**International Journal of Technical Research and Applications** e-ISSN: 2320-8163,
www.ijtra.com Volume 4, Issue 3 (May-June, 2016), PP. 413-418

# COMPLETE ANYLYSIS OF ROLL CAGE FOR ATV

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***Abstract*— While the designing of roll cage for the ATV vehicle, we have to perform the analysis likewise front impact, side impact, rollover, rear impact for to know what is effect on roll cage after sudden impact because the roll cage supports the other assembly parts of the ATV and provide 3-D cage which is protect driver and many internal components (Break and clutch pedal, master tandem cylinder etc.) of ATV. We have to take consider each and every critical point of roll cage for the improve performance without failure occur into roll cage A roll cage is main structure of ATV. After conducting deeply research on methods of analysis we start with the FEA (Finite Element Analysis). The roll cage also provides Aesthetic look to the ATV. FEA analysis is also help to determine the material selection, material cross section, requirement strength of different members of roll cage and stress-strain analysis to test the ATV against all sudden impact. We ensure that ATV is having high factor of safety.**

***Keywords:*** **ATV Vehicle, Roll cage, FEA, Material, Stress-Strain analysis, factor of safety.**

## I. INTRODUCTION

The main objective of the study is carried out stress-strain analysis of roll cage with different sudden impact condition like (Front Impact, Side Impact, Rear Impact, Roll over). The roll cage designed to incorporate for all the automotive subsystem. A 3-D model of roll cage is prepared on Solid-Works software by using Weldment feature. After that for roll cage is tested again all modes of failure and different load condition by conducting the stress-strain analysis using ANSYS Workbench Software. After successfully design of roll cage and consider all affecting variable we go for finally fabrication process.by preforming analysis we can assure the material selection is perfect from evaluation of factor of safety using of maximum allowable stress (N/mm^2).

The vehicle consisting roll cage and its structure member with it so while the designing of roll cage is we have to focused on minimum deformation of member and high factor of safety during variable load condition. And as we know that vehicle is having structure of steel members (round bar) we have design the roll cage so it's have minimum weight and also provide balance ratio of weight to strength. To optimize best design, the 3-D modelling and analysis software Solid works and ANSYS Workbench Respectively is extremely helpful. The following paper have the title complete analysis of roll cage for ATV.

## II. BASIC DESIGN AND DEVELOPMENT

### A. MAERTAIL SELECTION

The design and development is very crucial and important part because it involves: material selection, adequate strength, frame design, cross section determination, finite element analysis, total weight. From all above material selection is very important which is effect the safety, reliability, weight, performance and strength. For selection of optimal material, we have to go through deep research by comparing parameters of different materials like its cost, availability, required cross section, density and strength. The final selection material is given below with all considered parameter.

We are competing in SAE BAJA -2016 so there is rulebook with constrain is the is the cylindrical tube having outside diameter is 25mm (1 inch) and wall thickness of 3mm (0.120 inch) and a carbon content of at least 0.18 %. The table is given below with comparison of material:

| Material | Tensile ultimate (MPa) | Tensile yield (MPa) | Young modulus (GPa) | Density (kg/mm^3) |
|---|---|---|---|---|
| AISI 4130 | 670 | 435 | 205 | 7850 |
| AISI 1018 | 450 | 380 | 200 | 7850 |
| ASTM A106GrB | 414 | 385 | 210 | 7850 |
| AISI 1021 | 484 | 360 | 200 | 7858 |
| AISI 1026 | 490 | 360 | 205 | 7850 |
| DIN 2391 ST 52 | 590 | 415 | 205 | 7850 |

Table 1 Material Comparison

From above all material have different properties but among them choose ASTM A106 grade B material which is basic mild steel and the main reason of choose is availability and low cost. As we can see in the table that AISI 4130 have more strength then our material but cost of that material is very high compare to ASTM A106 grade B. and very important that ASTM A160 grade B contain 0.18 % carbon.

