17057_AARYANS_CAD/CAE Report

Author's Name: Deshpande Prasad

Co-Author's Name: Pawar Prateek

1. INTRODUCTION

The focus of designing is laid on the simplicity in design, high performance, comfort, easy maintenance and safety at very reasonable prices. The vehicle has an innovative tadpole recumbent design which is comfortable & ergonomically designed so that it can be used for travelling far areas. The vehicle roll cage has been designed in order to enhance the overall safety of the vehicle in case of a front, side, back and roll over impact. Software used for CAD is CATIA V5 R20 & CAE work is ANSYS 18.0 and SOLIDWORKS 2015.

2. FRAME MATERIAL OPTIONS

i. MATERIAL-1 (AISI 1018)
Circular Cross-Section ;1" X 0.94" X 0.087"

ii. MATERIAL-2 (AISI 1018)
Square Cross-Section; 1.57" X 1.57" X 0.06"

iii. MATERIAL-3 (AISI 1018)
Square Cross-Section ;1" X 1" X 0.063"

iv. MATERIAL-4 (AISI 4130)
Circular Cross-Section ;1" X 0.94" X 0.087

v. MATERIAL-5 (AISI 4130)
Square Cross-Section; 1.57" X 1.57" X 0.06"

vi. MATERIAL-6 (AISI 4130)
Square Cross-Section ;1" X 1" X 0.063"

Sr No	Properties	Material 1	Material 2	Material 3
1	Y.T.S. (MPa)	365	365	365
2	U.T.S (MPa)	440	440	440
3	Weight (kg/meter)	1.258	1.929	1.196
4	Cost (per Kg)	150	150	150
5	Lead time for delivery	6 days	6 days	6 days

Sr No	Properties	Material 4	Material 5	Material 6
1	Y.T.S. (MPa)	460	460	460
2	U.T.S (MPa)	560	560	560
3	Weight (kg/meter)	1.258	1.929	1.196
4	Cost (per Kg)	150	150	150
5	Lead time for delivery	6 days	6 days	6 days

3. CALCULATION OF BENDING STRENGTH AND BENDING STIFFNESS

Bending strength is given as;

$$M = (S_y * I)/C$$

Where:

S_y= Yield strength;
C= Distance from neutral axis to extreme fiber
I= Second Moment of Area

For circular section:

$$I = (\pi/64)*(D^4 - d^4)$$

Where,
D= outer diameter
d = inner diameter (outer diameter minus 2 X wall thickness)

For rectangular section:

$$I = (1/12)*(b_1*d_1^3 - b_2*d_2^3)$$

Where

b_1= width of outer cross section
d_1= depth/height of outer cross section (outer depth minus 2 X wall thickness)
b_2= width of inner cross section
d_2= depth/height of inner cross section (outer depth minus 2 X wall thickness)

For Reference Material:

$$I = \pi/64*(D^4 - d^4)$$

Here,
D= 1"= 25.4 mm,
d= 25.4-4= 21.4mm,
So,
I= 10136.75 mm^4,
C= D/2 = 12.7 mm,
So,

M= 291.18 N-m;

Bending stiffness is considered to be proportional to the product of EI where;
E = Modulus of elasticity
I = Second moment of area for structural cross section.
For steels E = 205 GPa ,
So,

E*I = 2076.97 N m^2

bending stiffness will be 2076.97*k N m^2

where

k is proportionality constant.

The similar calculations are done for all six materials and the results are tabulated below:

Material No.	Y.T.S (MPa)	I (mm^4)	C (mm)	M (N-m)	Bending Stiffness ($N\text{-}m^2$)
Ref.	365	10131.6	12.7	291.2	2076.97*k
1.	365	10885.1	12.7	312.8	2231.5*k
2.	365	60502.8	20	1104	12403.1*k
3.	365	14445	12.7	415.2	296.123*k
4.	460	10885.1	12.7	394.2	2231.5*k
5.	460	60502.8	20	1391	12403.1*k
6.	460	14445	12.7	523.2	296.123*k

4. CAE ANALYSIS OF VEHICLE/FRAME

CASE-1: (AISI 1018, TOTAL CIRCULAR CROSS SECTION: 1" x 0.94" x 0.087")

CASE-2: (AISI 1018, CIRCULAR CROSS SECTION: 1" x 0.94" x 0.087", SQUARE CROSS SECTION: 1.57" x 1.57" x 0.06", SQUARE CROSS-SECTION ;1" x 1" x 0.063")

CASE-3: (AISI 4130, TOTAL CIRCULAR CROSS SECTION: 1" x 0.94" x 0.087")

CASE-4: (AISI 4130, CIRCULAR CROSS SECTION: 1" x 0.94" x 0.087", SQUARE CROSS SECTION: 1.57" x 1.57" x 0.06", SQUARE CROSS-SECTION ;1" x 1" x 0.063")

4.1. FRONTAL IMPACT ANALYSIS

CASE-1 (AISI 1018, TOTAL CIRCULAR CROSS SECTION: 1" x 0.94" x 0.087")

a) **Assumption & Considerations**:

- Assumptions-

The vehicle is assumed to have impact from front side. As the vehicle is designed for medium speed, lesser impact force is considered for analysis. When impact occurs vehicle gets temporarily locked and front side gets impacted. Hence frame is given fixture and impact force is applied on the frame from front. Concentrated impact on front protection member is calculated.

- Analysis type- Static analysis
- Theory used- Von-Mises stress theory
- Simplification- omission of redundant members like seat support members, motor mounting support, etc.
- Meshing Conditions-
  - Mesh Type- Solid Mesh
  - Mesher used- Uniform based mesh
  - Maximum element size- 8.7 mm
  - Minimum element size- 1.7 mm
  - No. of nodes- 591000

The frontal impact analysis is performed on vehicle with1.25G force.

b) **Calculation of Impact Forces:**

The frontal impact analysis is performed on vehicle with 1.25G force.

Now, Force =1.25 G

Mass of one rider=115 kg

Mass of two rider= 115 X 2=230 kg

Mass of vehicle=100 kg

Utility mass = 20 kg

Total mass= 350 kg

Force-1.25 G= 1.25*350*9.81=4292N

c) **Analysis Results:**

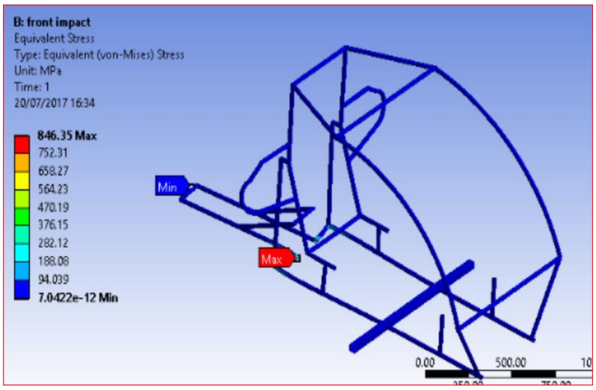

Figure 1- Front Impact Stress Analysis

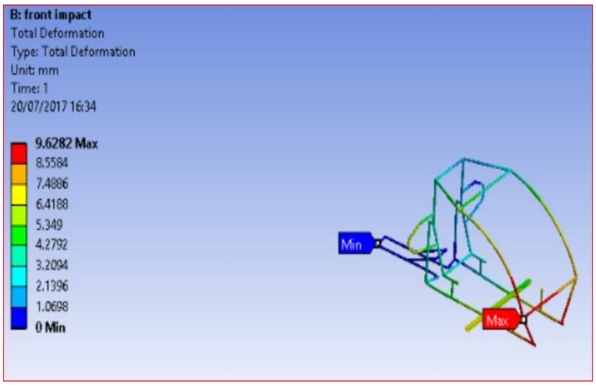

Figure 2- Front Impact Displacement Analysis

Maximum Von- Mises stress- 188.08 N/mm^2

Maximum static displacement- 9.628 mm

Maximum static displacement at driver- 3.28 mm

Factor of safety- 1.94

d) **Optimizations:**

Factor of safety for analysis with **minimum cross section** of frame member comes out to be more than 1. Also there is no redundant member in the frame. Hence there is no scope for optimization.

