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# A Project Report on Optimization of an Off Road Vehicle Ergonomics

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***Abstract: This paper contain the behaviour of A BAJA vehicle chassis which undergo the various load test like''Front impact test, Side impact test, Rear impact test, Roll over impact"all the analysis of the test has been performed with the help of ANSYS WORKBENCH 18.1,where maximum deformation ,stress and strain calculated over duration of the particular impact.For the theoretical calculation we have use the INELASTIC COLLISION THEORY with this we have applied a force at a point .The boundary conditions and loading use different methodology. Study of ergonomics which help to give the ergonomically safer design according to the driver perspective.***
***Keywords: Front impact test, Side impact test, Rear impact test, Roll over impact, Ansys Workbench ,ergonomic study***

## I. INTRODUCTION

1) A vehicle frame undergoes various endurance conditions and hence needs to be made rigid for the component and at the same time the driver clearance needs to be considered, judging at the premanufacturing stage becomes difficult by only CAE Analysis.
2) Not considering ergonomic factors can lead to certain physical problem as
a) Disorder of dorsal muscle & back pain.
b) Pain in neck
c) Disorder of muscles, tendons, ligaments associated with the back portion.

## II. WHAT IS ERGONOMIC AND WHY IT IS IMPORTANT

Ergonomics is a branch of a science that aims to learn about human abilities and limitation and then apply this learning to improve people's interaction

Ergonomics aims to improve the efficiency of the people and minimise the risk of injury or harm.

To achieve best practice design, Ergonomists use the data and techniques of several disciplines;

1) *Anthropometry:* body sizes, shapes
2) *Biomechanics:* muscles, levers, forces, strength
3) *Environmental Physics:* noise, light, heat, cold, radiation, vibration body system, hearing, vision, sensation.
4) *Applied Psychology:* skill, learning, errors, differences
5) *Social Psychology:* groups, communication, learning, behaviours.

## III. HISTORY OF ERGONOMICS

*ALPHONSE CHAPANIS* is known as the father of ergonomics; he was an American pioneer in the field of industrial design ,and widely considered one of the fathers of ergonomics or human factors, the science of ensuring that design takes account of human characteristics. Basic ergonomics has existed since the first ancestors of modern man began creating primitive tools to make tasks easier. Archaeological evidence from as far back as some of the earliest Egyptian dynasties, and other, more concrete findings from 5th Century BCE Greece, have shown that tools, household equipment, and other manmade devices illustrated sophisticated (for their time) ergonomic principles.Shortly after the Industrial Revolution, factory machinery and equipment started being built with design considerations closer to what we think of today as "ergonomics.

## IV. OFF ROAD VEHICLE DESIGN CONSIDERATION

### A. *Design Consideration*

Design consideration involves various factors such as material selection ,cross section selection, frame design and finite element analysis .

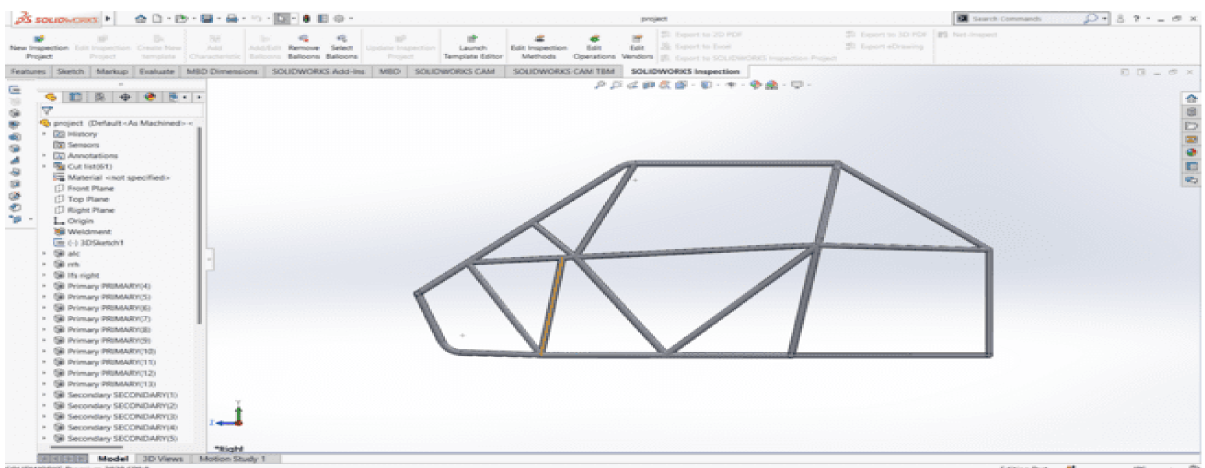
One of the key design decisions that tremendously increase the safety, reliability and performance in any vehicle structure is material selection.