After study all comparison between material properties and based on availability, cost and required strength, it was found that following material have appropriate properties:

| ASTM A160 Gr B Properties | VALUE |
|---|---|
| Tensile Ultimate strength In (MPa) | 414 |
| Tensile Yield strength In (MPa) | 385 |
| Young Modulus In (GPa) | 210 |
| Density In (Kg/mm^3) | 7850 |
| Percentage Elongation (%) | 20 |
| Poisson's ratio | 0.28-0.30 |
| Hardness In (HRB) | 100 |

Table 2 ASTM A160 grade B

B. Roll cage design

While to begin design of roll cage we have follow some guidelines of SAE -BAJA Rulebook and some other factor like transmission system, mounting of steering system and brake system mounting, driver comfort, mounting of seat (we have to maintain some distance from driver seat to firewall for provide safety to the driver from fire), aesthetic look and also manufacturing methods. Its also required to keep minimum distance between the driver's helmet to upper top surfaces 152mm (6 inches) and the driver's shoulders, torso, hips, thighs, knees, elbows, arms, hands, shall have 76mm (3 inches) clearance to the side surfaces. It is necessary to keep low as much the centre of gravity of vehicle for avoiding toppling. For keeping the centre of gravity low we have mount heavier parts like engine (power plant), seats, gear box, CVT (continuous variable transmission system, if use) directly to the chassis. We can reduce the cost of manufacturing of roll cage by using bending of pipe instead of welding (wherever is not must be required).

We were try each and every point that if there is not requirement of welding we use bending for save the manufacturing cost and its also provide good aesthetic look, and finishing is not required in bending in compare of welding. A final geometrical representation of roll cage is given below with all rule following of SAE BAJA 2016 Rulebook.

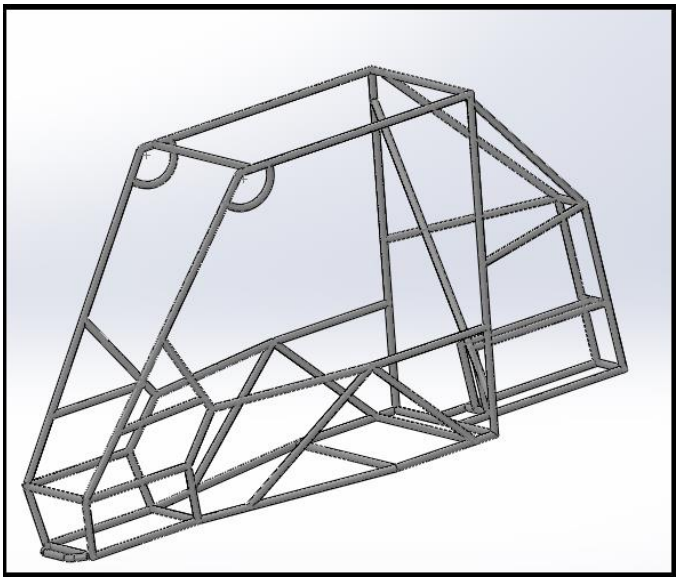

Fig 1 FINAL 3-D MODEL OF ROLL CAGE

## III. FINITE ELEMENT ANALYSIS (FEA)

After finalize the 3-D model of roll cage along with its material and appropriate cross section, it is very important to test the strength and rigidity of frame under different load condition. The frame of roll cage should able to with stand on different load condition like Front impact, side impact, rear impact, roll over impact and provide greatest safety to the driver without too much damage and deformation. We were performing following test on roll cage which is given below:

- FRONT IMPACT -5G
- SIDE IMPACT - 3G
- REAR IMPACT -5G
- ROLL OVER – 3G

A. Front impact

Front impact test is performed by taking assumptions that total curb weight (driver plus ATV weight) is equal to 350 Kg, and maximum travelling speed of ATV is 58 km/hour colliding with any heavy vehicle which have five times weight of our curb weight. And that's why it is known as 5G impact test also.