Analysis of other frame materials:

CASE-2: (AISI 1018, CIRCULAR CROSS SECTION: 1" x 0.94" x 0.087", SQUARE CROSS SECTION: 1.57" x 1.57" x 0.06", SQUARE CROSS-SECTION ;1" x 1" x 0.063")

a) **Assumption & Considerations**:
Assumptions and considerations remaining same except the no. of nodes

- No. of nodes: 288000

b) **Calculation of Impact Forces:**
Impact Force is as above which is **4292 N.**

c) **Analysis Results:**

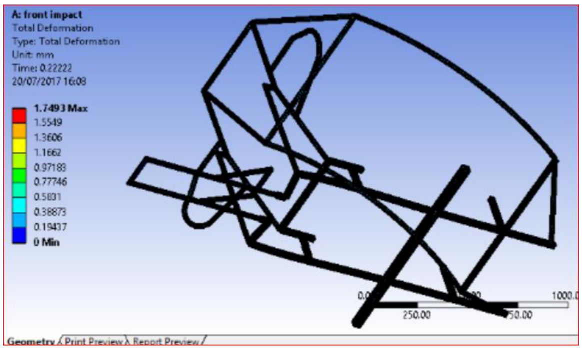

Figure 3- Front Impact Displacement Analysis

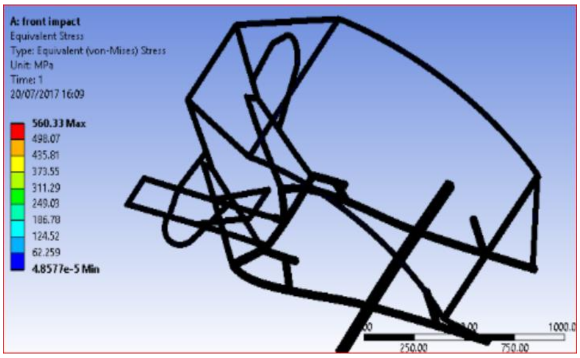

Figure 4- Front Impact Stress Analysis

Maximum Von- Mises stress- 152.02 N/mm²
Maximum static displacement- 1.75 mm
Maximum static displacement at driver- 1.16 mm
Factor of safety- 2.41

d) **Optimizations:**
Factor of safety for analysis with **minimum cross section** of frame member comes out to be more than 1. Also there is no redundant member in the frame. Hence there is no scope for optimization.

CASE-3: (AISI 4130, TOTAL CIRCULAR CROSS SECTION: 1" x 0.94" x 0.087")

we think, there is no need to perform analysis on the this case, as this is stronger and heavier than above cases and it may lead us to overdesign. Hence the analysis on this case is not performed.

CASE-4: (AISI 4130, CIRCULAR CROSS SECTION: 1" x 0.94" x 0.087", SQUARE CROSS SECTION: 1.57" x 1.57" x 0.06", SQUARE CROSS-SECTION ;1" x 1" x 0.063")

we think, there is no need to perform analysis on the this case, as this is stronger and heavier than above cases and it may lead us to overdesign. Hence the analysis on this case is not performed.

4.2. SIDE IMPACT ANALYSIS

CASE-1 (AISI 1018, TOTAL CIRCULAR CROSS SECTION: 1" x 0.94" x 0.087")

a) **Assumption & Considerations**:

In side impact analysis frame is assumed to be impacted from one side. For performing analysis frame with its one side is given fixture & impact force is applied on other side. Impact on side protection member is considered which is concentrated impact on body.

- Analysis type- Static analysis
- Theory used- Von-Mises stress theory
- Simplification- omission of redundant members like seat support members, motor mounting support, etc.
- Meshing Conditions-
  - Mesh Type- Solid Mesh
  - Mesher used- Uniform based mesh
  - No. of Nodes- 591000
  - Maximum element size- 8.7 mm
  - Minimum element size- 1.7 mm

b) **Calculation of Impact Forces:**
The side impact analysis is performed on vehicle with 1.25G force.
Now,
Force =1.25 G
Mass of one rider-115 kg
Mass of two rider- 115*2=230 kg
Mass of vehicle-100 kg
Utility mass – 20 kg
Total mass- 350 kg

Force-1.25 G= 1.25*350*9.81=4292 N
.

c) **Analysis Results:**

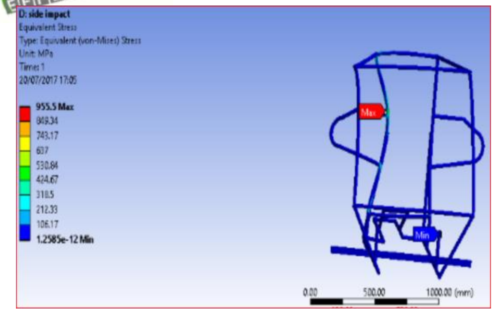

Figure 5- Side Impact Stress Analysis

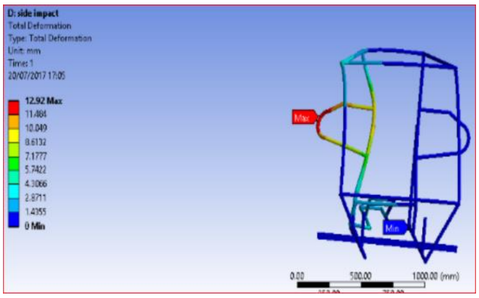

Figure 6- Side Impact Displacement Analysis

Maximum Von- Mises stress- 212.32 N/mm²
Maximum static displacement- 12.92 mm
Maximum static displacement at driver- 11.1 mm
Factor of safety- 1.71

d) Optimizations:

Factor of safety for analysis with **minimum cross section** of frame member comes out to be more than 1. Also there is no redundant member in the frame. Hence there is no scope for optimization.

CASE-2: (AISI 1018, CIRCULAR CROSS SECTION: 1" x 0.94" x 0.087", SQUARE CROSS SECTION: 1.57" x 1.57" x 0.06", SQUARE CROSS-SECTION ;1" x 1" x 0.063")

a) Assumption & Considerations:

Assumptions and considerations remaining same except the no. of nodes

- No. of nodes: 288000

b) Calculation of Impact Forces:

Impact Force is as above which is **4292 N.**

c) Analysis Results:

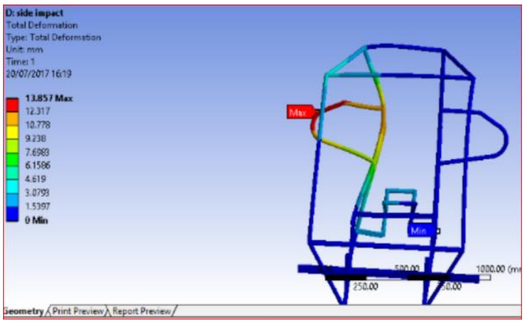

Figure 7- Side Impact Displacement Analysis

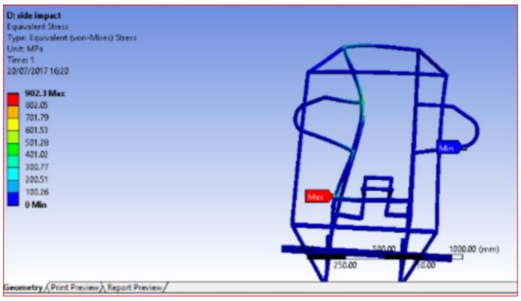

Figure 8- Side Impact Stress Analysis

Maximum Von- Mises stress- 202.02 N/mm²
Maximum static displacement- 13.875 mm
Maximum static displacement at driver- 10.2 mm
Factor of safety- 1.80

d) Optimizations:

Factor of safety for analysis with **minimum cross section** of frame member comes out to be more than 1. Also there is no redundant member in the frame. Hence there is no scope for optimization.

