

Group No.	23
Part No.	5
Part Name	rod2
Material	Aluminium
Quantity	2

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
TOLERANCES:
LINEAR: ±1
ANGULAR: ±1°

	DATE	NAME	SIGNATURE
DRAWN	04/11/16	Group 23	
CHK'D			
APPV'D			
MFG			

MATERIAL: Aluminium

TITLE:
ME451A Group 23
Design and Fabrication of Throat Surgery Holder and Retractor

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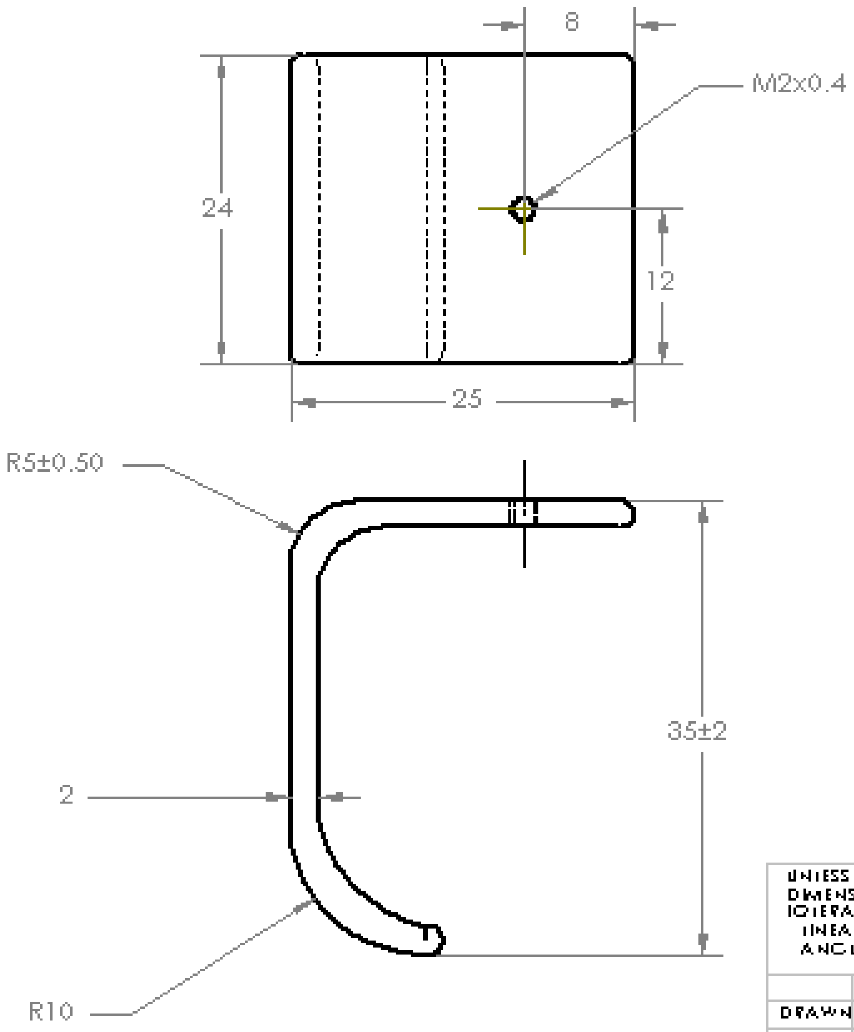
PART No. 5
Rod2

SCALE: 1:3

SHEET 7 OF 13



Group No.	23
Part No.	7
Part Name	blade
Material	Stainless steel
Quantity	3

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
TOLERANCES:
LINEAR: ±1
ANGULAR: ±1°

	DATE	NAME	SIGNATURE
DRAWN	04/11/16	Group 23	
CHK'D			
APPV'D			
MFG			

MATERIAL: 316 Stainless Steel

TITLE:
ME451A Group 23
Design and Fabrication of Throat Surgery Holder and Retractor

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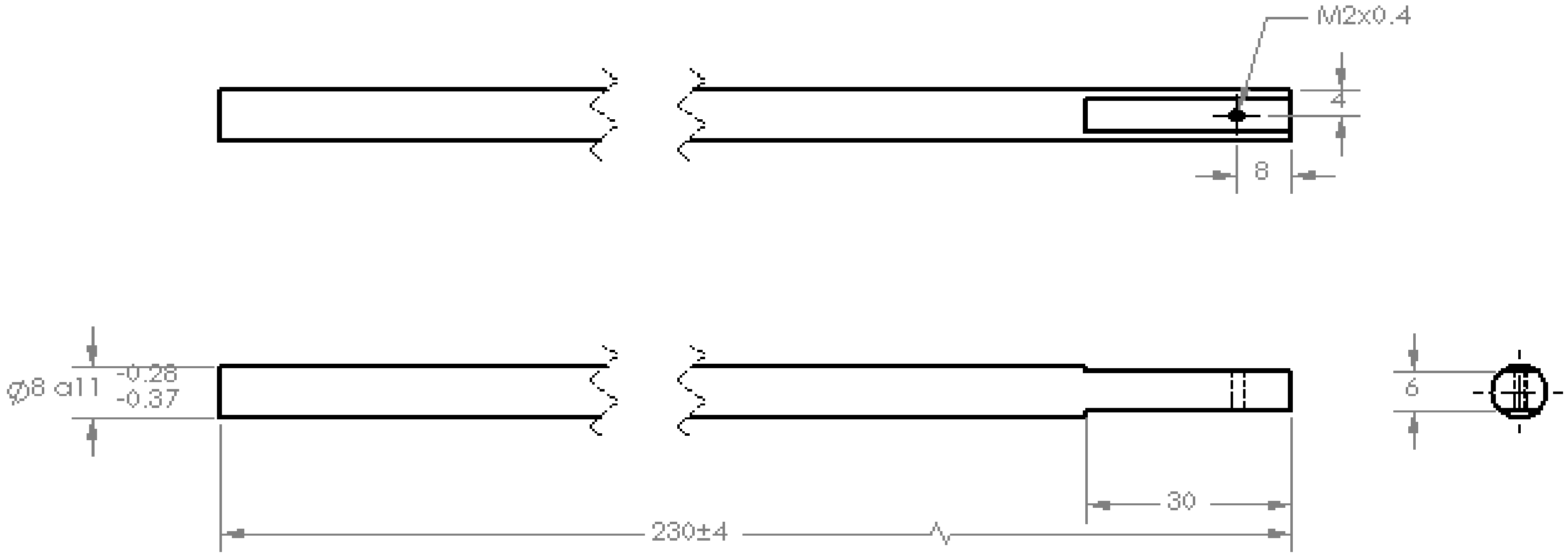
PART No. 7 Blade

SCALE: 2:1 SHEET 8 OF 13



Group No.	23
Part No.	8
Part Name	bladerod
Material	Aluminium
Quantity	3

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
TOLERANCES:
LINEAR: ±1
ANGULAR: ±1°

TITLE:
ME451A Group 23
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	DATE	NAME	SIGNATURE
DRAWN	04/11/16	Group 23	
CHK'D			
APPV'D			
MFG			

GROUP MEMBERS:
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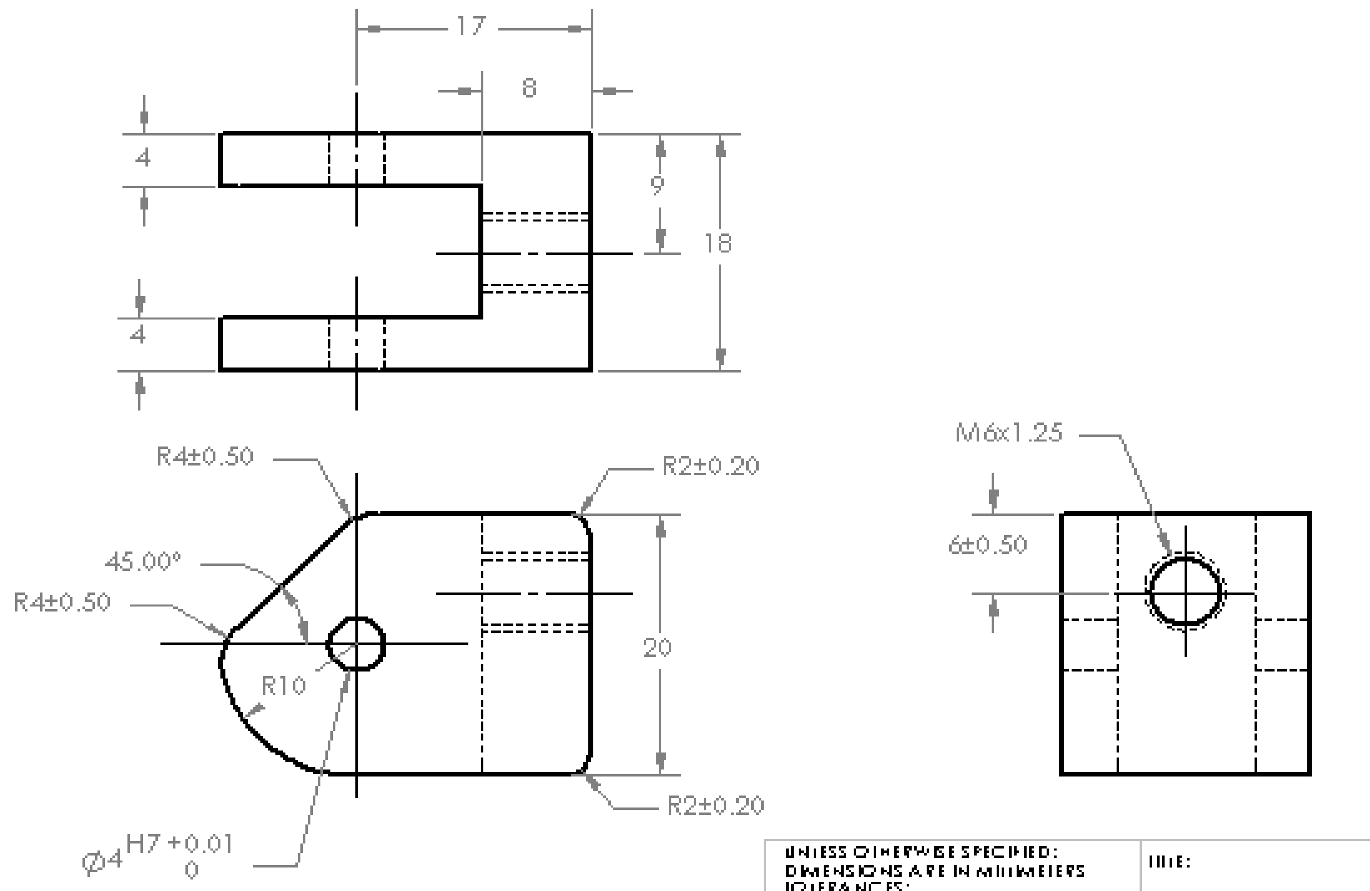
Dr. AMIT AGARWAL