*B. Material Selection*

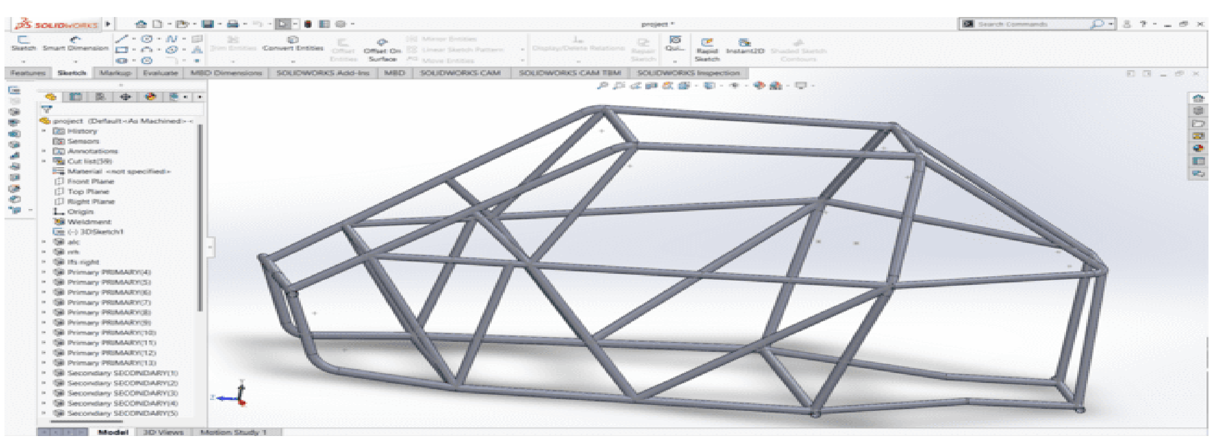
AISI 4130 is a low alloy steel containing chromium and molybdenum as strengthening agent. The steel has good strength, toughness, weldability, and machinability .AISI 4130 is corrosion resistance and has a reasonable strength ,also it has high strength to weight ratio .It easily available in the market .In light of the over the favourable circumstances referenced the suitable material is AISI 4130

PROPERTIES OF AISI 4130

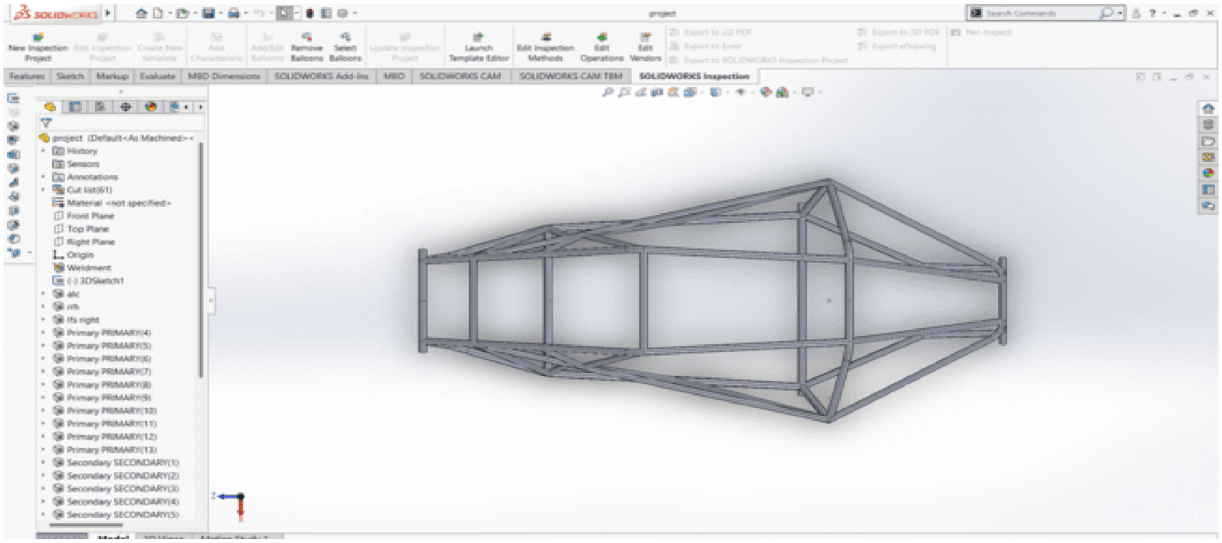
| SR.NO | PROPERTY | VALUE |
|---|---|---|
| 1 | DENSITY | 7850 KG/$M^3$ |
| 2 | YIELD STRENGTH | 460MPa |
| 3 | ULTIMATE TENSILE STRENGTH | 560MPa |
| 4 | MODULUS OF ELASTICITY | 205GPa |
| 5 | POISSONN'S RATIO | 0.29 |