**Loading conditions:**

1.total load ≈ 16000 N

2.boundary condition = At the Rear members of roll cage have zero Degree of freedom.

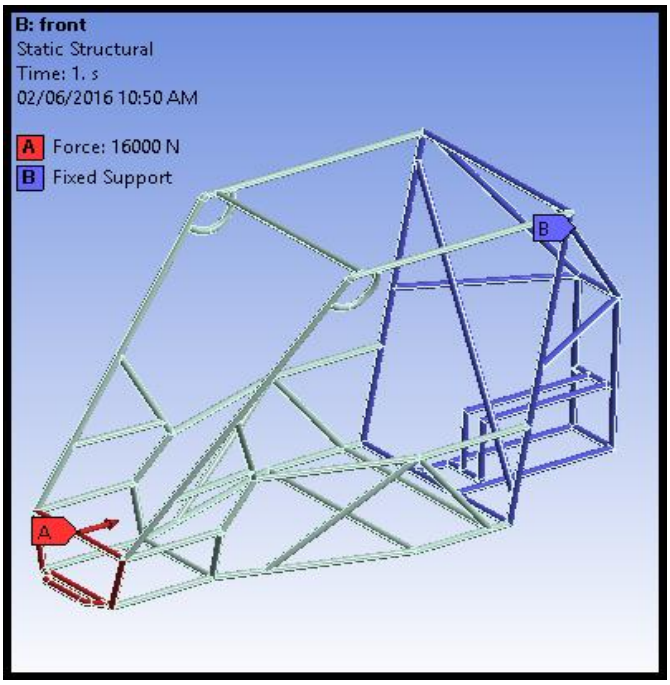


Fig 3 Load acting during Front Impact condition

**Results:**

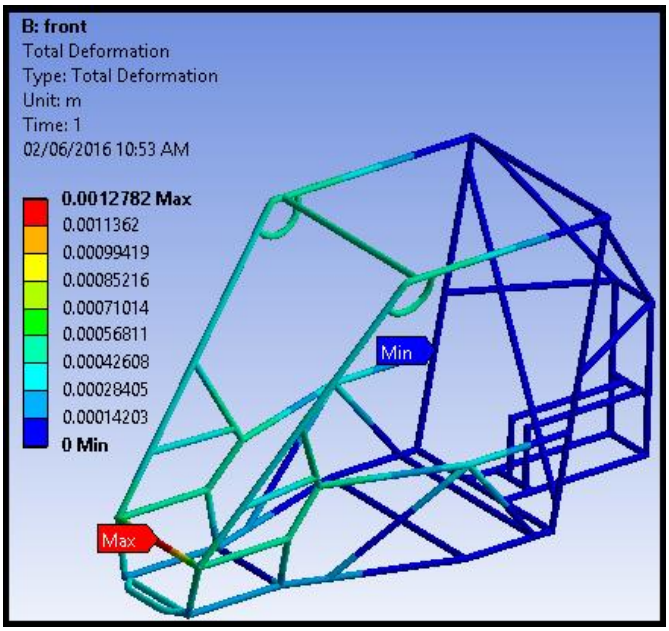


Fig 4 Total Deformation (FI)