MATERIAL: Aluminium

PART No. 8 Bladerod

SCALE 1:1 SHEET 9 OF 13



Group No.	23
Part No.	9
Part Name	cam
Material	Aluminium
Quantity	6

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
TOLERANCES:
LINEAR: ±1
ANGULAR: ±1°

TITLE:
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	DATE	NAME	SIGNATURE
DRAWN	04/11/16	Group 23	
CHK'D			
APPV'D			
MFG			

GROUP MEMBERS:
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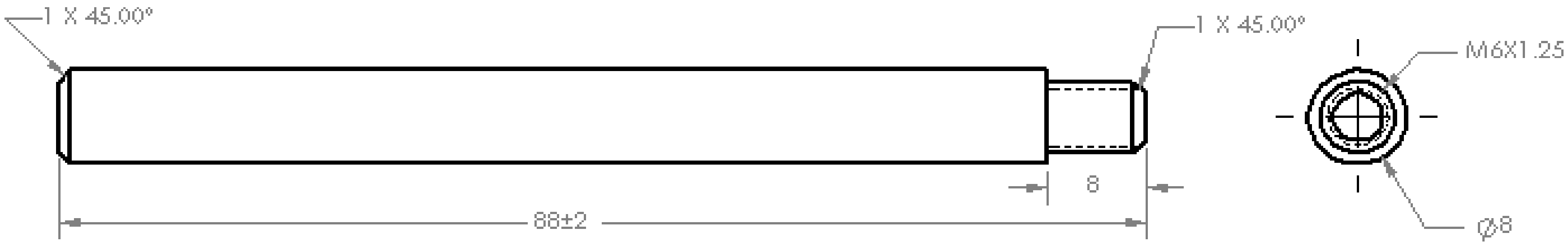
Dr. AMIT AGARWAL

MATERIAL: Aluminium

PART No. 9 Cam

SCALE: 2:1

SHEET 10 OF 13



Group No.	23
Part No.	10
Part Name	lever
Material	Aluminium
Quantity	6

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
TOLERANCES:
LINEAR: ±1
ANGULAR: ±1°

	DATE	NAME	SIGNATURE
DRAWN	06/11/16	Group 23	
CHK'D			
APPV'D			
MFG			

MATERIAL: Aluminium

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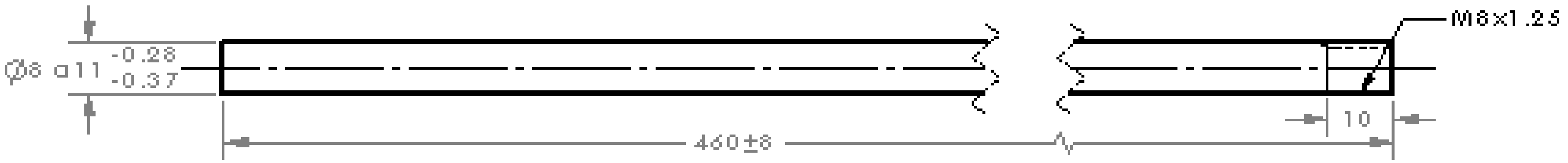
PART No. ID Lever

SCALE: 1:1

SHEET 11 OF 13



Group No.	23
Part No.	11
Part Name	tablemount_shaft
Material	Aluminium
Quantity	1

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
TOLERANCES:
LINEAR: ±1
ANGULAR: ±1°

	DATE	NAME	SIGNATURE
DRAWN	06/11/16	Group 23	
CHK'D			
APPV'D			
MFG			

MATERIAL: Aluminium

TITLE:
ME451A Group 23
Design and Fabrication of Throat Surgery Holder and Retractor

GROUP MEMBERS:
SHYAMSUNDER SHOBHA [13692]
SUNIL KUMAR [13720]
SUNIL KUMAR [13723]

PROJECT ADVISORS:
Dr. SIDHARTH BHATTACHARYA
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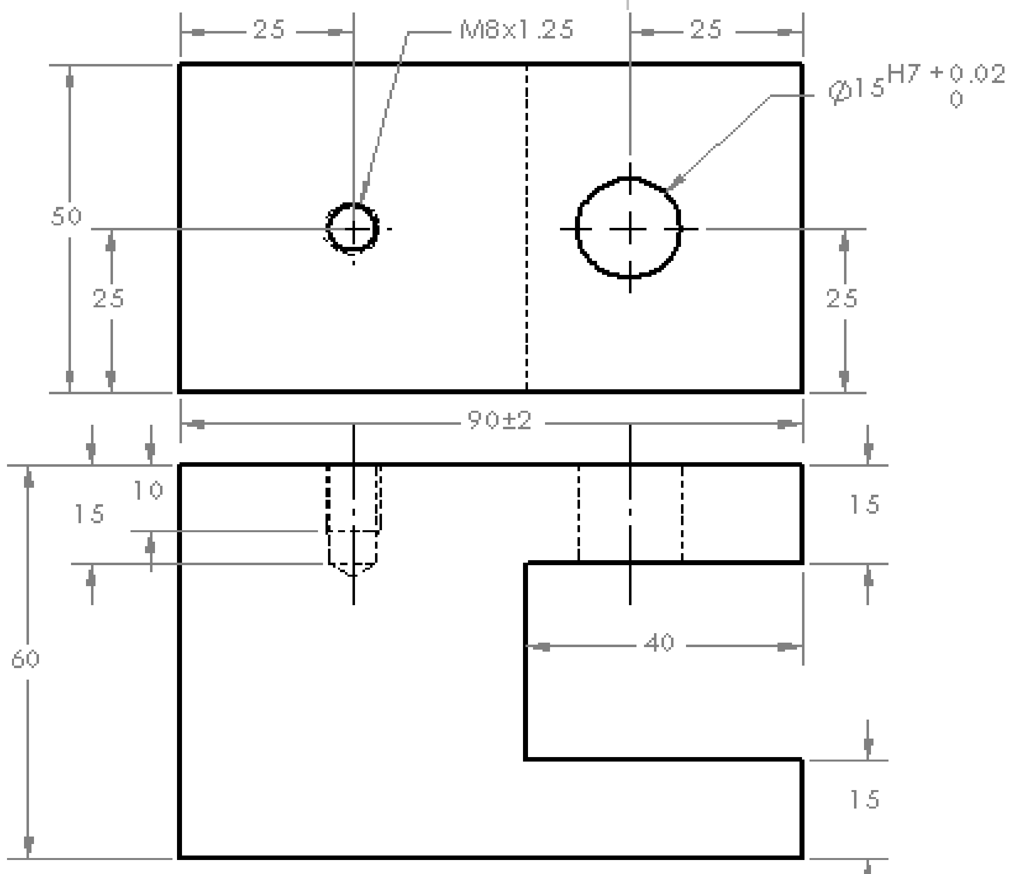
PART No. 11
Tablemount_shaft

SCALE: 1:1
SHEET 12 OF 13



Group No.	23
Part No.	12
Part Name	tablemount_base
Material	Aluminium
Quantity	1

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DIMENSIONS ARE IN MILLIMETERS
TOLERANCES:
LINEAR: ±1
ANGULAR: ±1°

TITLE:
ME451A Group 23
Design and Fabrication of Throat Surgery Holder and Retractor

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DRAWN	04/11/16	Group 23	
CHK'D			
APPV'D			
MFG			

GROUP MEMBERS:
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SUNIL KUMAR (13723)

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Dr. AMIT AGARWAL

MATERIAL: Aluminium

PART No. 12
Tablemount_base

SCALE:1:1
SHEET 13 OF 13

Final Design Specifications

- Light weight: The complete retractor system weighs just 1.3 kg. This increases the usability of the product and also makes it portable. Also, with light weight it decreases the risks during surgery.

- Degrees of Freedom: The system has a total of 21 degrees of freedom providing it unhindered movement and useful in all variety of circumstances.

- Lifecycle: The fatigue testing results carried out with more than enough quantity of force shows 10^6 lifecycles before failure.

- Mechanical Stress Analysis: The mechanical stress analysis calculations clearly mark the system safe and not prone to failure with safety factors much higher than 1.