CASE-3: (AISI 4130, TOTAL CIRCULAR CROSS SECTION: 1" x 0.94" x 0.087")

We think, there is no need to perform analysis on the this case, as this is stronger and heavier than above cases and it may lead us to overdesign. Hence the analysis on this case is not performed.

CASE-4: (AISI 4130, CIRCULAR CROSS SECTION: 1" x 0.94" x 0.087", SQUARE CROSS SECTION: 1.57" x 1.57" x 0.06", SQUARE CROSS-SECTION ;1" x 1" x 0.063")

We think, there is no need to perform analysis on the this case, as this is stronger and heavier than above cases and it may lead us to overdesign. Hence the analysis on this case is not performed.

4.3. ROLLOVER ANALYSIS

CASE-1: (AISI 1018, TOTAL CIRCULAR CROSS SECTION: 1" x 0.94" x 0.087")

a) Assumption & Considerations:

While doing rollover analysis vehicle is assumed to be completely rolled over on top. Hence while performing the analysis, base frame is given fixtures and distributed roll over force is applied on the top.

- Analysis type- Static analysis
- Theory used- Von-Mises stress theory
- Simplification- omission of redundant members like seat support members, motor mounting support, etc.
- Meshing Conditions-
  - Mesh Type- Solid Mesh
  - Mesher used- Uniform based mesh
  - No of Nodes- 591000
  - Maximum element size- 8.7 mm
  - Minimum element size- 1.7 mm

b) Calculation of Impact Forces

The roll over analysis is performed on vehicle with 1.25G force.

Now,

Force =1.25 G
Mass of one rider= 115 kg
Mass of two ride= 115*2=230 kg
Mass of vehicle= 100 kg
Utility mass = 20 kg
Total mass= 350 kg

Force-1.25G=1.25*350*9.81=4292 N

c) Analysis Results:

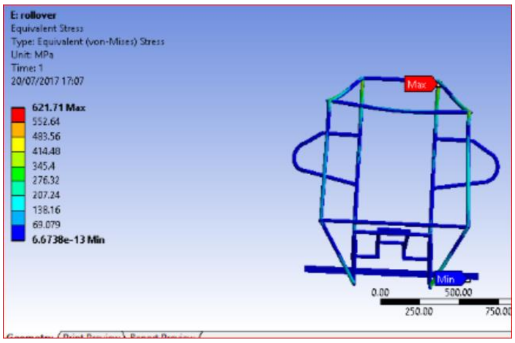

Figure 9- Rollover Stress Analysis

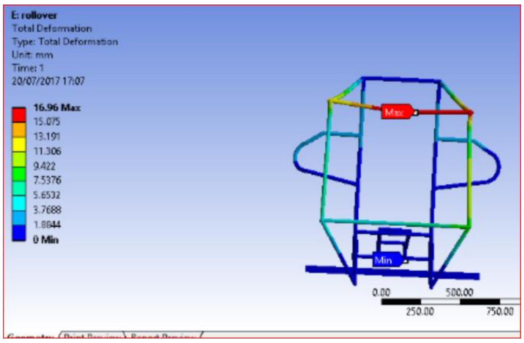

Figure 10- Rollover Displacement Analysis

Maximum Von- Mises stress- 276.32 N/mm²
Maximum static displacement- 16.96 mm
Maximum static displacement at driver- 5.88 mm
Factor of safety- 1.33

d) Optimizations:

Factor of safety for analysis with **minimum cross section** of frame member comes out to be more than 1. Also there is no redundant member in the frame. Hence there is no scope for optimization.

CASE-2: (AISI 1018, CIRCULAR CROSS SECTION: 1” x 0.94” x 0.087”, SQUARE CROSS SECTION: 1.57” x 1.57” x 0.06”, SQUARE CROSS-SECTION ;1” x 1” x 0.063”)

a) Assumption & Considerations:

Assumptions and considerations remaining same except the no. of nodes

- No. of nodes- 288000

b) Calculation of Impact Forces:

Impact Force is as above which is **4292 N.**

c) Analysis Results:

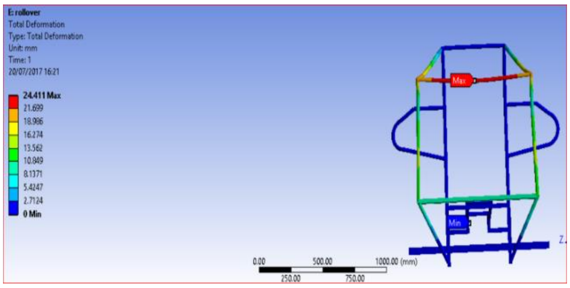

Figure 11- Rollover Displacement Analysis

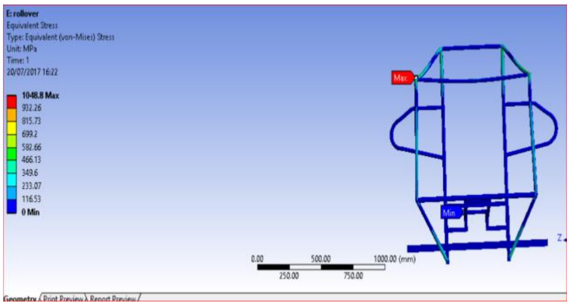

Figure 12- Rollover Stress Analysis

Maximum Von- Mises stress- 233.07 N/mm²
Maximum static displacement- 24.41 mm
Maximum static displacement at driver- 2.01 mm
Factor of safety- 1.57

d) Optimizations:

Factor of safety for analysis with **minimum cross section** of frame member comes out to be more than 1. Also there is no redundant member in the frame. Hence there is no scope for optimization.

CASE-3: (AISI 4130, TOTAL CIRCULAR CROSS SECTION: 1” x 0.94” x 0.087”)

we think, there is no need to perform analysis on the this case, as this is stronger and heavier than above cases and it may lead us to overdesign. Hence the analysis on this case is not performed.

CASE-4: (AISI 4130, CIRCULAR CROSS SECTION: 1” x 0.94” x 0.087”, SQUARE CROSS SECTION: 1.57” x 1.57” x 0.06”, SQUARE CROSS-SECTION ;1” x 1” x 0.063”)

we think, there is no need to perform analysis on the this case, as this is stronger and heavier than above cases and it may lead us to overdesign. Hence the analysis on this case is not performed.

4.4. BACK IMPACT ANALYSIS

CASE-1 (AISI 1018, TOTAL CIRCULAR CROSS SECTION: 1” x 0.94” x 0.087”)

a) Assumption & Considerations:

In back impact analysis, frame is assumed to be impacted at back support. For performing analysis frame with its front side is given fixture & impact force is applied on back side. Impact on back protection member is considered which is concentrated impact on body.

- Analysis type- Static analysis
- Theory used- Von-Mises stress theory
- Simplification- omission of redundant members like seat support members, motor mounting support, etc.
- Meshing Conditions-
  - Mesh Type- Solid Mesh
  - Masher used- Uniform based mesh
  - No. of Nodes- 591000
  - Maximum element size- 8.7 mm
  - Minimum element size- 1.7 mm

b) Calculation of Impact Forces:

The back impact analysis is performed on vehicle with 1.25G force.