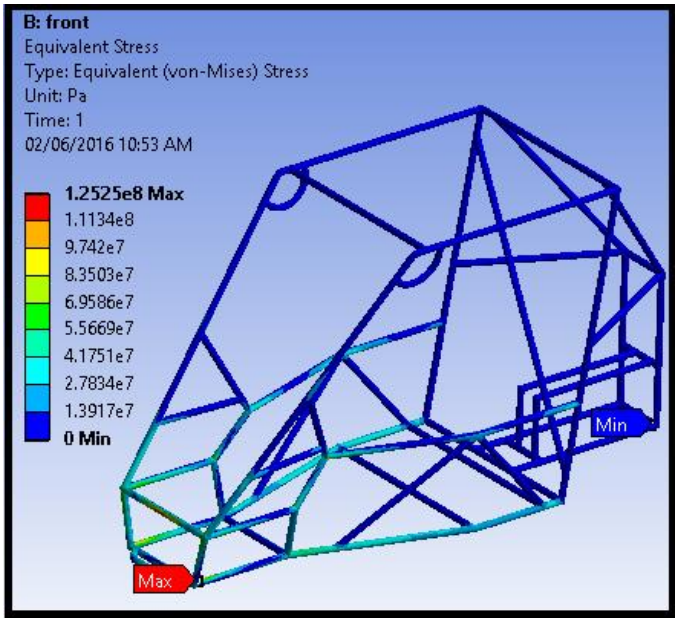


Fig 5 maximum(vonmises) stress (FI)

Total deformation is 1.2782 mm and maximum(vonmises) stress is 127.80 MPa, hence factor of safety is around 3.5. so we can say that design of roll cage is safe.

B. Side Impact

Side impact test is performed by taking assumptions that total curb weight (driver plus ATV weight) is equal to 350 Kg, and maximum travelling speed of ATV is 58 km/hour colliding with any heavy vehicle which have three times weight of our curb weight. And that's why it is known as 3G impact test also.

**Loading conditions:**

1.total load ≈ 10000 N

2.Boundary condition = At the side members of roll cage have zero Degree of freedom.

(Note: Side Impact is very rare in ATV race so that's why we take 3G as acting load instead of 5G. So if there will collision happen so we know that which member of roll cage will affect.)