- Thermal Stress Analysis: Thermal analysis when conducted for the system made with surgical steel shows no sign of failure at any region.

- Surgical versatility: The system is versatile. With a change in the number and type of blades and proper alignment of rods, this system could even be used for performing surgeries at different locations and not just throat.

Bill of materials

PART NO.	PART NAME	QTY.	Material	Major Dimensions (mm)
1	Rod 1	1	Aluminium	Φ8 x 910
2	Connector	12	Aluminium	30 x 20 x 15
3	Connector Pin	6	Aluminium	Φ12 x 45
4	Lever Pin	6	Aluminium	Φ4 x 32
5	Rod 2	2	Aluminium	Φ8 x 555
6	B18.6.7M - M2 x 0.4 x 6 Indented HHMS --6C	3	Standard product (off-shelf)	M2 x 0.4 x 6
7	Blade	3	316 Stainless Steel	60 x 24 x 2
8	Blade Rod	3	Aluminium	Φ8 x 230
9	Cam	6	Aluminium	27 x 20 x 18
10	Lever	6	Aluminium	Φ8 x 88
11	Table mount Shaft	1	Aluminium	Φ8 x 460
12	Table mount Base	1	Aluminium	90 x 60 x 50

Design Calculations

- **Blade Rod Analysis (Stress Calculations)**

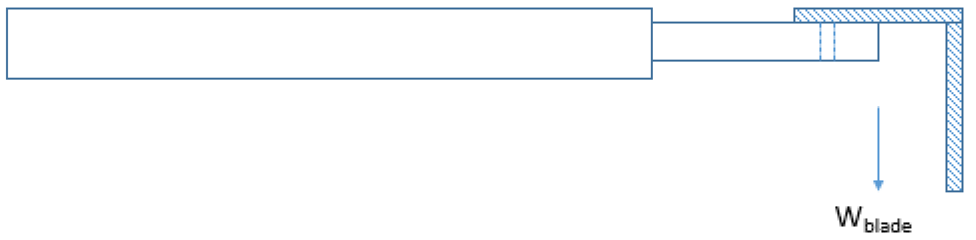


Fig. 1: FBD of Rod

$W_{blade} = M_{blade}$ x g = (6.76 x 10^{-3} x 9.81) N
W_{blade} = 0.066N

W_{blade} will act at the center of mass of the blade

Consider it as two rectangular sections of masses (25/60 x 6.76g)mg and (36/60 x 6.76g)mg

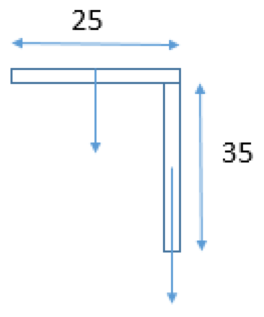


Fig 2. FBD of blade

$$R_{cm} = \frac{\frac{25}{60} \text{x } 6.76\text{x}12.5 + \frac{36}{60} \text{x } 6.76\text{x}12.5}{6.76}$$

R_{cm} = 19.79mm

Taking a conservative approach, consider the situation where whole blade hangs from the cam joint; i.e.

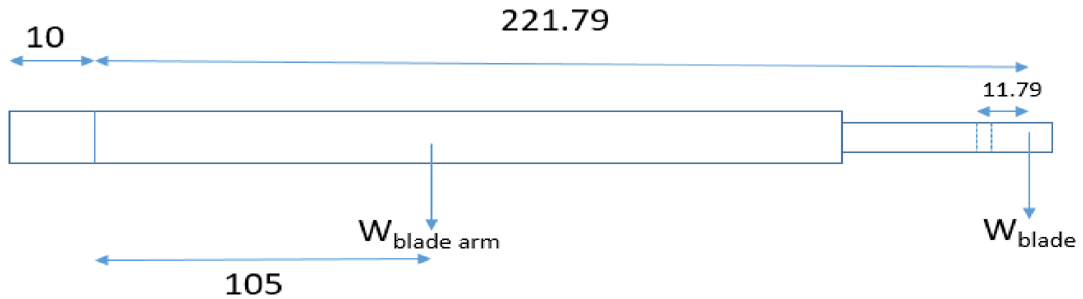


Fig. 3: FBD of blade arm

Let the forces and moment at support be $\vec{F}$ and $\vec{M}$
Then,
$\vec{F} = W_{blade} + W_{blade\ arm}$
$\boldsymbol{\vec{F} = 0.37N}$
$\vec{M} = W_{blade\ arm} \times 0.105 + W_{blade} \times 0.22179$
$\boldsymbol{\vec{M} = 0.046}$ **Nm** [Direction is perpendicular to the blade arm]

Now, consider equilibrium of cam joint
$\boldsymbol{\vec{W}_{joint} = 0.56N}$
$\vec{F}_2 = \vec{F} + \vec{W}_{joint}$
$\boldsymbol{\vec{F}_2 = 0.93N}$
Now,
$\boldsymbol{\vec{M}_2 = \vec{M} = 0.046}$ **Nm** $[\ \vec{M}_{joint} + (-\vec{M}) = 0\ ]$

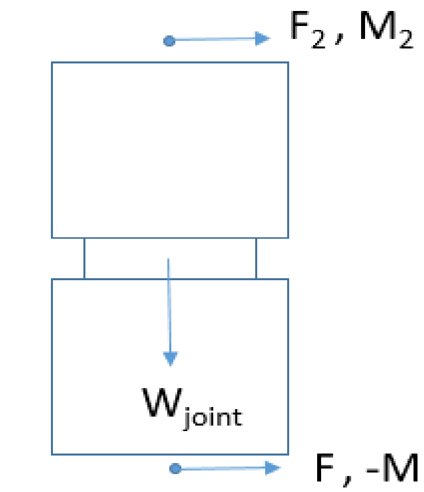


Figure 4 : FBD of CAM joint

- ## Arm Rod Analysis (Left Rod)

Now, consider Rod 2

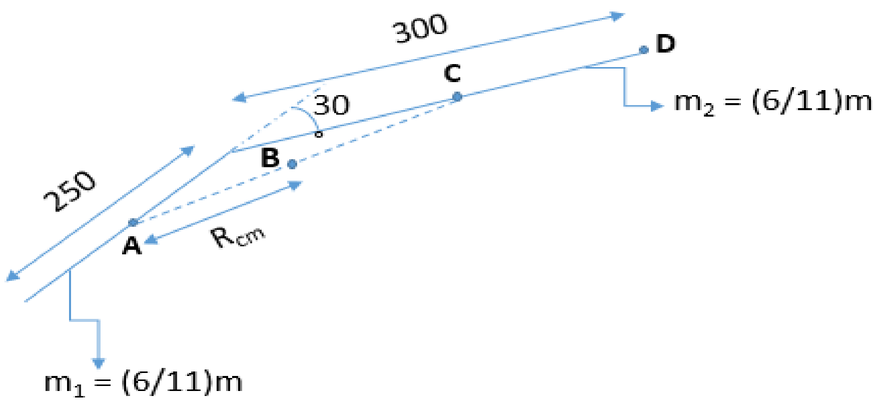


Figure 5: rod 2

$$R_{cm} = \frac{m1 \times 0 + m2 \times r}{m1 + m2}$$

$r = \sqrt{125^2 + 150^2 - 2xa125x150xcos(150)}$

r = 265.71mm

R_{cm} = (6/11)r = 144.9mm

Hence,

AB = 144.9mm

BC = 120.81mm

Weight of Rod1 acts at point B.

again, taking a conservative approach, we take the case when blade arm is mounted at the extreme end of Rod1

FG= 10mm

DE=10mm

DC=140mm

CB=120.81mm

In $\triangle AOC$, $\angle ACO = 13.60°$

$\angle BCD = 166.39°$

Now, BD = 259mm

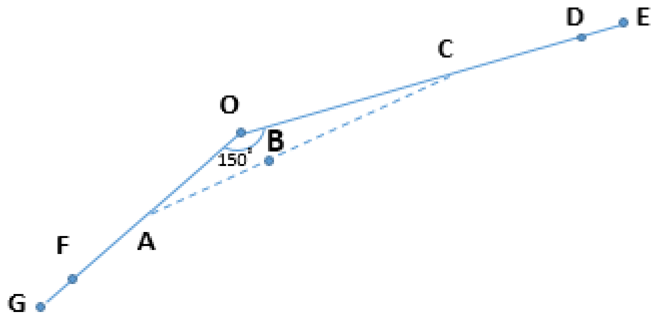


Figure 6: rod1

Moment of weight of rod = 0.31Nm [perpendicular to BD]