Now,

Force =1.25 G
Mass of one rider-115 kg
Mass of two rider- 115*2=230 kg
Mass of vehicle-100 kg
Utility mass – 20 kg
Total mass- 350 kg

Force-1.25 G= 1.25*350*9.81=4292 N

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c) Analysis Results:

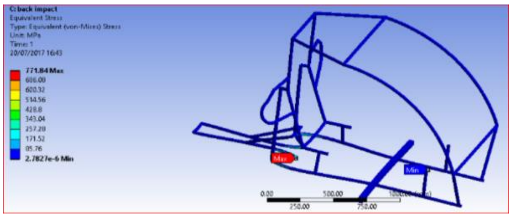


Figure 13- Back Impact Stress Analysis

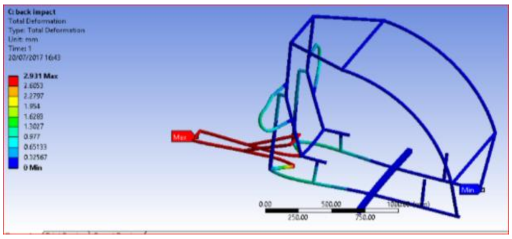


Figure 14- Back Impact Displacement Analysis

Maximum Von- Mises stress- 171.52 N/mm^2
Maximum static displacement- 2.93 mm
Maximum static displacement at driver- 0.3 mm
Factor of safety- 2.13

d) Optimizations:

Factor of safety for analysis with **minimum cross section** of frame member comes out to be more than 1. Also there is no redundant member in the frame. Hence there is no scope for optimization.

CASE-2: (AISI 1018, CIRCULAR CROSS SECTION: 1” x 0.94” x 0.087”, SQUARE CROSS SECTION: 1.57” x 1.57” x 0.06”, SQUARE CROSS-SECTION ;1” x 1” x 0.063”)

a) Assumption & Considerations:

Assumptions and considerations remaining same except the no. of nodes

- No. of nodes- 288000

b) Calculation of Impact Forces:

Impact Force is as above which is **4292 N.**

c) Analysis Results:

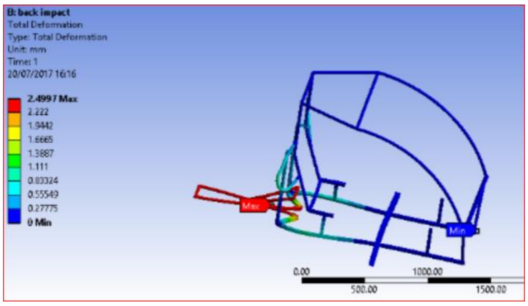


Figure 15- Back Impact Displacement Analysis

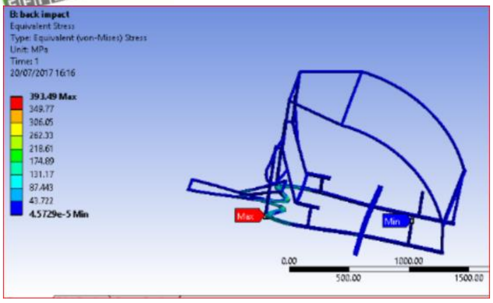


Figure 16- Back Impact Stress Analysis

Maximum Von- Mises stress- 174.89 N/mm^2
Maximum static displacement- 2.49 mm
Maximum static displacement at driver- 0.27 mm
Factor of safety- 2.09

d) Optimizations:

Factor of safety for analysis with **minimum cross section** of frame member comes out to be more than 1. Also there is no redundant member in the frame. Hence there is no scope for optimization.

CASE-3: (AISI 4130, TOTAL CIRCULAR CROSS SECTION: 1" x 0.94" x 0.087")

we think, there is no need to perform analysis on the this case, as this is stronger and heavier than above cases and it may lead us to overdesign. Hence the analysis on this case is not performed.

CASE-4: (AISI 4130, CIRCULAR CROSS SECTION: 1" x 0.94" x 0.087", SQUARE CROSS SECTION: 1.57" x 1.57" x 0.06", SQUARE CROSS-SECTION ;1" x 1" x 0.063")

we think, there is no need to perform analysis on the this case, as this is stronger and heavier than above cases and it may lead us to overdesign. Hence the analysis on this case is not performed.

5. FINAL MATERIAL SELECTION

We have used circular cross section (material 1) in frame as lower supporting member. But considering fabrication point of view, as we have to mount seat support member and sprocket support member on the frame, fabrication will be easy and effective if we use rectangular or I-section instead of circular section on the lower side of frame. This replacement will also help to improve the quality of weld joints by improving effective contact area. Hence we are replacing the lower circular member (materaial1) with square member (material 2 and 3) both. This replacement will surely tend to increase the overall strength of the frame, as material 2 and material 3 are the stronger and firm options. Hence this replacement is fair.
So, we finalize the **case 1** as our frame.

Case 1: (AISI 1018, TOTAL CIRCULAR CROSS SECTION: 1" x 0.94" x 0.087")

<u>Materials Selected for Frame:</u>

i. MATERIAL-1 (AISI 1018)
Circular Cross-Section ;1" X 0.94" X 0.087"

ii. MATERIAL-2 (AISI 1018)
Square Cross-Section; 1.57" x 1.57" x 0.06"

iii. MATERIAL-3 (AISI 1018)
Square Cross-Section ;1" X 1" X 0.063"

6. CAE ANALYSIS OF OTHER PARTS

6.1 Analysis of Rear Wheel Fork:

CASE-1: (AISI 1018, TOTAL CIRCULAR CROSS SECTION: 1" x 0.94" x 0.087")

a) Assumption & Considerations

While doing the analysis of rear wheel fork, one point of the fork is hinged, one point is connected to the eye of the suspension spring, and the axle of rear wheel is connected to third point (axle's space).
For analysis of the fork suspension spring is assumed to be fully compressed and the normal force due to vehicle weight is assumed to act at axle's space. While the remaining end is hinged. Hence the spring point is given a fixture. Force is applied on the axle's space and third point is given hinged support and analysis is performed.

- Analysis type- Static analysis
- Theory used- Von-Mises stress theory
- Meshing Conditions-
  - ➢ Mesh Type- Solid Mesh
  - ➢ Masher used- Curvature based mesh
  - ➢ Jacobins points- 4 points
  - ➢ Maximum element size- 1.5748 inch
  - ➢ Minimum element size- 0.3149 inch.

b) Calculation of Impact Forces:

Force on the wheel fork at axle's place is taken as 1.25G.
Now,

Force =1.25.5G
Mass of one rider=115 kg
Mass of two rider= 115*2=230 kg
Mass of vehicle=100 kg
Utility mass= 20 kg
Total mass= 350 kg

Force-1.25 G= 1.25*350*9.81=4292 N

c) Analysis Results:

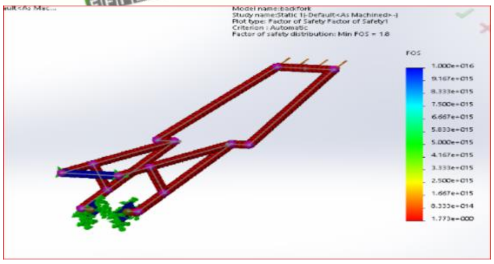


Figure 18- rear wheel fork Factor of Safety

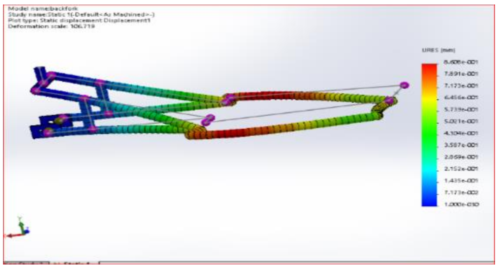


Figure 18- rear wheel fork Displacement Analysis

Maximum static displacement-8.62 mm
Factor of Safety-1.77

6.2 Analysis of Seat Support Members:

CASE-1: (AISI 1018, TOTAL CIRCULAR CROSS SECTION: 1" x 0.94" x 0.087")

a) Assumption & Considerations

While doing the analysis of seat support members it is assumed that each driver applies the 50 kg along the horizontal axis and also the weight of 115 kg for each driver acting in vertically downward direction.