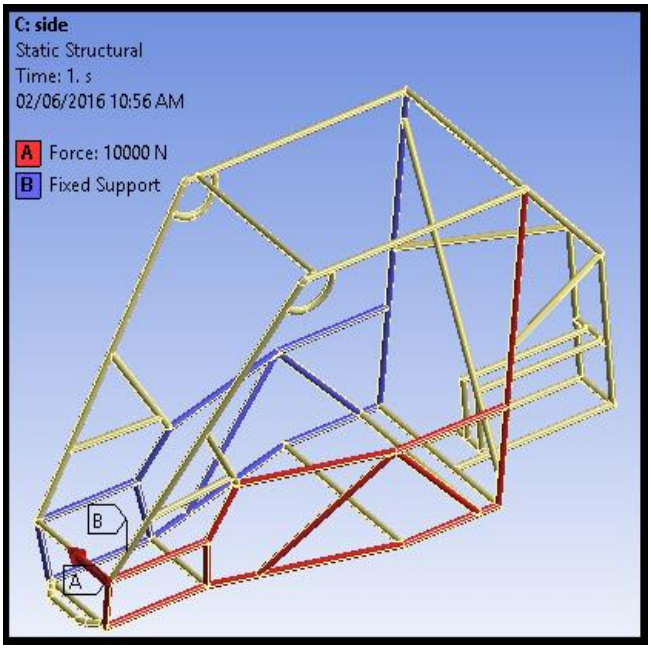


Fig 6 Load acting during Side Impact test

**Results:**

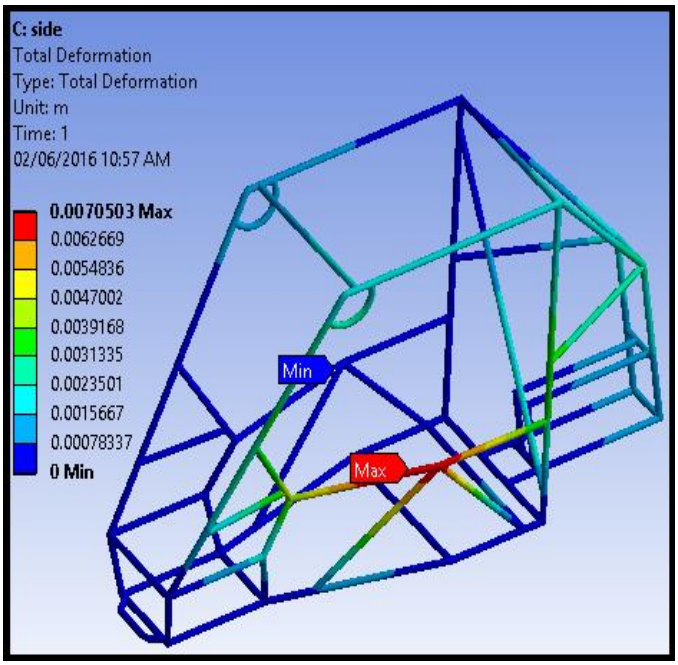


Fig 7 total deformation (SI)

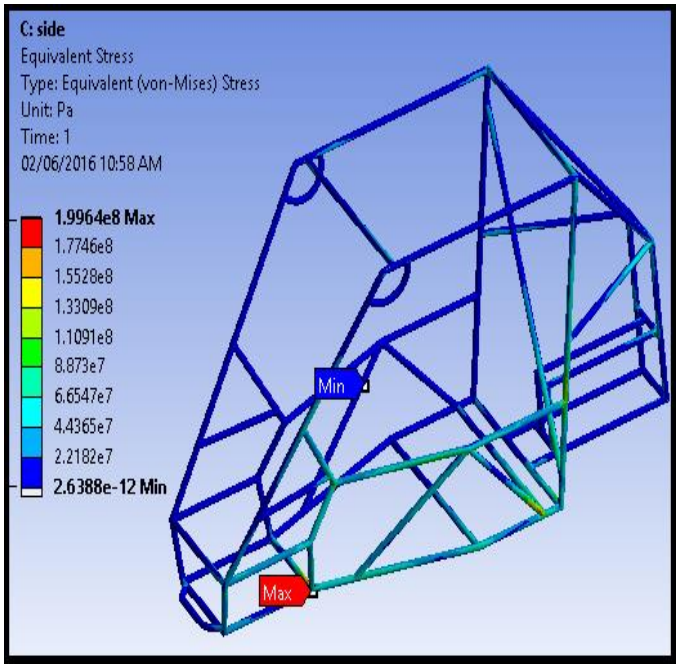


Fig 8 maximum(vonmises) stress (SI)

Total deformation is 7.05 mm and maximum stress is 20oMPa.Hence factor of safety is around 2.5. so we can say that design of roll cage is safe.

C. Rear Impact

Rear Impact test is performed by taking assumptions that total curb weight (driver plus ATV weight) is equal to 350 Kg, and maximum travelling speed of ATV is 58 km/hour colliding with any heavy vehicle which have five times weight of our curb weight. And that's why it is known as 5G impact test also.

**Loading conditions:**

1.total load ≈ 16000 N

2.boundary condition = At the front members of roll cage have zero Degree of freedom.

(NOTE: When we participate in Maneuverablitiy Event then chances of rear impact is more because driver's wants take over and secure his poll position, so we take 5G loading condition in rear impact same as front impact.)