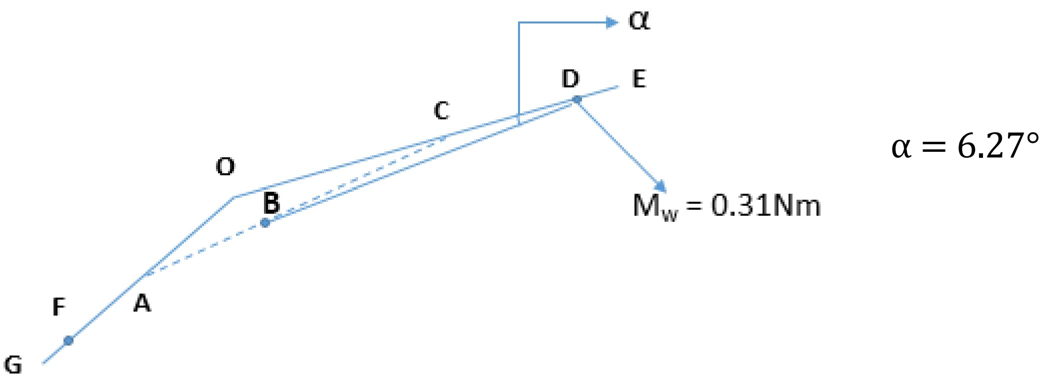


Figure 7: rod 1

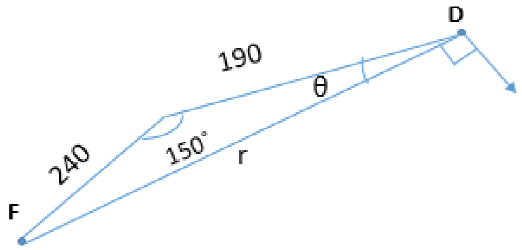


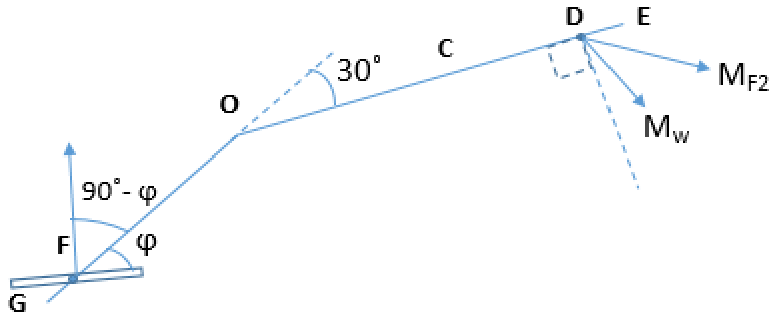
Figure 8: rod 1 section

Let us find out moment due to force $\vec{F}_2$ which acts at point F

$r = 415.55mm$
$\theta = 16.78º$

$\vec{M}F2 = 0.38$ Nm

Superposition of all moments at point D.



φ is the angle between blade rod and Rod2
Take $\varphi = 30º$

Figure 9: Moments acting on rod

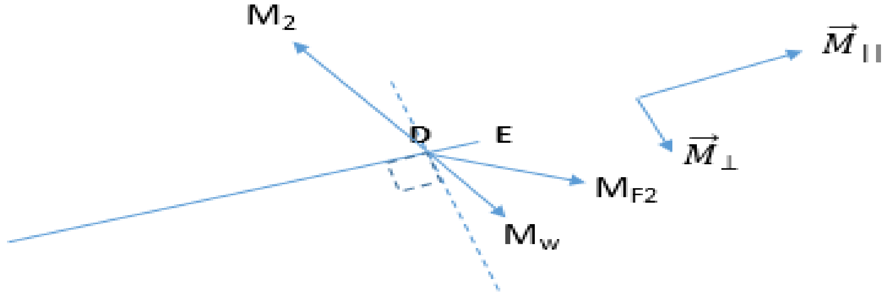


Figure 10: Net moment

Resultant,

$\vec{M}_{||} = \vec{M}$F2 x sin(16.78°) + $\vec{M}_{\text{rod}}$ x cos(6.27°)
$\vec{M}_{||}$ = 0.143 Nm

$\vec{M}_{\perp} = \vec{M}$F2 x cos(16.78°) + $\vec{M}_{\text{rod}}$ x sin(6.27°) - $\vec{M}_2$
$\vec{M}_{\perp}$ = 0.63 Nm

$\vec{F}_{\text{net}} = \vec{W}_{\text{rod1}} + \vec{F}_2 = 0.93+0.74$
$\vec{F}_{\text{net}}$ = 1.67N

Bending Stress $= \frac{Mc}{I}$

$= \frac{(0.63)(0.004)}{(\Pi/4)(0.004)^\wedge 4}$

=12.53 MPa

Yield Strength = 240 MPa

Factor of safety (n) = 240/12.53= 19.15

n>>1

Torsional Stress $= \frac{(\vec{M}||,\text{net})r}{J}$

$= \frac{(0.143)(0.004)}{(\Pi/2)(0.004)^\wedge 4}$

= 1.422 MPa

Tensile Strength = 290 MPa

Factor of safety (n) = 290/1.422 = 203

n>>1

- ## Arm Rod Analysis (Right Rod)

Now, considering the second rod having the two blade rods impended

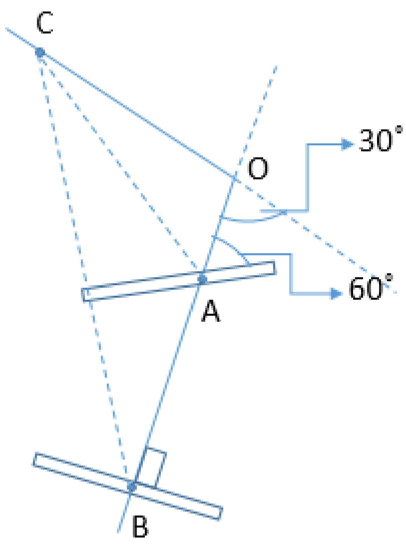


Figure 11: right rod

Force and Moment at B and C are $\vec{F}_{3,}\vec{M}_3$ and $\vec{F}_{4,}\vec{M}_4$ respectively.

φ1 and φ2 have been taken to be 60° and 90° respectively. This is one of the various possible variations.

Also, take
OA=40mm

OB=240mm
OC=290mm
CB=512.10mm
CA=325.26mm

As calculated in previous section
$\vec{F}_3 = \vec{F}_4 = 0.93$ N
$\vec{M}_3 = \vec{M}_4 = 0.046$ Nm

Now,
$\angle BCO = 13.55°$
$\angle ACO = 3.25°$
Using these values to calculate moments through these forces we get,

$\vec{M}F_3 = 0.48$ Nm, $\vec{M}F_4 = 0.30$ Nm

Calculating net moment, setup and steps are same as in previous section, therefore

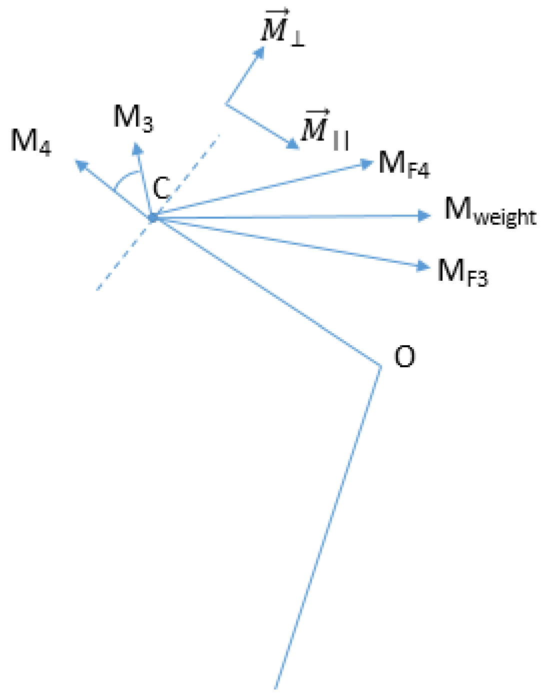


Figure 12: Moments acting on right rod

$\vec{M}_{\text{weight}} = 0.31\ \text{Nm}$

$\vec{M}_{||} = 0.193\ \text{Nm}$

$\vec{M}_{\perp} = 1.097\ \text{Nm}$

$\vec{F}_{\text{net}} = 2\text{x}0.93 + 0.74$
$\vec{F}_{\text{net}} = 2.56\ \text{N}$

$$\text{Bending Stress} = \frac{Mc}{I}$$

$$= \frac{(1.097)(0.004)}{(\Pi/4)(0.004)\text{\textasciicircum}4}$$

=21.82 MPa

Yield Strength = 240 MPa

Factor of safety (n) = 240/21.82 = 10.99

n>>1

$$\textbf{Torsional Stress} = \frac{(\vec{M}||,\text{net})r}{J}$$

$$= \frac{(0.193)(0.004)}{(\Pi/2)(0.004)^4}$$

$= 1.919$ MPa

Tensile Strength = 290 MPa

Factor of safety (n) = 290/1.919 = 151

n>>1

- ## Analysis of Connecting Rod

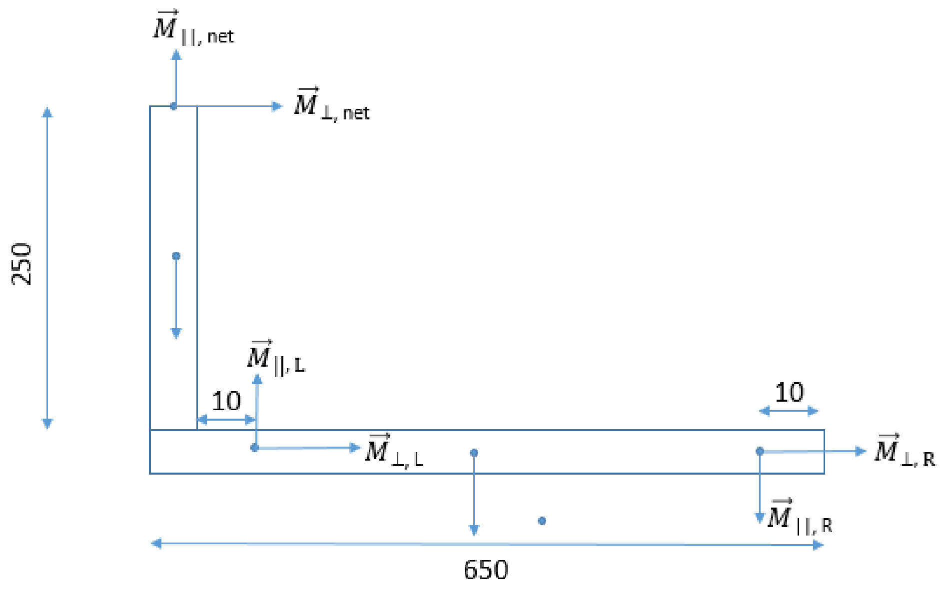


Figure 13: Rod 1

$$\vec{F}_1 = \vec{F}_{\text{net, L}} + \vec{W}_{\text{j}}$$

$\vec{\boldsymbol{F}}_1 = \mathbf{1.67 + 0.56 = 2.23\ N}$

$\vec{F}_2 = \vec{F}_{\text{net, R}} + \vec{W}_{\text{j}}$
$\vec{\boldsymbol{F}}_2 = \mathbf{2.56 + 0.56 = 3.12\ N}$