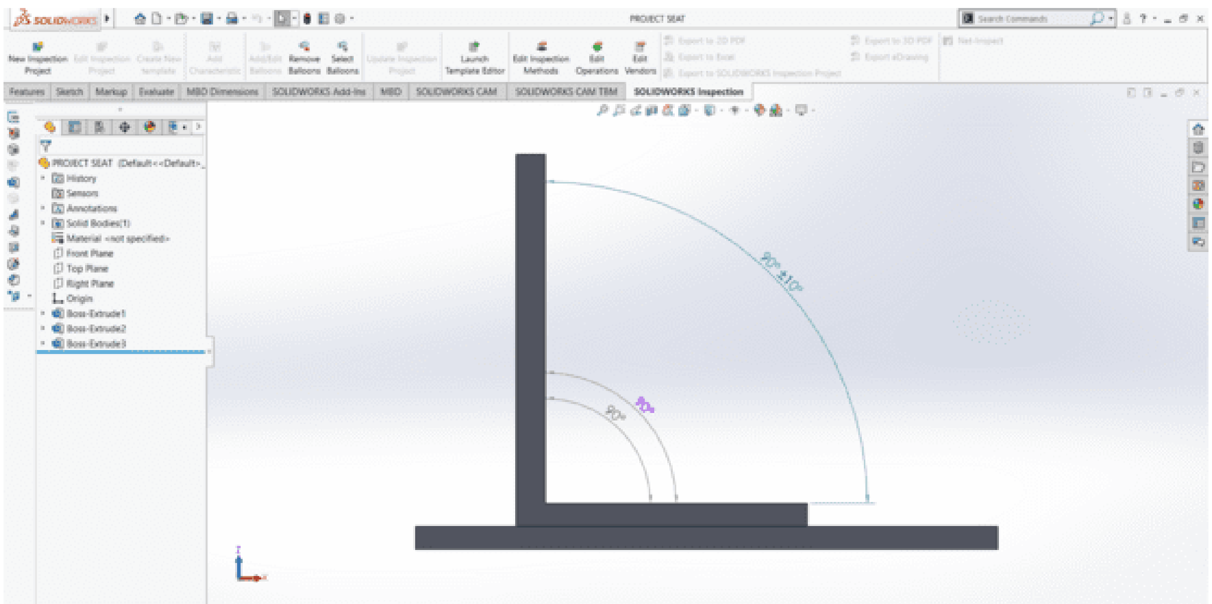
SIDE VIEW



ISOMETRIC VIEW



TOP VIEW



**SEAT DESIGN**

## V. OFFROAD VEHICLE ANALYSIS CONSIDERATION

Static analysis for all possible case of impact along with modal analysis was carried out in Ansys 18.1 .In analysis, several impact test were done on the roll cage modal

### A. *Front Impact Test*

In case of front impact it is assume that the AV may hit a wall another vehicle or tree.For this case we assume that it to be a wall
CALCULATION METHOD:
Impact Force method by speed limit:
For inelastic collision impact force is calculated as;

$$W_{net} = \frac{mv_f^2}{2} - \frac{mv_i^2}{2}$$

$$W_{net} = -\frac{mv_i^2}{2}$$

But $W_{net} - impact\ force\ \times d$

Where d= distance travelled during impact.

An impact time of 0.15s is assumed for the wall in case of static analysis .

For a vehicle which moves at 16.66m/s, the travel after impact will be 2.5m for 0.15s.

Impact force= $\frac{mv_i^2}{2d}$

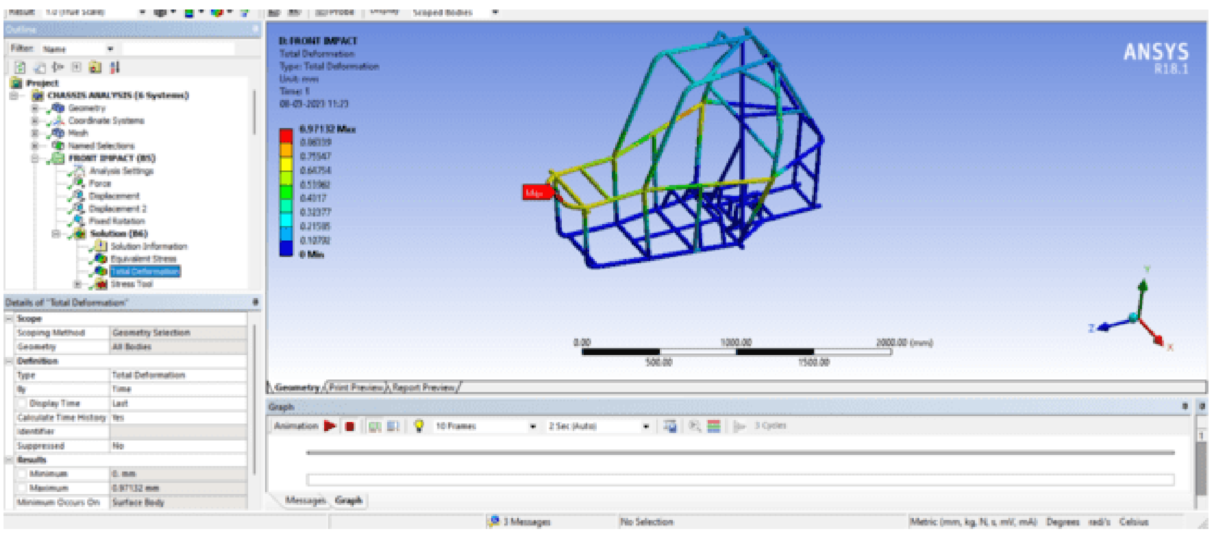
$=(\frac{250\times16.65\times16.66}{2\times2.5})$