For analysis of the seat support members it is assumed that the base frame is fixed and force is applied in horizontal direction pointing at back and another force resulting weight of both drivers applied on the support member pointing in downward direction.

- Analysis type- Static analysis
- Theory used- Von-Mises stress theory
- Meshing Conditions-
  - ➢ Mesh Type- Solid Mesh
  - ➢ Masher used- Curvature based mesh
  - ➢ No. of Nodes- 288000
  - ➢ Maximum element size- 8.7 mm
  - ➢ Minimum element size- 1.7 mm.

b) Calculation of Impact Forces:

It is assumed that half of the vehicle weight is taken by rear wheel. Hence force on the wheel fork at axle's place is taken as 0.5 G.
Now,

Force acting in Downward Direction-
Mass of one rider= 115 kg
Mass of two rider= 115*2=230 kg
Force= 1G= 1*230*9.81=2256.3 N

Force acting in Horizontal Direction-
Force applied by one rider= 50 kg
Force applied by two riders= 50*2=100 kg

Force= 1G= 1*100*9.81=981 N

c) Analysis Results:

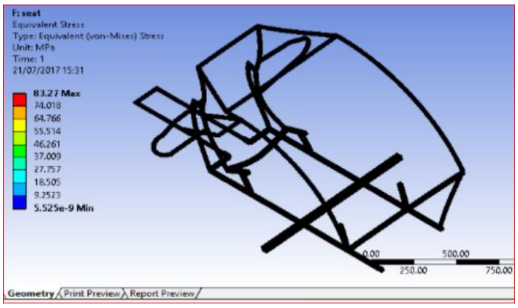


Figure 19-seat support members Stress Analysis

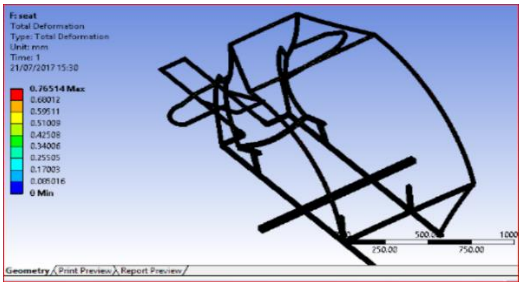


Figure 20- seat support members Displacement Analysis

Maximum Von- Mises stress- 83.27 N/mm2
Maximum static displacement-0.76 mm

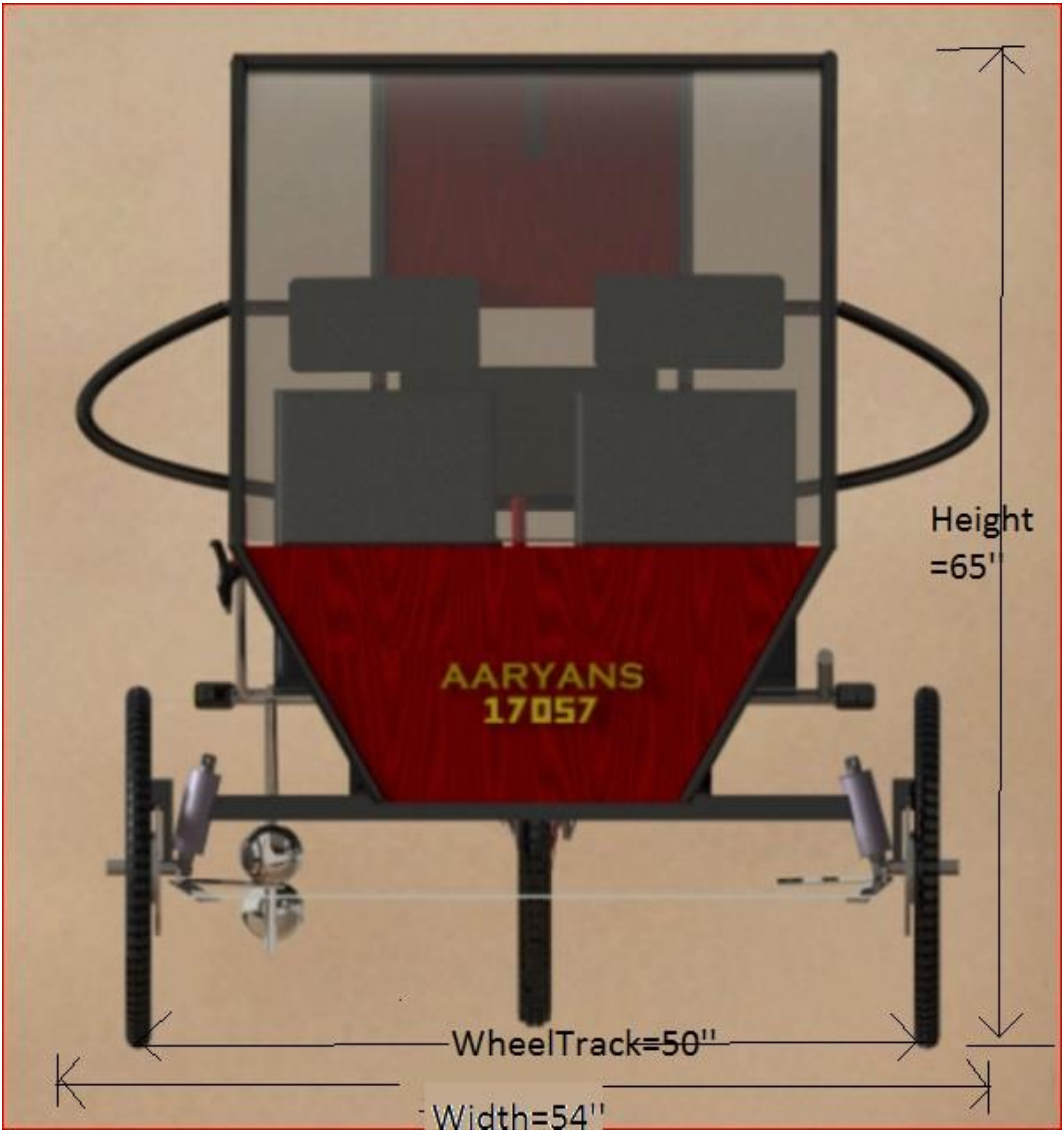
7. VEHICLE VIEWS

APPENDIX-1 : Vehicle Views

Figure-1 (Isometric View of Vehicle)