$\vec{W}_1 = 120\text{g x } 0.001 \text{ x } 250/900$
$\vec{\boldsymbol{W}}_1 = \mathbf{0.326\ N}$

$\vec{W}_2 = 120\text{g x } 0.001 \text{ x } 650/900$
$\vec{\boldsymbol{W}}_2 = \mathbf{0.85\ N}$

At Point O,
$\vec{F}_{\text{net}} = \vec{W}_1 + \vec{W}_2 + \vec{F}_1 + \vec{F}_2$
$= 120\text{g x } 0.001 + 2.23 + 3.12$
$\vec{\boldsymbol{F}}_{\text{net}} = \mathbf{6.55\ N}$

$\vec{M}_{||,\text{ net}} = \vec{M}_{||,\text{ L}} - \vec{M}_{||,\text{ R}} + \vec{W}_2 \text{ x } 0.325 + \vec{F}_1 \text{ x } 0.001 + \vec{F}_2 \text{ x } 0.640$
$\vec{\boldsymbol{M}}_{||,\text{ net}} = \mathbf{2.23\ Nm}$

$\vec{M}_{\perp,\text{ net}} = \vec{M}_{\perp,\text{ L}} + \vec{W}_1 \text{ x } 0.125 + \vec{W}_2 \text{ x } 0.250 + \vec{F}_1 \text{ x } 0.250 + \vec{F}_2 \text{ x } 0.250 + \vec{M}_{\perp,\text{ R}}$