=1387778N

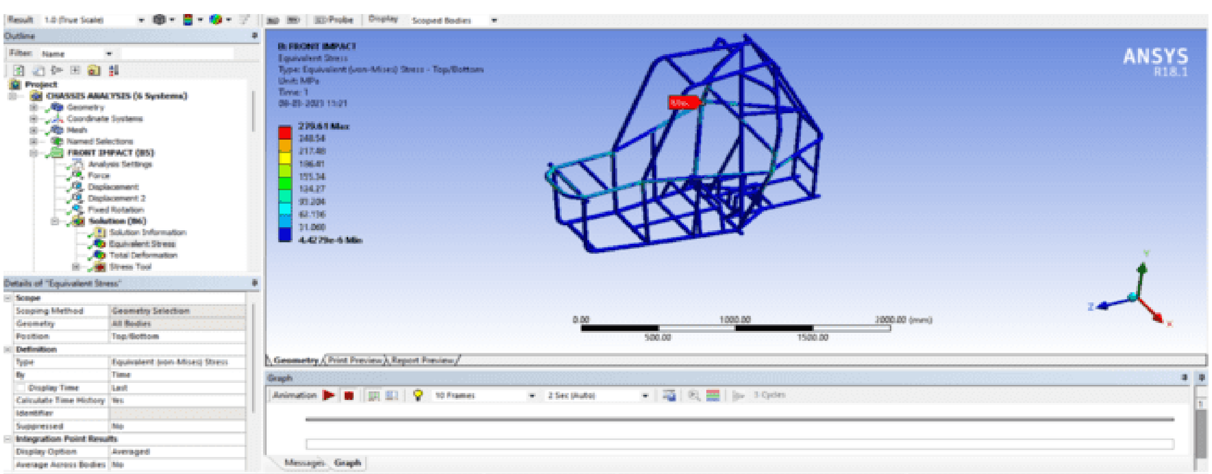
The force equivalent is 5.7G force,

For the worst case scenario, the weight is considered to be 15000N which is equivalent to 6G force.

| | |
|---|---|
| Force applied | Frontal most members |
| Constraints | Rear suspension points |




FRONT IMPACT TOTAL DEFORMATION




FRONT IMPACT EQUIVALENT STRESS

*B. Rear Impact Test*

In case of rear impact ,another vehicle is hitting the vehicle from behind .

We have considered a worst case scenario where a vehicle hits at 16.66m/s.

CALCULATION METHOD:

Impact Force method by speed limit:

For inelastic collision impact force is calculated as;

$$W_{net} = \frac{mv_f^2}{2} - \frac{mv_i^2}{2}$$

$$W_{net} = -\frac{mv_i^2}{2}$$

But $W_{net} = impact\ force \times d$

Where d= distance travelled during impact.

An impact time of 0.3s is assumed for rear impact as impact time for two deformable bodies is greater than a rigid body in case of static analysis .

For a vehicle which moves at 16.66m/s,the travel after impact will be 5m for 0.3s.

Impact force$=\frac{mv_i^2}{2d}$

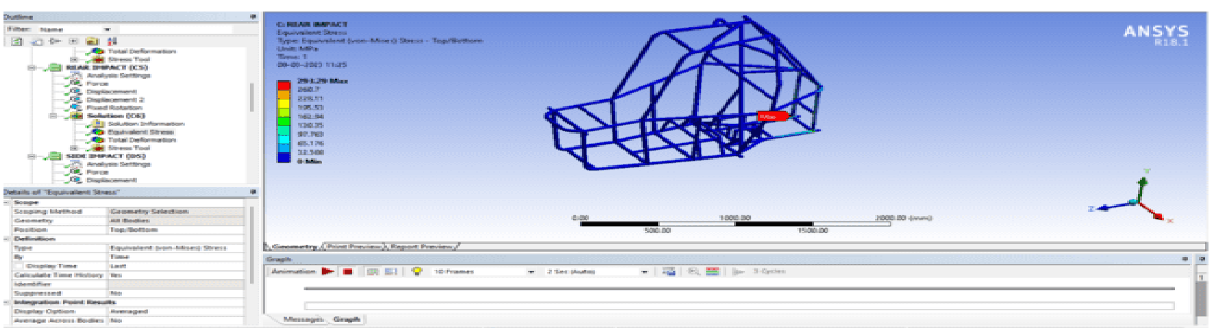
$=\left(\frac{250\times16.66\times16.66}{2\times5}\right)$

$=6938.9N$

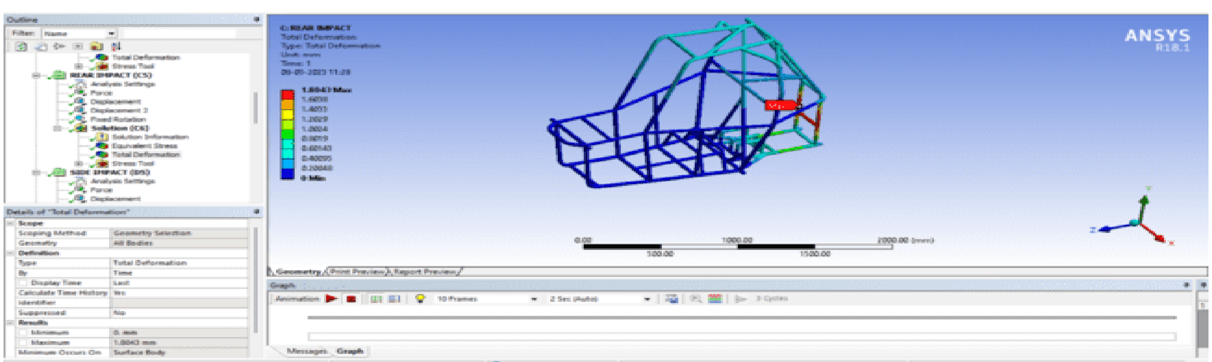
This force is equivalent to 2.9G of force .