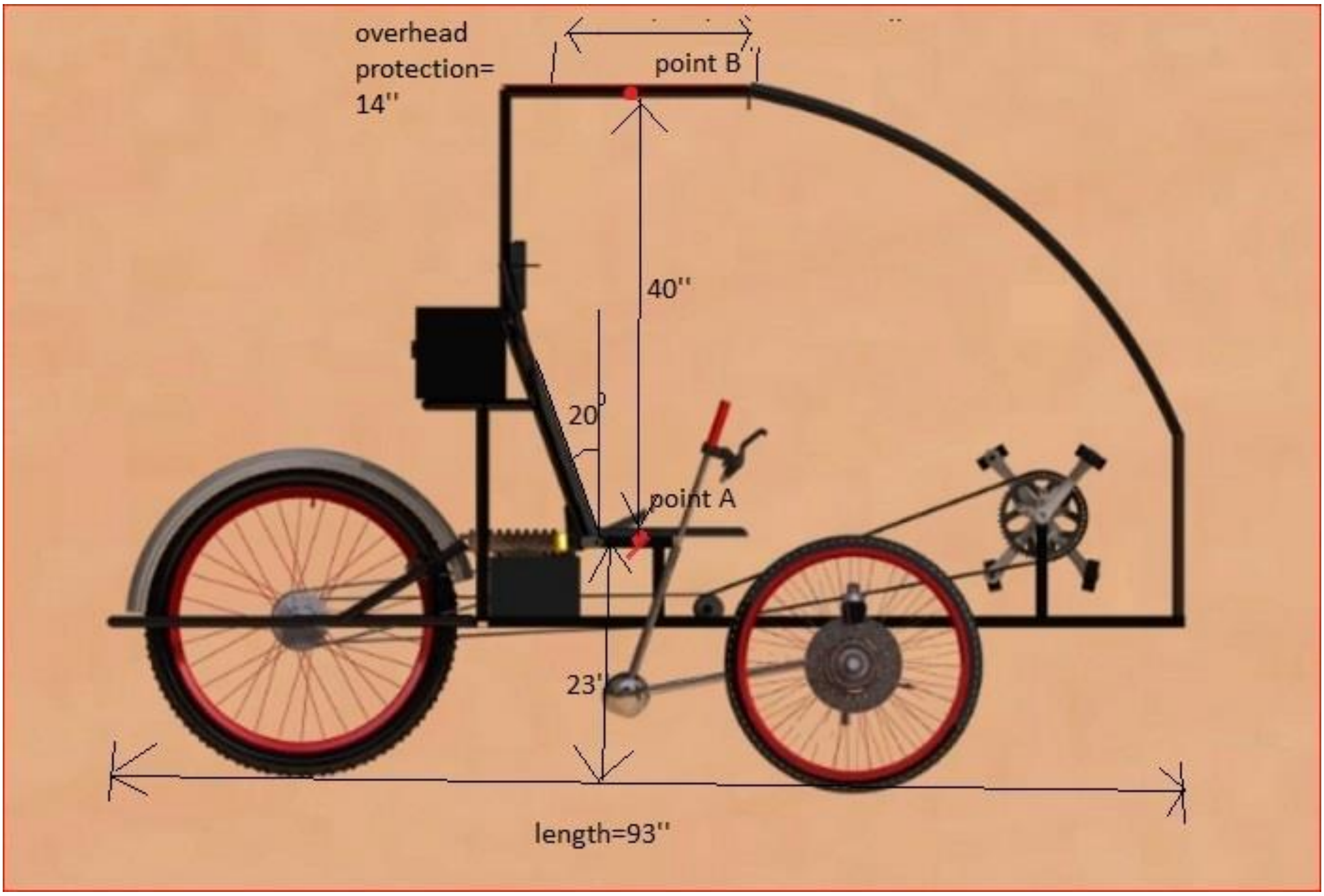
APPENDIX-1 : Vehicle Views (contd..)

Figure-2 (Front View of Vehicle)



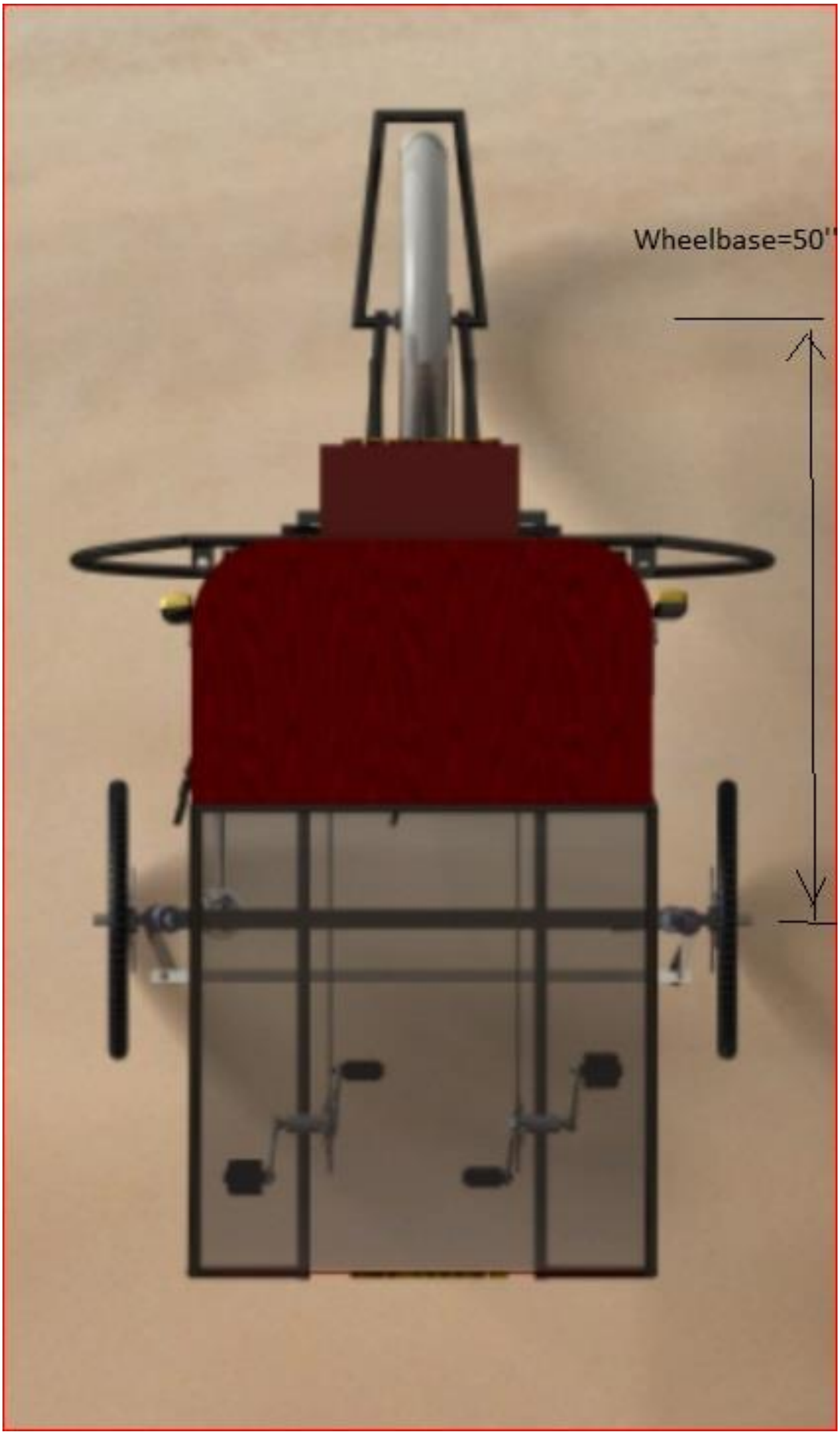
APPENDIX-1 : Vehicle Views (contd..)