$\vec{\boldsymbol{M}}_{\perp,\text{ net}} = \mathbf{3.95\ Nm}$

Bending Stress $= \dfrac{(\vec{M}\perp\text{,net })c}{I}$

$= \dfrac{(3.95)(0.004)}{(\Pi/4)(0.004)\text{^}4}$

=78.58 MPa

Yield Strength = 240 MPa

Factor of safety (n) = 240/78.58 = 3.05

n>1

Torsional Stress $= \dfrac{(\vec{M}||\text{,net })r}{J}$

$$= \frac{(2.23)(0.004)}{(\Pi/2)(0.004)^4}$$

$= 22.18$ MPa

Tensile Strength $= 290$ MPa

Factor of safety (n) $= 290/22.18 = 13.07$

n>>1

- ## Analysis of Table Mount

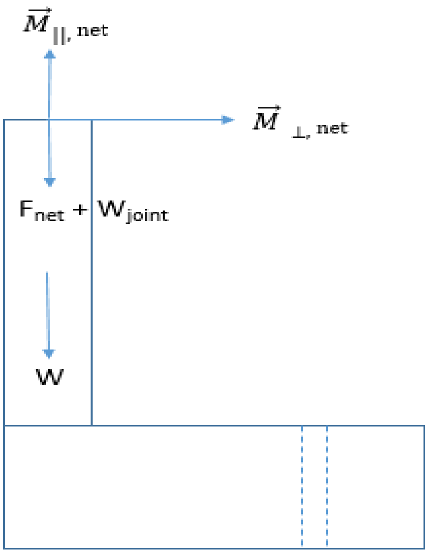


Figure 14: Table mount assembly

Bending Stress $= \frac{(\vec{M}\perp,\text{net})c}{I}$

$$= \frac{(3.95)(0.004)}{(\Pi/4)(0.004)^4}$$

$=78.58$ MPa

Yield Strength $= 240$ MPa

Factor of safety (n) $= 240/78.58 = 3.05$

n>1

Torsional Stress $= \frac{(\vec{M}||,\text{net })r}{J}$

$= \frac{(2.23)(0.004)}{(\Pi/2)(0.004)^4}$

$= 22.18$ MPa

Tensile Strength $= 290$ MPa

Factor of safety (n) $= 290/22.18 = 13.07$

n>>1

Finite element stress analysis of cam

Force applied 100 N

