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# CAE Analysis of Off-Road Vehicle Rollcage Subjected to Various Impact Forces

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**Abstract -** *This paper tries to summarize the steps taken in finalizing the design in a nutshell. The requirements of roll cage, front and rear suspension systems, steering and drive train are considered here. The design analysis have been performed with special considerations given to safety of the occupant, ease of manufacturing, cost, weight (dynamic behavior) and overall aesthetics and performance.*

***Key Words***: rollcage; rollover; factor of safety; CAE

## 1. INTRODUCTION

The main objective of this paper is to carry out stress-strain analysis of roll cage with different sudden impact conditions like Front Impact, Side Impact, Rear Impact, Rollover and Bump. A 3-D model of roll cage is prepared on creo software by using swip feature. After that, roll cage is tested against all modes of failure and different load conditions by conducting the stress-strain analysis using **HYPEMESH** and **ANYSIS** Software.

## 2. ROLLCAGE DESIGN

While to begin design of roll cage factors like transmission system, mounting of steering system and brake system mounting, driver comfort, mounting of seat, aesthetic look and manufacturing methods are to be taken into account. It is also mandatory 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 the centre of gravity as low as possible of vehicle for avoiding toppling. For keeping the centre of gravity low we have to mount heavier parts like engine (power plant), seats, gear box, CVT (continuous variable transmission system, if use) directly to the chassis. To reduce the cost of manufacturing of roll cage, bending of pipe can be used instead of welding. One type of secondary members is used for weight optimization without compromising the structural integrity.

**Table -1:** Vehicle Specifications

| | |
|---|---|
| Vehicle speed | 15.66m/sec |
| Impact time | 0.2sec |
| Impact force | 8784N ~9000 N |
| Force appiled member | Front members |
| Fixed members | Rear members |

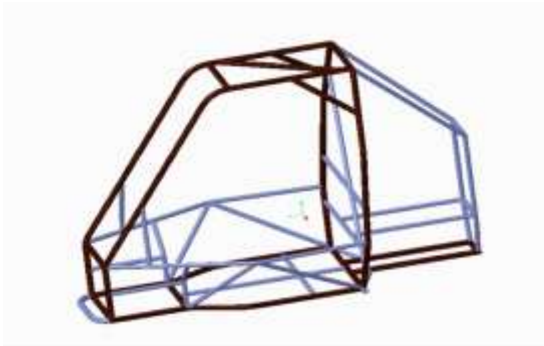

**Fig -1**: Rollcage Design

### 2.1. FINITE ELEMENT ANALYSIS

Mid surface were created in CREO and analysis done on HYPERMESH.

Mesh was created in 2D quad and tri-element.Mesh size is as possible kept small to minimize the inaccuracies.

**Table -2**

| | |
|---|---|
| Number of nodes | 93978 |
| Number of elements | 94608 |
| Element size | 5MM |
| Jacobian ratio | 0.98 |

## 3. CALCULATIONS

Work done = change in kinetic energy

Force * displacement = 0.5*mass*$(velocity)^2$

Force = 0.5*mass*$(velocity)^2$ /displacement

Displacement = velocity *time

Factor of safety = Yield strength /maximum stress

### 3.1. FRONT IMPACT

It is the impact wherein there is a possibility of vehicle crashing into another vehicle head on during the race. The deceleration value for frontal impact is 4G. This is equivalent to a loading force of 9000 N. Front impact test is performed by taking total curb weight (driver plus ATV weight) is equal to 230 Kg.

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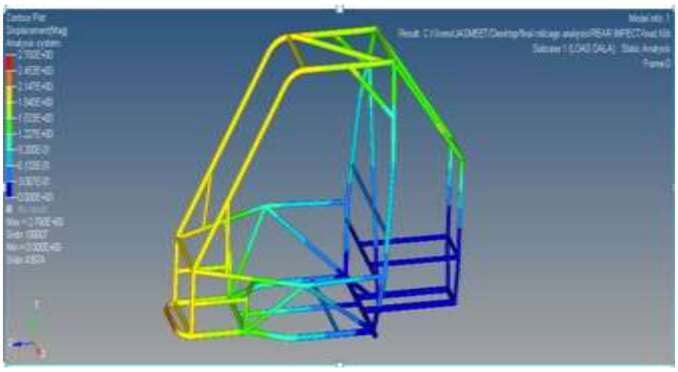


STRESS

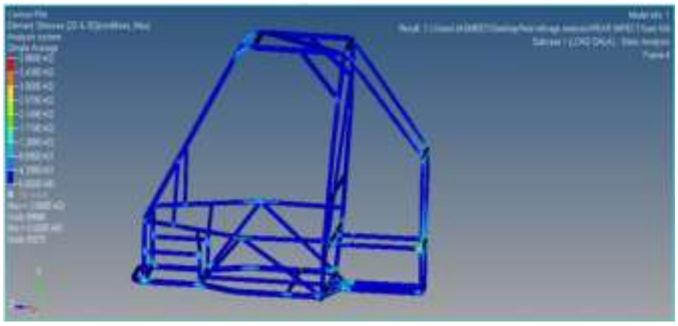


**Table -3**

| | |
|---|---|
| Max. Stress | 386.8MPa |
| Max.deformation | 2.67mm |
| Factor of Safety | 1.14 |