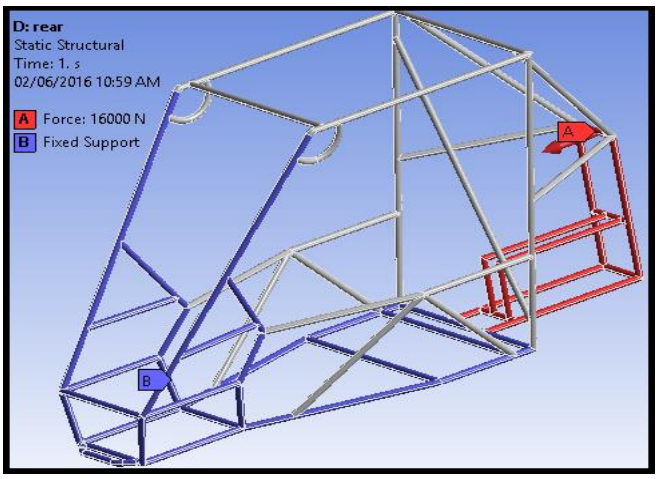


Fig 9 Load acting during Rear Impact test

**Results:**

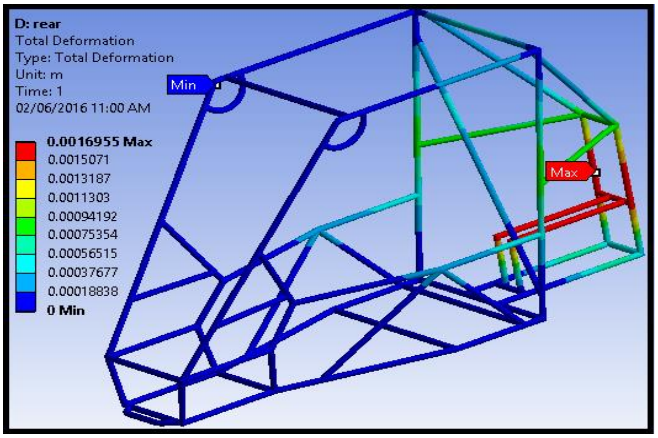


Fig 10 Total deformation (RI)

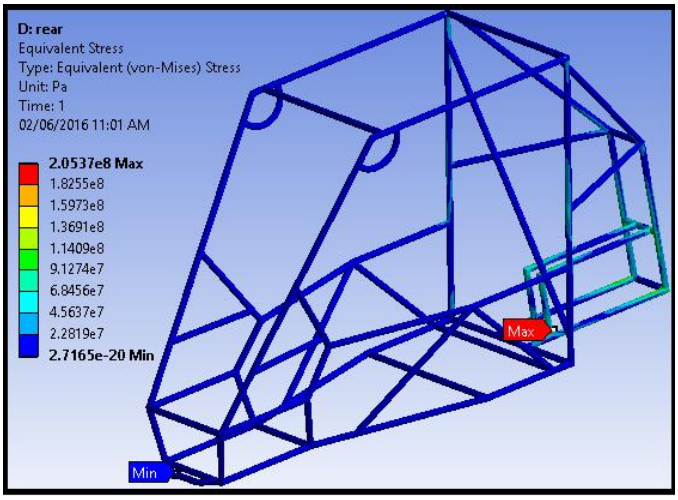


Fig 11 maximum (vonmises) stress (RI)

Total deformation is 1.695 mm and maximum stress is 205 MPa. Hence the factor of safety is around 2.3. So we can say that design of roll cage is safe.

D. Roll Over Impact

Roll Over Impact test is performed by taking assumptions that total curb weight (driver plus ATV weight) is equal to 350 Kg, and maximum travelling speed of ATV is 58 km/hour colliding with any heavy vehicle which have three times weight of our curb weight. And that's why it is known as 3G impact test also

**Loading conditions:**

1.Total load ≈ 10000 N

2.Boundary conditions = at the bottom members of roll cage have zero degree of freedom.

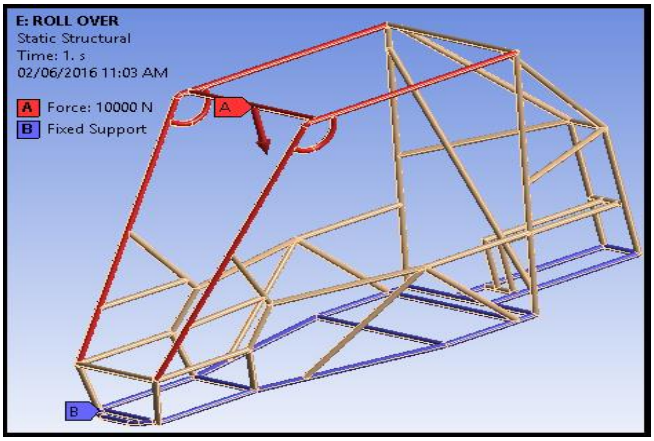


Fig 12 Load acting during Roll Over Impact test.