1. Resultant stress

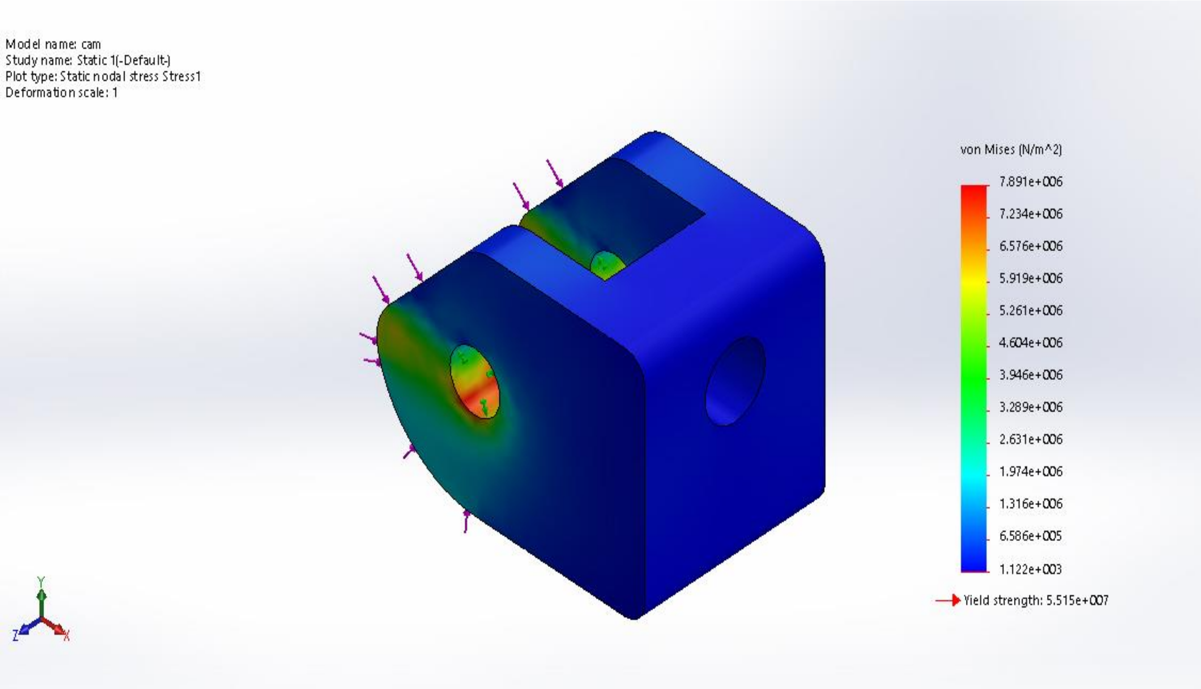


Figure 15: Resultant stress on cam

2. Resultant deformation

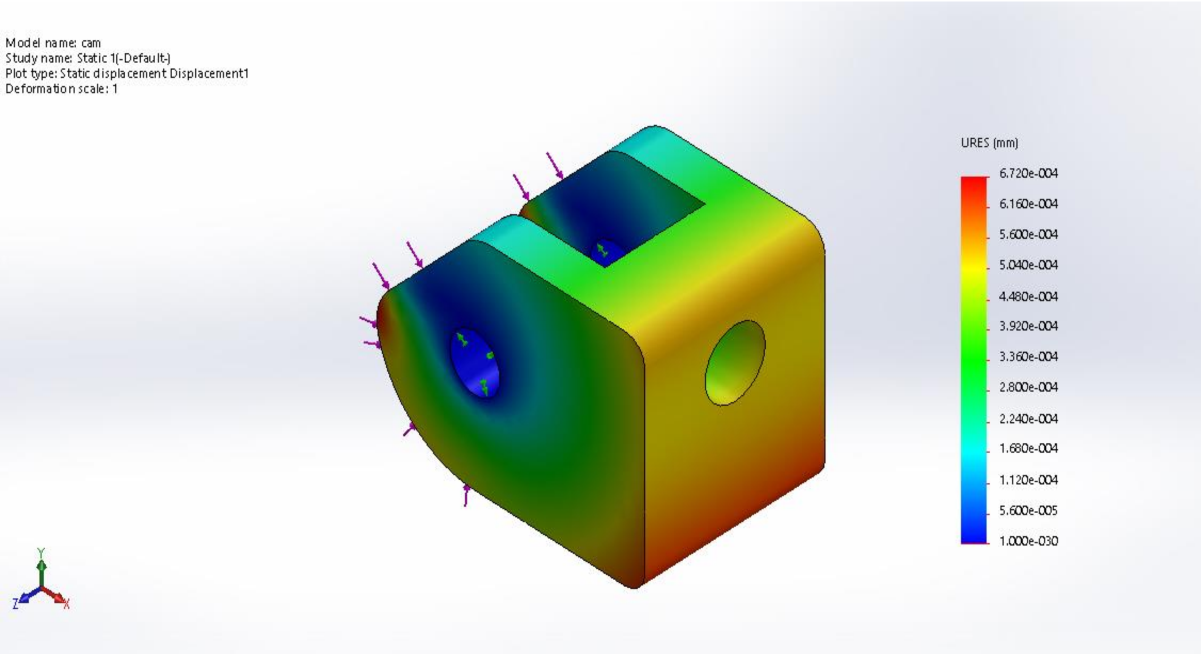


Figure 16: Resultant deformation in cam

3. Resultant strain

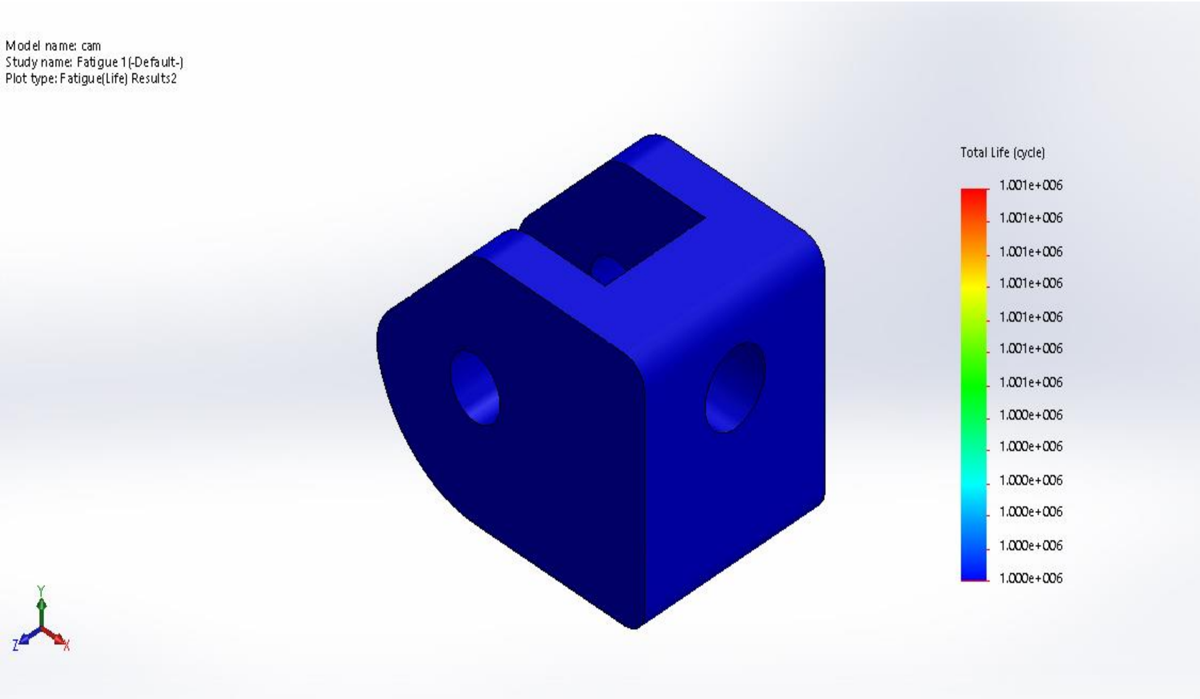


Figure 17: Resultant strain in cam

Finite element stress analysis of cam lock assembly

1. Stress results

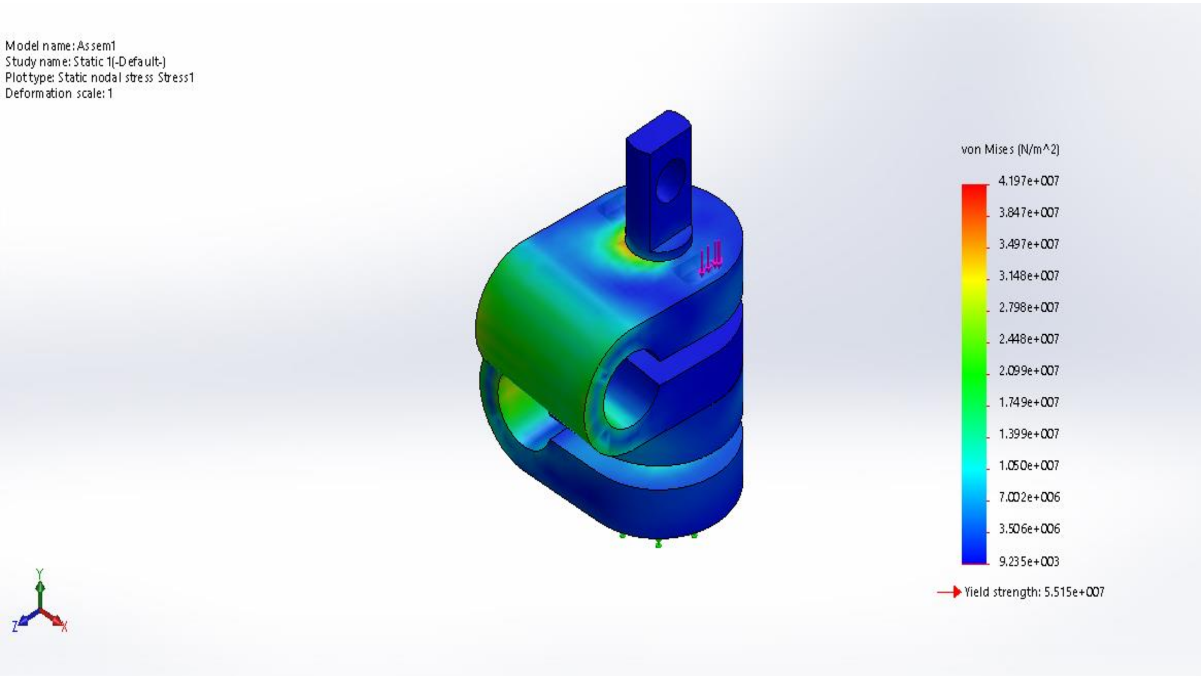


Figure 18: resultant stress on the sub-assembly

2. Deformation results

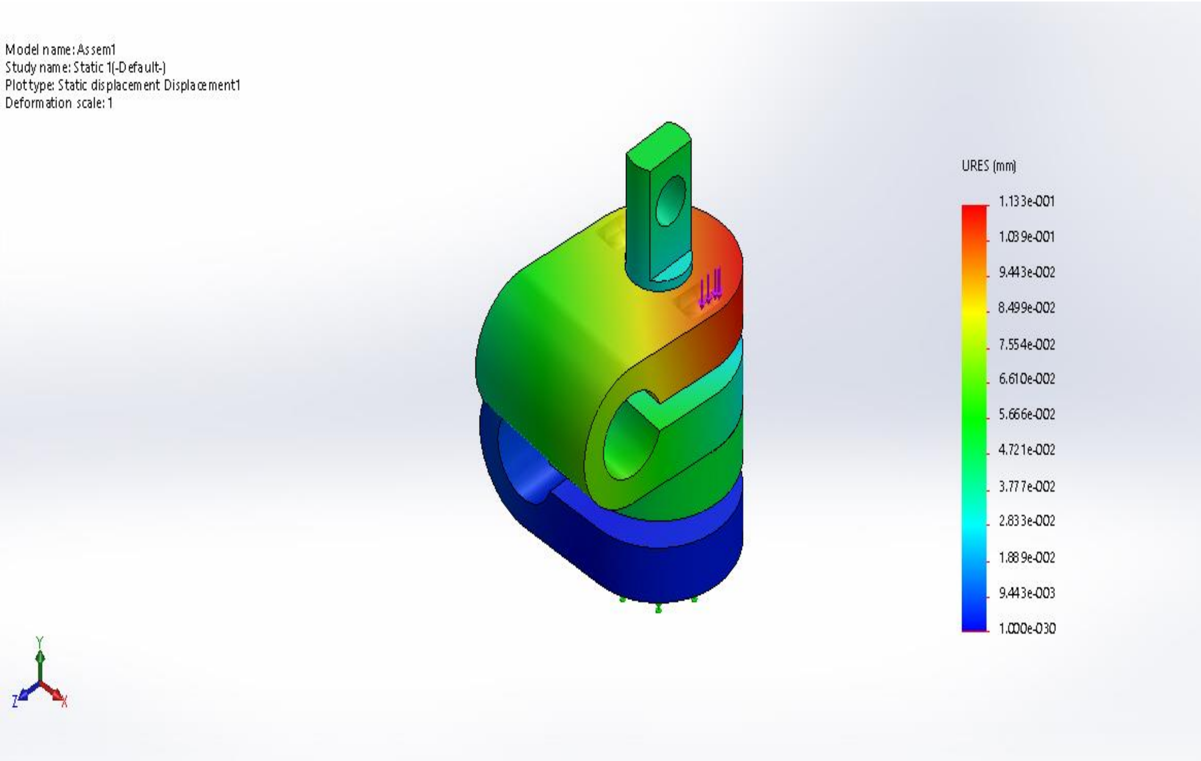


Figure 19: resultant deformation on the sub-assembly

3. Strain results

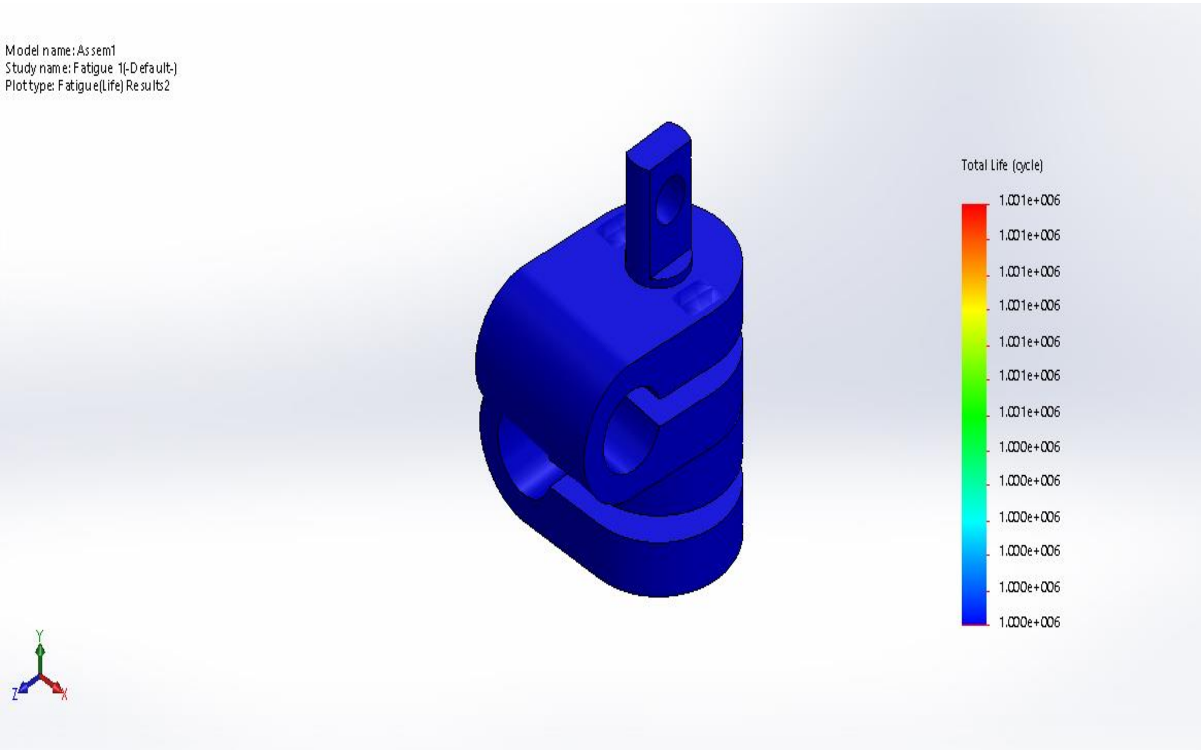


Figure 20: resultant strain on the sub-assembly

- **Force exerted by flesh on the blade at the incision during surgery**

F_v = force due to weight of the flesh above the blade

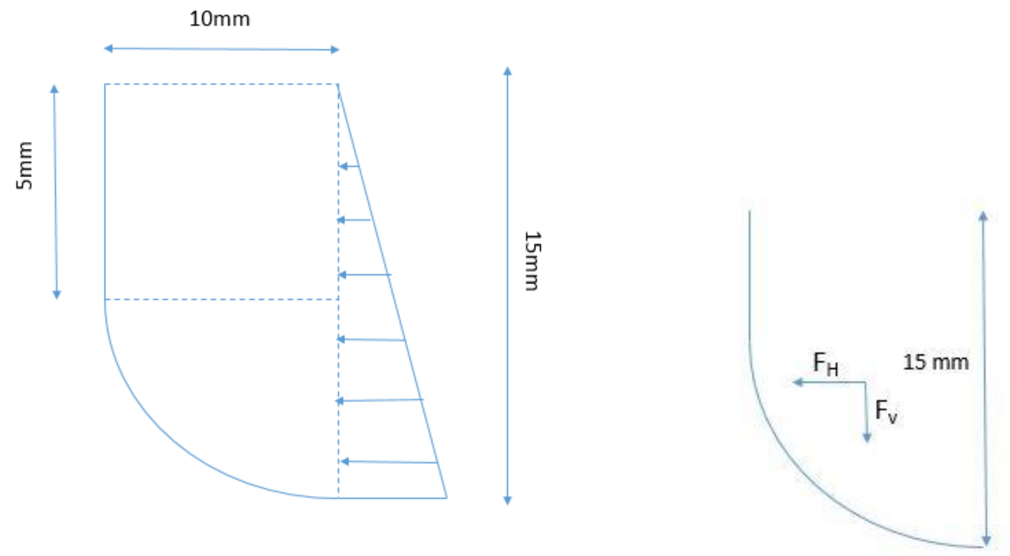


Figure 21: Forces acting on the blade surface due to human flesh

$\mathbf{F_v = \rho g V}$

Where,

ρ (average density of human flesh) = 1050 kg/m^3.