Figure-3 (Side View of Vehicle)



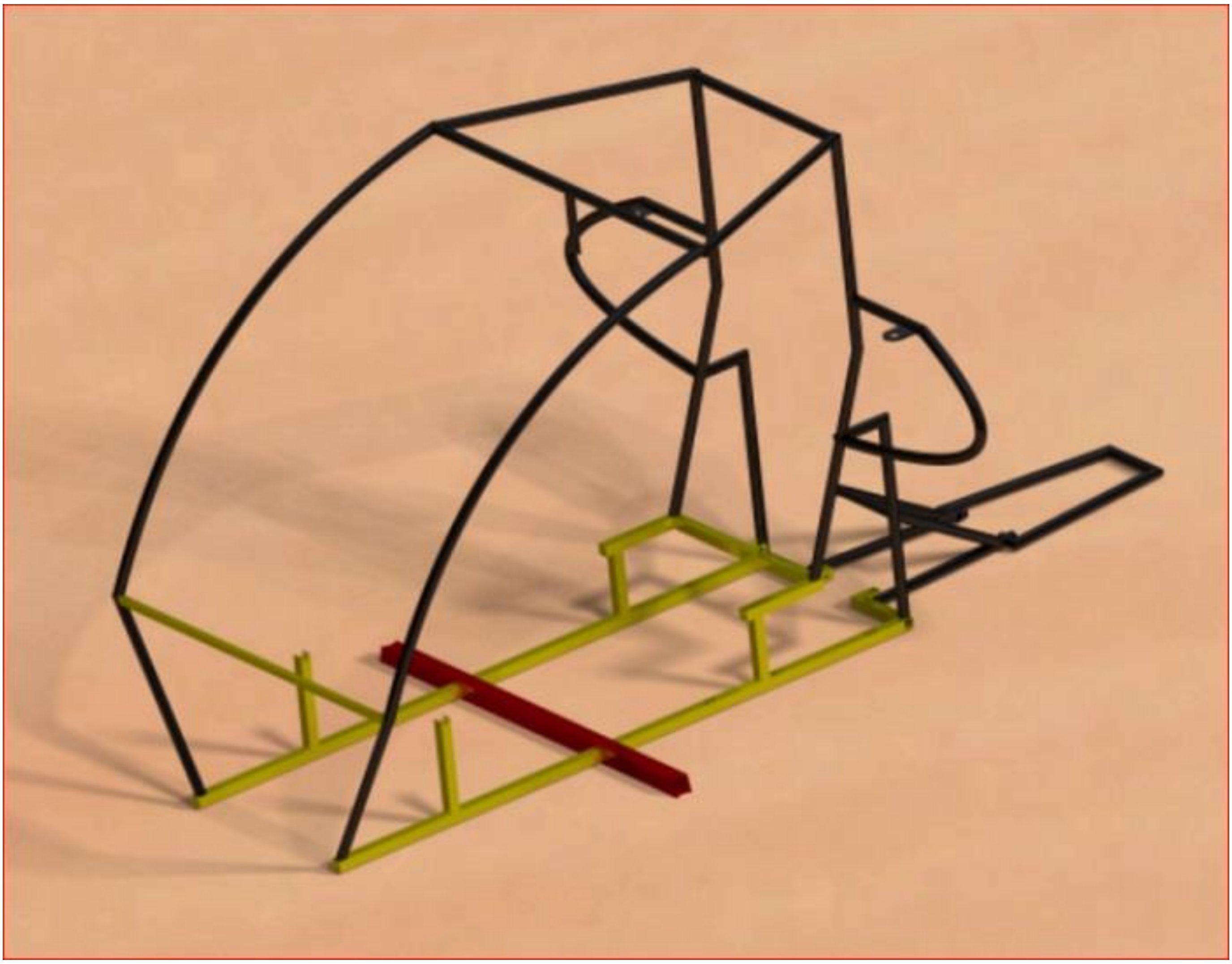
APPENDIX-1 : Vehicle Views (contd..)

Figure-4 (Top View of Vehicle)



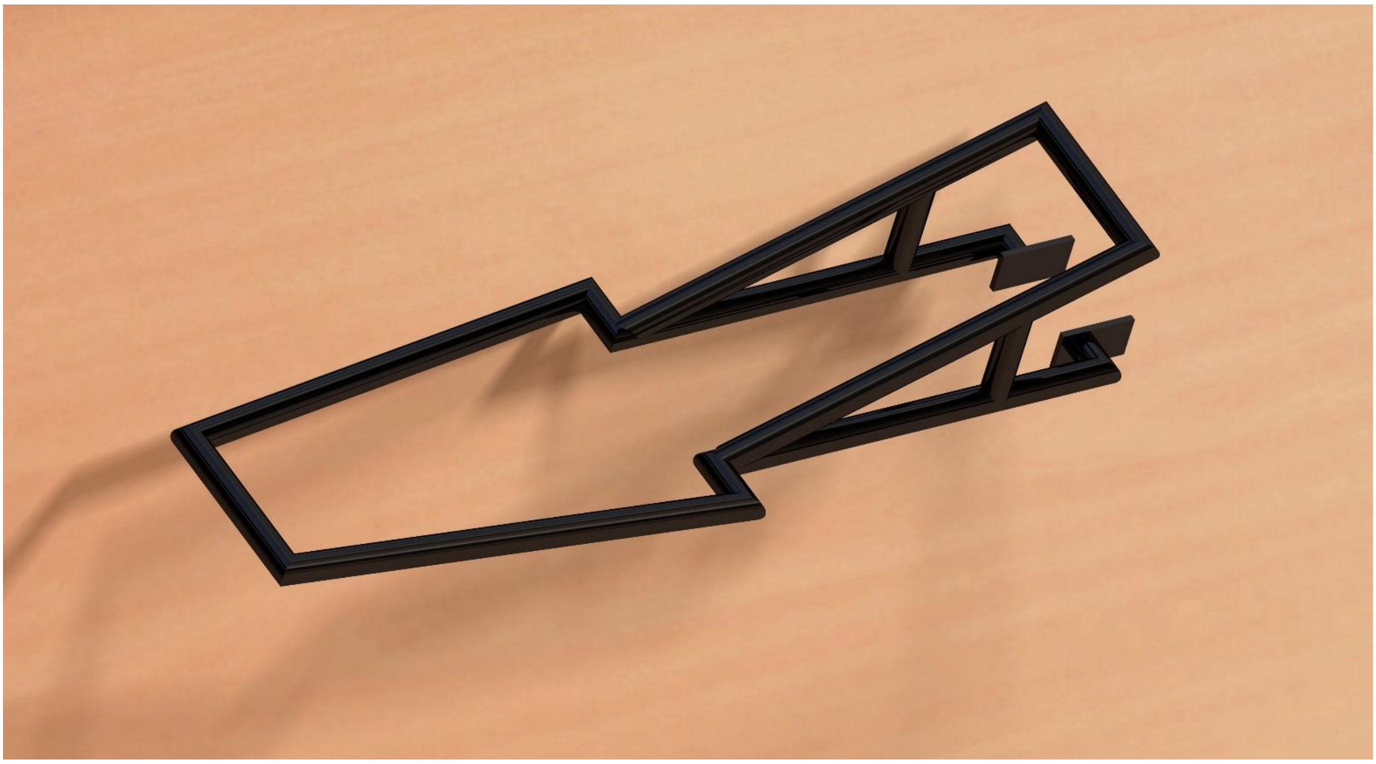
APPENDIX-1 : Vehicle Views (contd..)