For worst case scenario weight considered to be 7500N which is equivalent to 3G.

| | |
|---|---|
| Force applied | Rear most member |
| Constraints | Front suspension points |




REAR IMPACT EQUIVALENT STRESS




REAR IMPACT TOTAL DEFORMATION

### *C. Side Impact Test*

During side impact another vehicle is going to hit the atv on the side most members of the roll cage. For this situation the impact time is considered to be 0.3s as the vehicle should be deformable body .

CALCULATION METHOD:

Impact Force method by speed limit:

For inelastic collision impact force is calculated as;

$$W_{net} = \frac{mv_f^2}{2} - \frac{mv_i^2}{2}$$

$$W_{net} = -\frac{mv_i^2}{2}$$

But $W_{net} = impact\ force \times d$

Where d= distance travelled during impact.

An impact time of 0.3s in cas of static analysis .

For a vehicle which moves at 16.66m/s,the travel after impact will be 5m for 0.3s.

Impact force= $\frac{mv_i^2}{2d}$

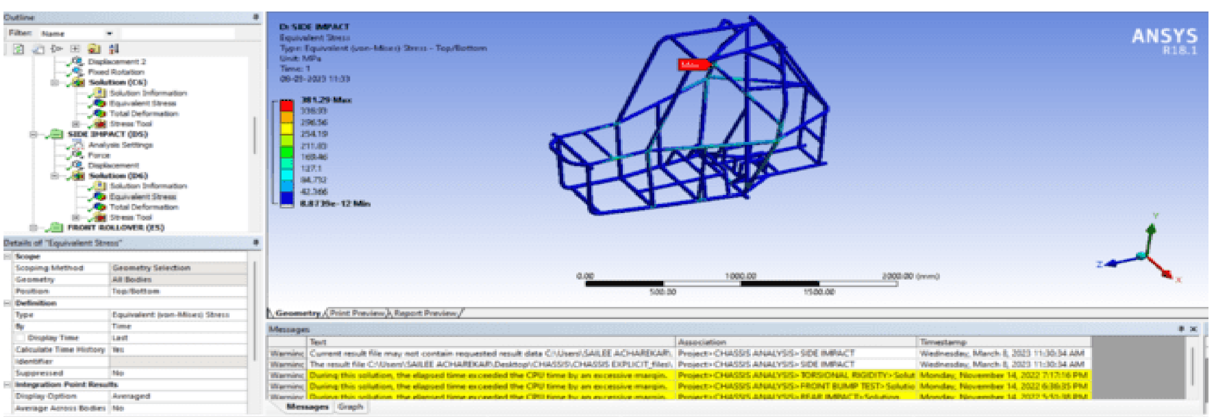
$=(\frac{250\times16.66\times16.66}{2\times5})$

=6938.9N

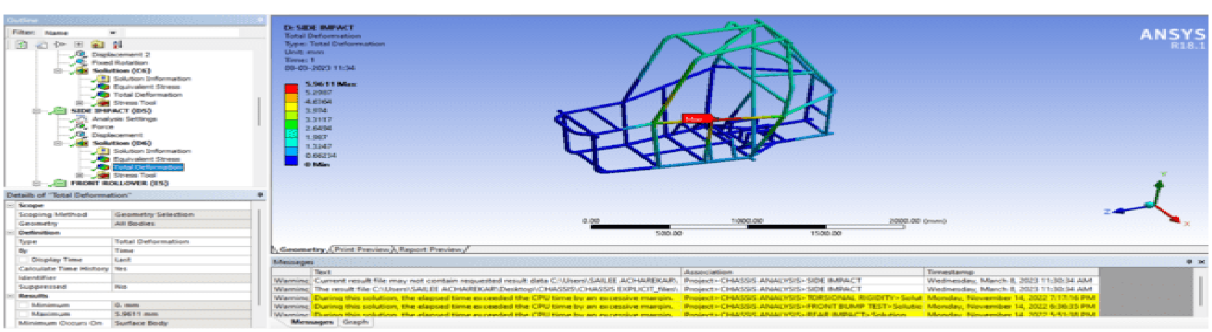
This force is equivalent to 2.9G force .