$V = [10x5 + \pi(10)^2/4] \times 24 \times 10^{-9}$ m^3 = 3084.96×10^{-9} m^3

g (acceleration due to gravity) = 9.81 ms^{-2}

$F_v = \rho g V = 1050 \times 9.81 \times 3084.96 \times 10^{-9}$

$\mathbf{F_v = 0.032\ N}$

F_H = horizontal force on the blade

$\mathbf{F_H = \rho g h_c A}$

Where, h_c = 7.5 mm

A = 15 x 24 mm^2 = 360 mm^2

$F_H = 1050 \times 9.81 \times 7.5 \times 360 \times 10^{-9}$

$\mathbf{F_H = 0.028\ N}$

Thus, total force will be

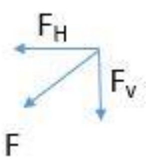


Figure 22: Resultant force

$\mathbf{F = [\ F_H^2 + F_V^2\ ]^{1/2}}$

$= [\ .028^2 + .032^2\ ]^{1/2}$

$= [\ 0.001794\ ]^{1/2}$

$\mathbf{F = 0.042\ N}$

Finite element stress analysis of Blade

Force applied 0.042 N

1. Stress results

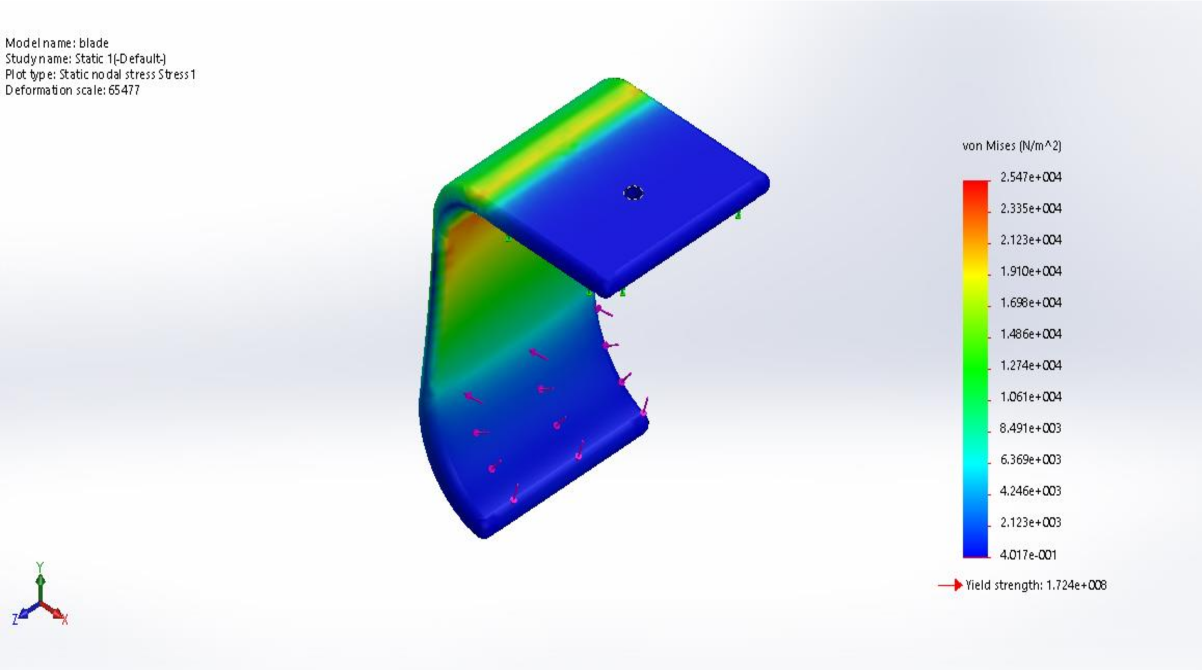


Figure 23: Resultant stresses on the blade

2. Deformation results

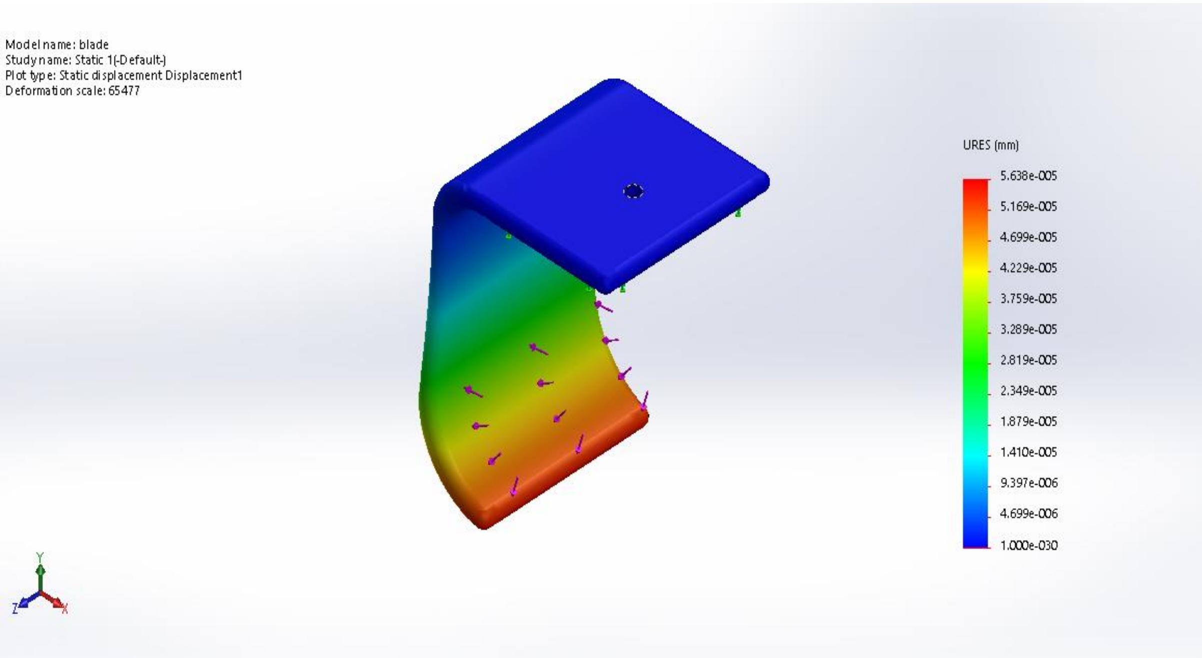


Figure 24: Resultant deformation

- **Thermal Stress analysis**

1. Stress results

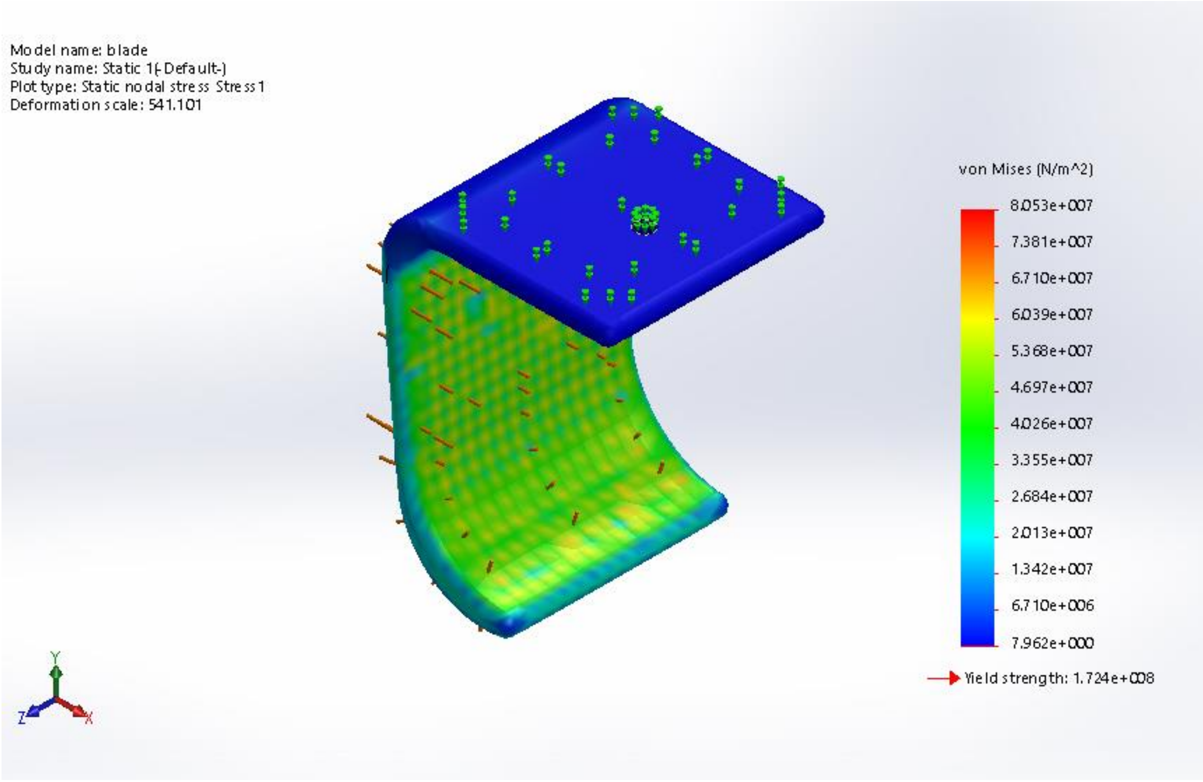


Figure 25: Thermal stress analysis of blade

2. Deflection results

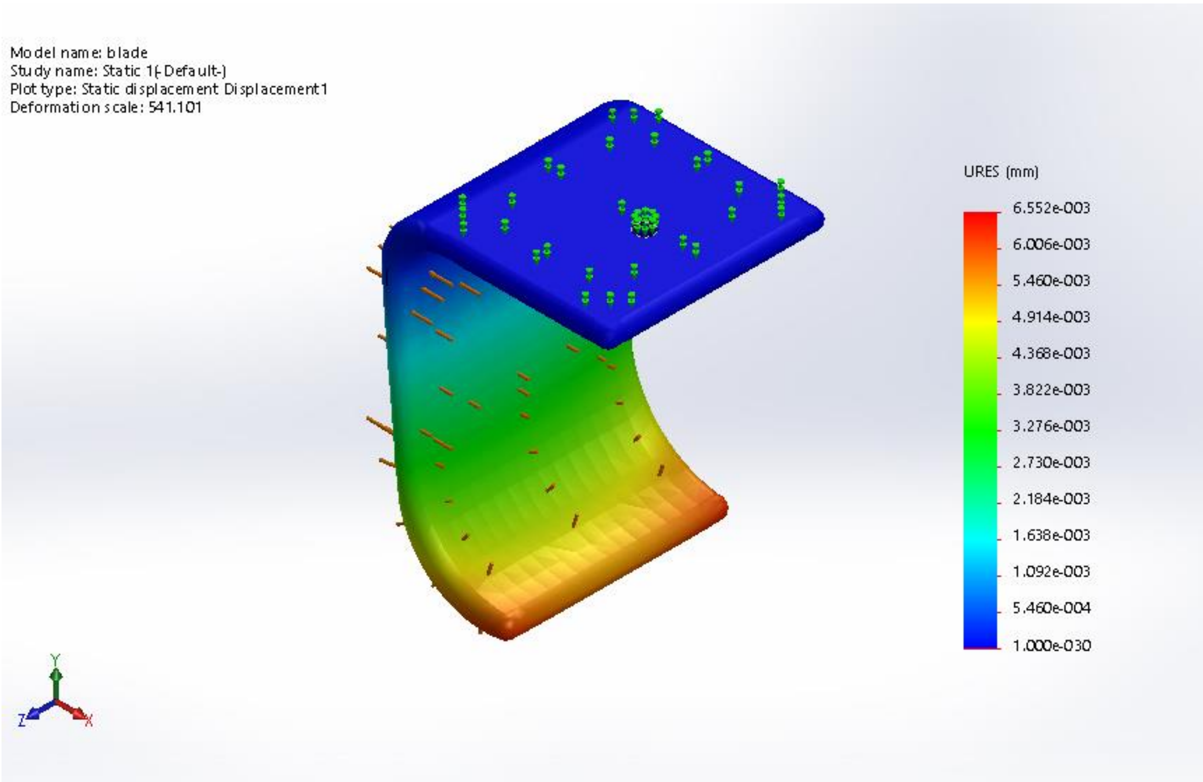


Figure 26: deflection on blade

Parts designed using Design Calculations

PART NO.	PART NAME	QTY.
1	Rod 1	1
2	Connector	12
5	Rod 2	2
7	Blade	3
8	Blade Rod	3
9	Cam	6
11	Table mount Shaft	1

Summary

Out of the total number of 12 parts, design calculations have been done for 7 parts. Out of these 5 parts have written calculations and design calculations for 2 parts were through available softwares like Solidworks.

Parts to be manufactured at IIT Kanpur:

All the parts of the assembly except part no. 6 will be manufactured at IIT Kanpur itself.

PART NO.	PART NAME	Material	Major Dimensions (mm)	QTY.
1	Rod 1	Aluminium	Φ8 x 910	1
2	Connector	Aluminium	30 x 20 x 15	12
3	Connector Pin	Aluminium	Φ12 x 45	6
4	Lever Pin	Aluminium	Φ4 x 32	6
5	Rod 2	Aluminium	Φ8 x 555	2
7	Blade	316 Stainless Steel	60 x 24 x 2	3
8	Blade Rod	Aluminium	Φ8 x 230	3
9	Cam	Aluminium	27 x 20 x 18	6
10	Lever	Aluminium	Φ8 x 88	6
11	Table mount Shaft	Aluminium	Φ8 x 460	1
12	Table mount Base	Aluminium	90 x 60 x 50	1

Off the shelf parts:

Part No. 6 is a standard part. It is available in the central workshop and will be used directly.

Part No.	Part Name	Material	Dimension	Qty.
6	B18.6.7M - M2 x 0.4 x 6 Indented HHMS --6C	Mild steel	M2 x 0.4 x 6	3

<u>Comments</u>

Manufacturing challenges:
The most intricate part of our design is the cam lock sub-assembly. It should be manufactured within the prescribed tolerances to enable the proper functioning of the entire model.

Cam profile has to be manufactured properly as per the proposed design. Moreover, the surface should be sufficiently smooth in order to avoid unnecessary noise while locking the joint.