**Results:**

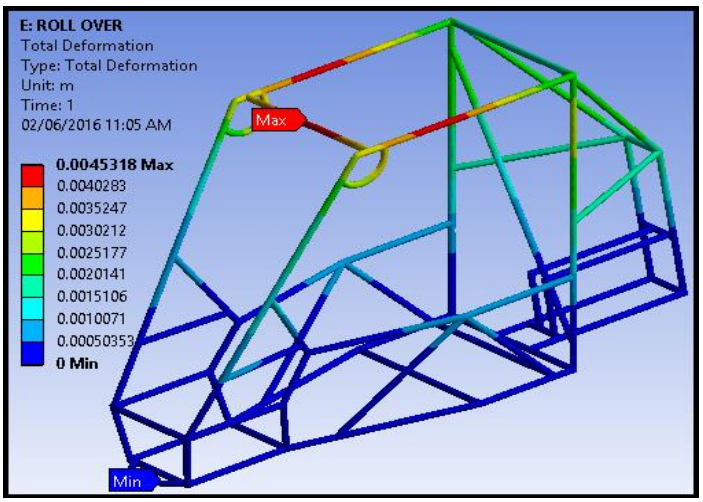


Fig 12 Total Deformation (RO Impact)

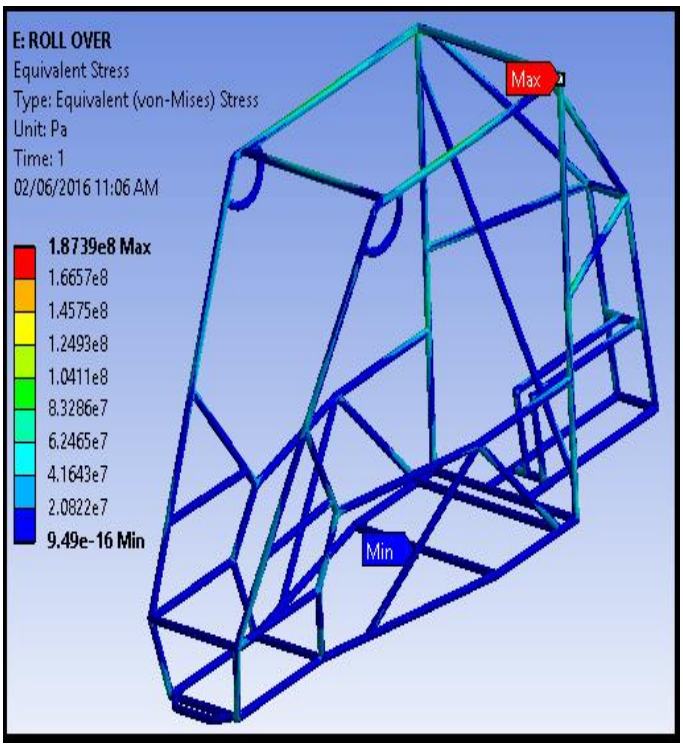


Fig 13 maximum (vonmises) stress (RO Impact)

Total deformation is 4.531 mm and maximum stress is 187 MPa. Hence the factor of safety is around 2.1. So we can say that design of roll cage is safe.

## IV. Conclusion

The FEA analysis shows the changes required in structure of roll cage when we try to lowering the ratio of weight to power output (in terms of transmission efficiency). The vehicle provides its better performance on Maneuverablitiy Event when its have low weight to power ratio. The customer's need is to maintain that ratio lower as possible as low, so it is our top priority. And using FEA analysis we can determine that which joint need good welding and which member having chances of breakdown. And FEA Analysis is less time required process so we can provide that time into fabrication of roll cage. Finally, ATV is made by using roll cage with integrating all other automotive systems like transmission system, engine (power plant), suspension system, braking system, and other miscellaneous components.

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