For the worst case scenario weight considered to be 7500N which is equivalent to be 3G.

| | |
|---|---|
| Force applied | Side most member |
| Constraints | Opposite side suspension points |




SIDE IMPACT EQUIVALENT STRESS




SIDE IMPACT TOTAL DEFORMATION

*D. Roll Over Test*

In case of roll over, it is assumed that ATV experience an roll over situation and then hits the front most members when it rolls overs , namely two members ,the front hitch point and the lateral members of the RHO member at specified angle

CALCULATION METHOD:

Work energy principle;

Impact time is considered to be 0.15s as the roll cage is expected to hit the ground .

mgh=$\frac{mv^2}{2}$

Here g = acceleration due to gravity =9.81m/$s^2$

h=wheelbase=1.422m

v=$\sqrt{2gh}$

v=5.27m/s

W=$\frac{MV^2}{2}$

W=$(\frac{250\times5.27\times5.27}{2})$

W=3471.6J

W=F$\times d$

d=distance travelled during impact=5.27$\times 0.15 - 0.8m$

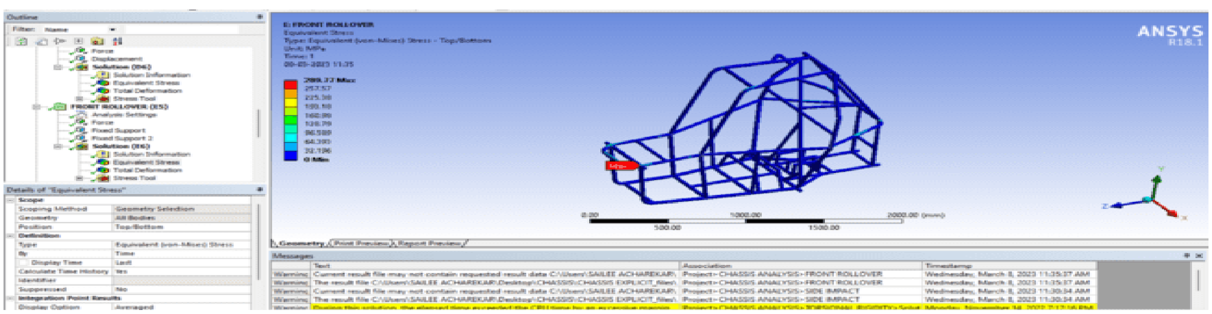
F=$\frac{3471.6}{0.8}$

F=4340N

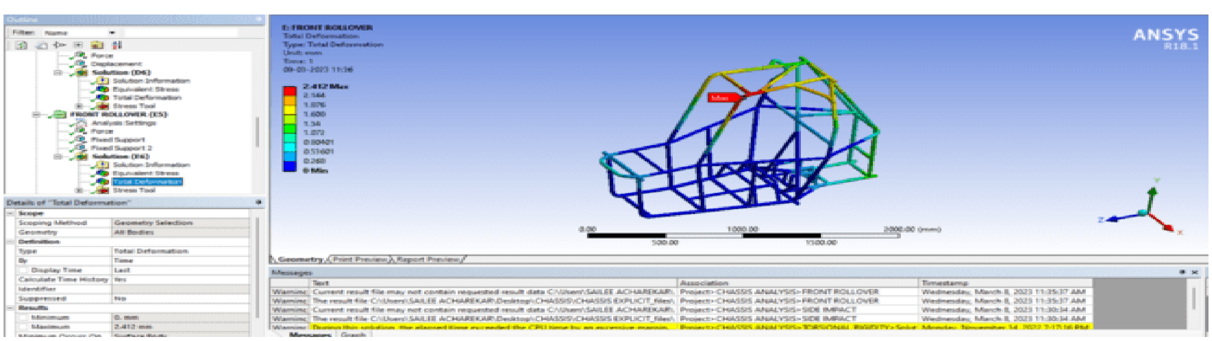
This force is equivalent to 1.76G force .

For worst case scenario consider it to be as 5000N which is equivalent to 2G force

| | |
|---|---|
| Force applied | RHO,LC and front hitch point |
| Constraints | Front and Rear suspension point |




ROLL OVER EQUIVALENT STRESS




ROLL OVER TOTAL DEFORMATION

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*E. Torsional Rigidity Test*

Roll cage is subjected to torsional load during cornering and when one wheel goes over a bump