Figure-5 (CAD Model of Frame)

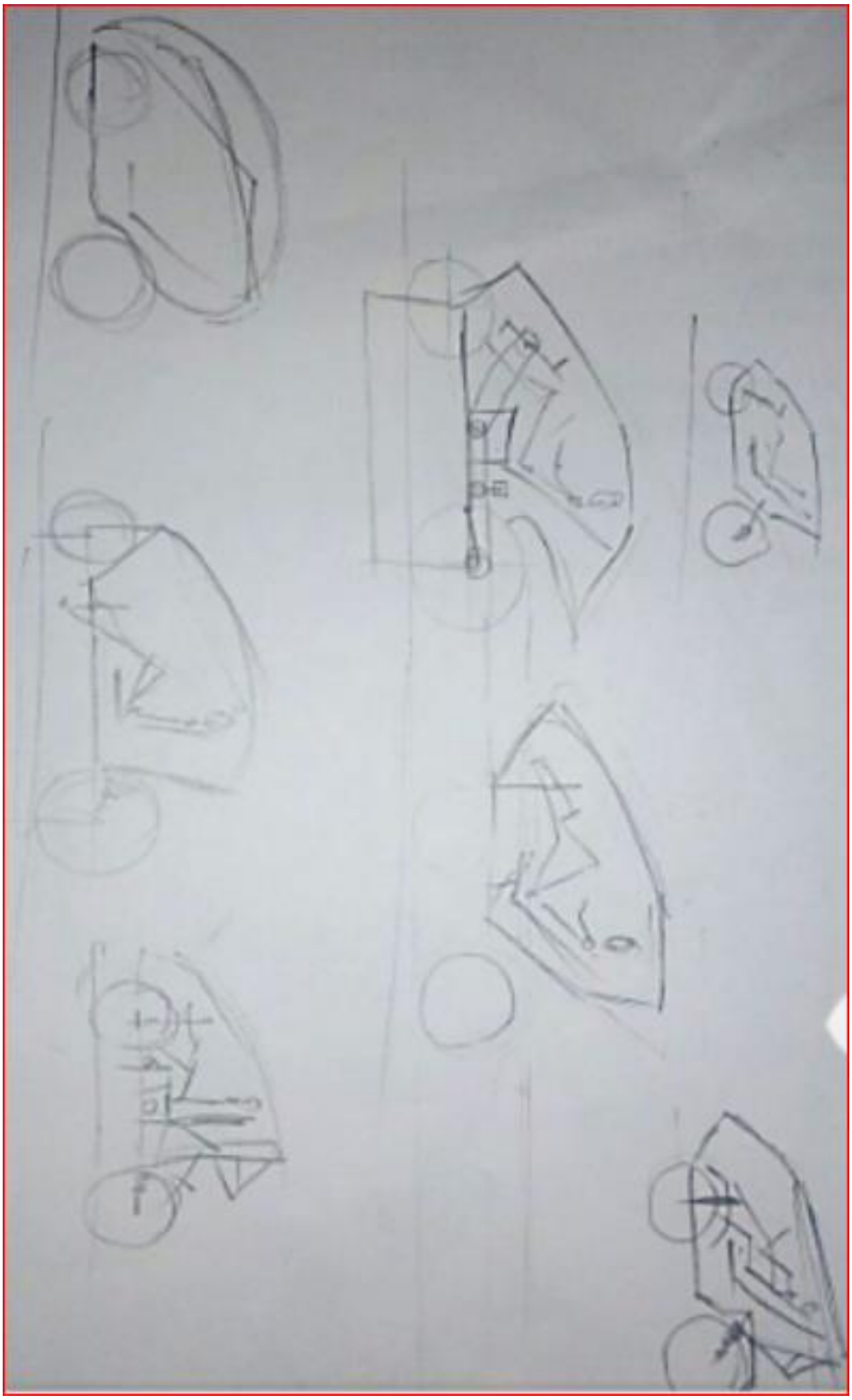


APPENDIX-1 : Vehicle Views (contd..)

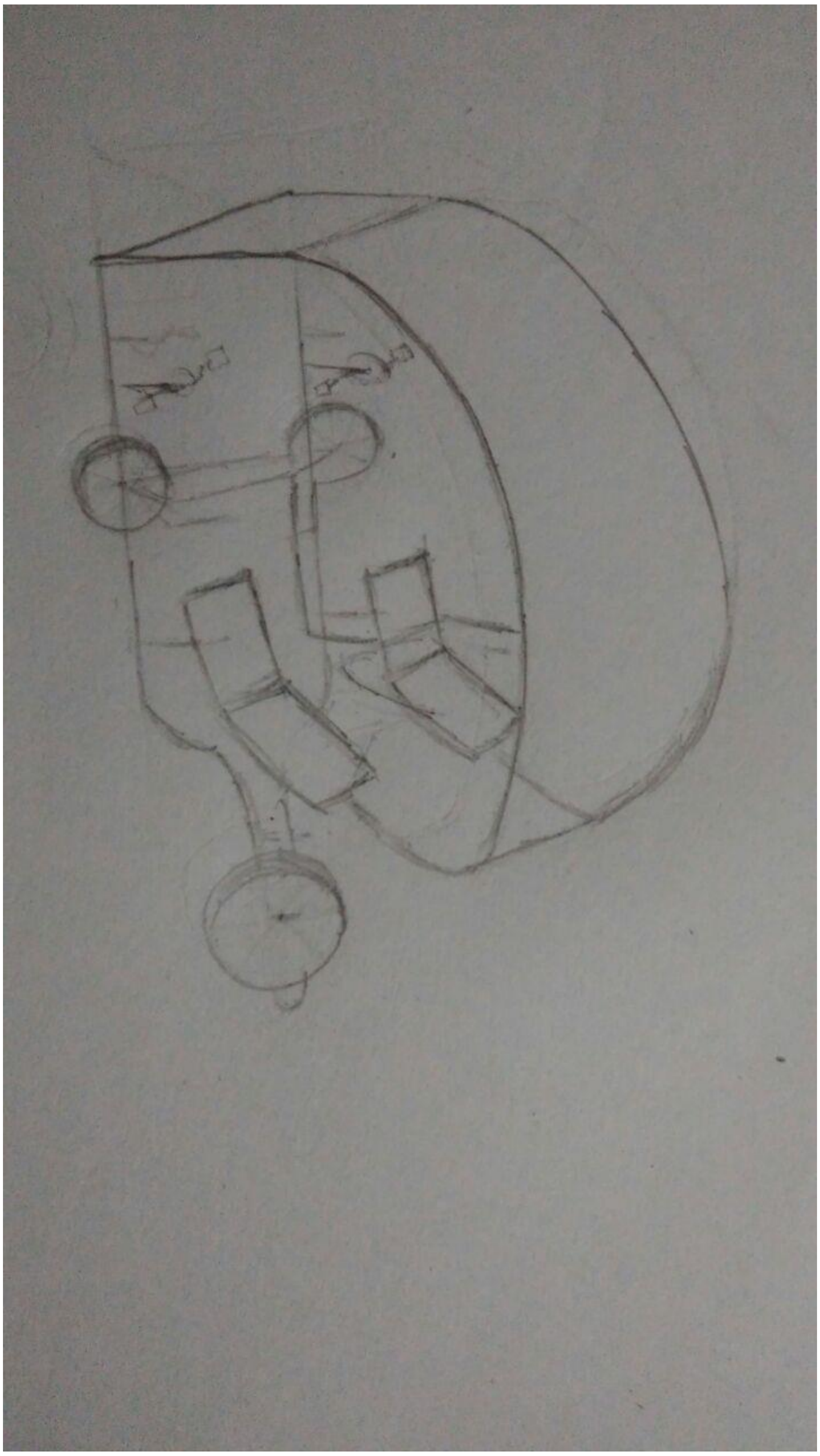
Figure-5 (CAD Model of Rear Fork Assembly)



APPENDIX-2 : Hand Sketches



APPENDIX-2 : Hand Sketches (contd..)



APPENDIX-2 : Hand Sketches (contd..)