FRONT TORSIONAL TEST

T=$(P_L - P_R) \times \frac{B}{2}$

Where $p_L = force\ on\ left\ wheel$

$p_r - force\ on\ right\ wheel$

B=front track width =1.32m

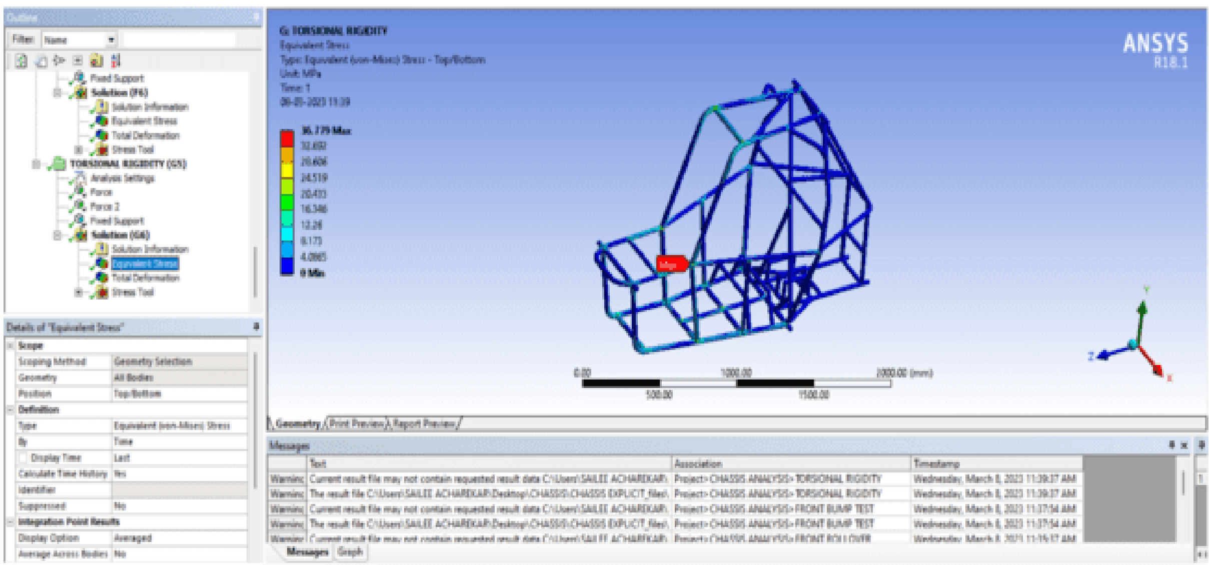
Torque T will reach a limit when one wheel lifts off the ground .

The weight of the vehicle will be ;

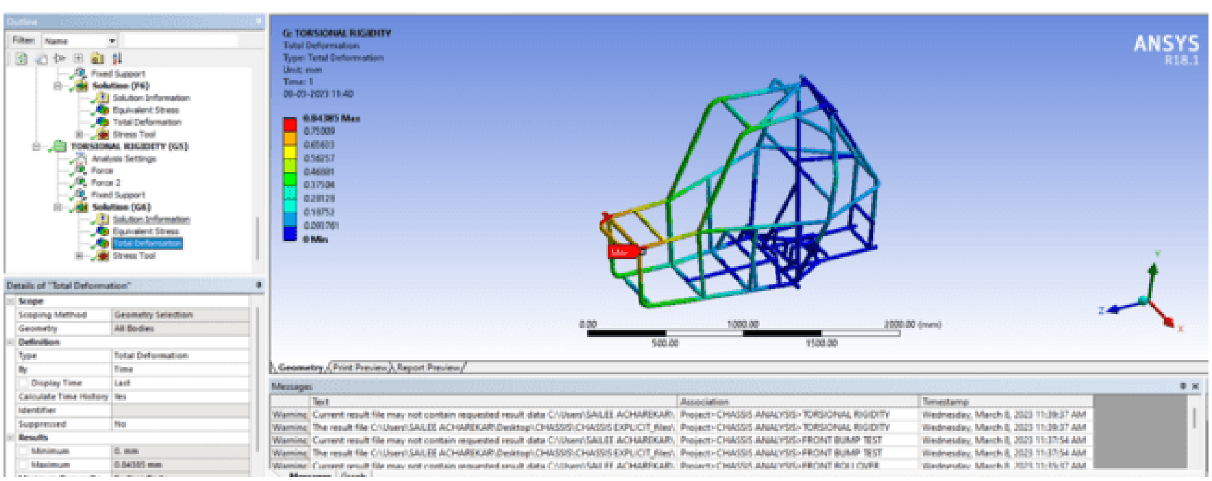
P=mg=$230 \times 9.81 = 2256.3$

So T=2256.3$\times\ 0.66 = 1500Nm$

| | |
|---|---|
| Force applied | Front suspension points |
| Constraints | Rear suspension points |




TORSIONAL RIGIDITY FOR EQUIVALENT STRESS




TORSIONAL RIGIDITY FOR TOTAL DEFORMATION

### *F. Bump Test*

For bump test analysis we have considered a situation where roll cage travels from an elevation 2 feet high and then hits the ground level involving its front mass and the force initially imparted to the front suspension points .

Here the vehicle will follow projectile motion and the calculation is as follows

v=16.66m/s

g=acceleration due to gravity =9.81m/$s^2$

Height from the ground level (h)=0.601m

Vertical speed is given by

v=$\sqrt{2gh}$

Vv=3.43m/s

Resultant velocity at time of impact will be given by

Vr=$\sqrt{v_h^2 + v_v^2}$

Vr=17m/s

By work energy method we know that

$$w_{net} = \frac{mv^2}{2}$$

$$wnet = impact\ force\ \times d$$

Since the roll cage hits the ground the time of impact is considered to be 0.15s.hence distance travelled during an impact will be

d=16.66$\times 0.15 = 2.5m$

For the front bump test the mass of the vehicle is considered as front mass which is 40%of the actual mass of the vehicle .

m=0.4$\times 250 = 100kg$

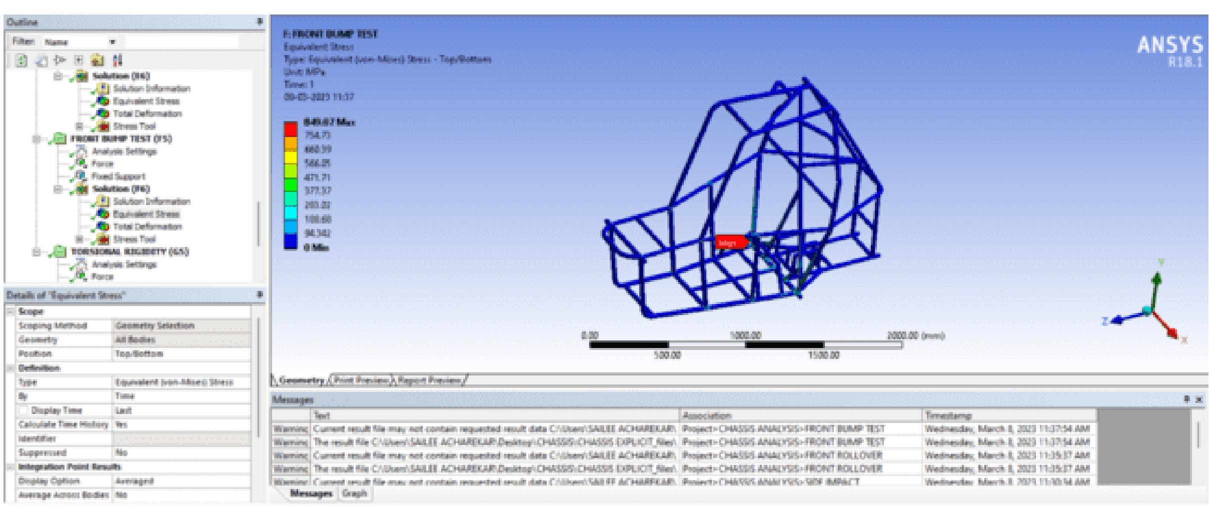
Impact force =$\frac{mv^2}{2d}$

=$\left(\frac{100\times16.56\times16.66}{2\times2.5}\right)$

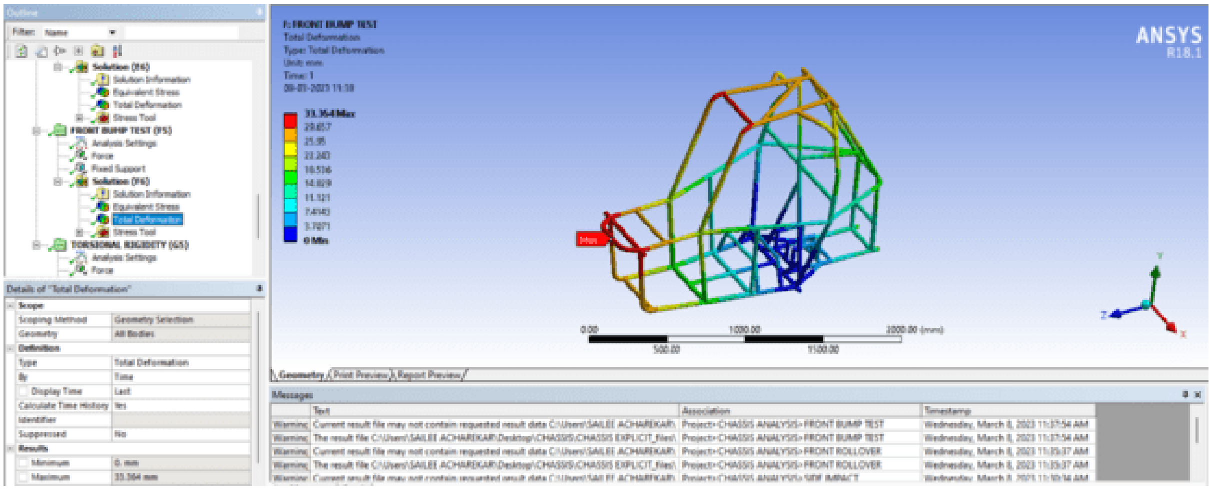
=5500N

This force is equivalent to 2.3G and will be acting at a 12 degree angle.

| | |
|---|---|
| Force applied | Front suspension points |
| Constraints | RRH and Front damper points |




BUMP TEST EQUIVALENT STRESS




BUMP TEST TOTAL DEFORMATION

| TYPE | FORCE(N) | VON MISES STRESS(MPa) | TOTAL DEFORMATION (mm) | F.O.S |
|---|---|---|---|---|
| FRONT IMPACT | 15000 | 340.04 | 0.9834 | 1.38 |
| REAR IMPACT | 7500 | 156.01 | 0.4119 | 3.012 |
| SIDE IMPACT | 7500 | 357.23 | 3.1944 | 1.315 |
| ROLL OVER | 5000 | 167.23 | 0.5675 | 2.8 |
| TORSIONAL RIGIDITY | 1500Nm | 324.87 | 4.0599 | 1.45 |
| BUMP | 3500 | 319.71 | 3.4383 | 1.47 |

## VI. CONCLUSION

Safety of the driver is the first and foremost priority .therefore, considerable factor of safety is applied to roll cage of an atv reduce the risk of failure and possible injuries .Considering the ergonomically safer design will help the driver to drive a vehicle smoothly during an endurance race. larger factor of safety implies large ability of an ATV to withstand all kinds of loads and capable of moving on various terrains .this paper illustrate the entire analysis and design methodology of an atv an ergonomic safer design calculator for atv.