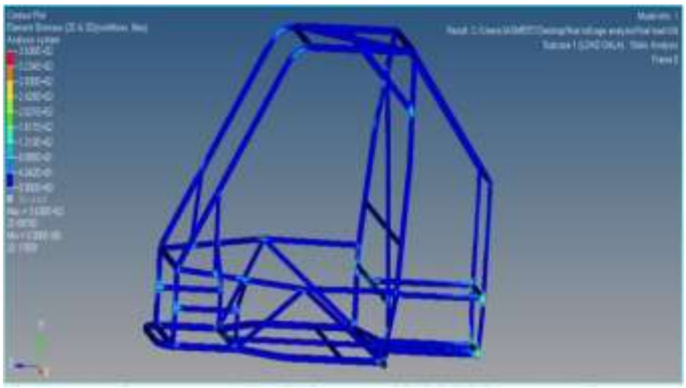
### 3.2. REAR IMPACT

Rear impact is when other vehicle collides with our vehicle at the rear of the vehicle. The impact force is considered same as that of front impact.

**Table -4**

| | |
|---|---|
| Vehicle speed | 15.66m/sec |
| Impact time | 0.2sec |
| Impact force | 8784N ~9000 N |
| Force applied members | Rear member |
| Fixed members | Front members |

DISPLACEMENT



*STRESS*

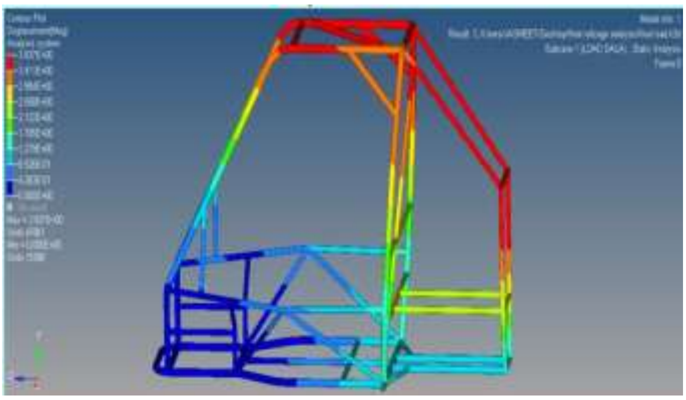


**Table -5**

| | |
|---|---|
| Max. Stress | 363.8MPa |
| Max.deformation | 3.8 |
| Fator of Safety | 1.18 |

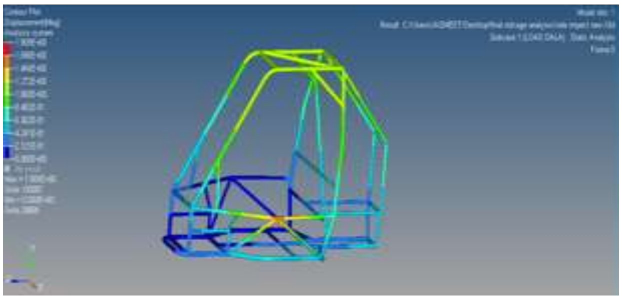
### 3.3. SIDE IMPACT

The side impact analysis is carried out as there is a possibility of collision with another vehicle from either direction. Thus, the stresses acting on the side members of the roll cage are analyzed. The deceleration value for side impact is 2.5G.

**Table -6**

| | |
|---|---|
| Vehicle speed | 15.69m/sec |
| Impact time | 0.3sec |
| Impact force | 5856N |
| Force applied members | Left SIM |
| Fixed members | Right SIM |

DISPLACEMENT



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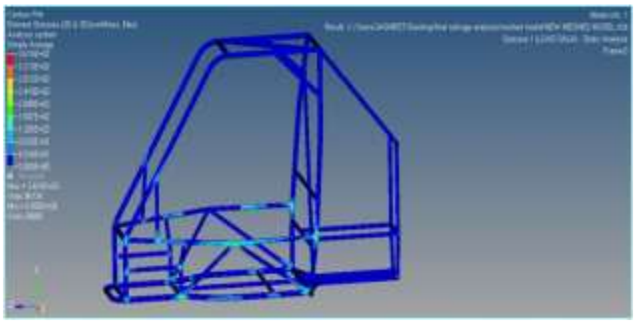


**Table -7**

| | |
|---|---|
| Max.Stress | 383.7MPa |
| Max.Deformation | 1.3mm |
| Factor of safety | 1.19 |

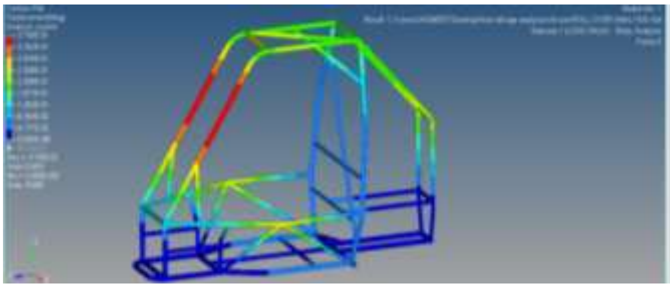
### 3.4. ROLL OVER

The rollover impact analysis is carried out by considering the stresses induced on the members of the roll cage when the vehicle topples down from a slope. In this impact, the upper and rear members of the vehicle will bear the force. The load taken is equivalent to 2.5g, the curb weight of the vehicle i.e.5856N

**Table -8**

| | |
|---|---|
| Vehicle speed | 15.66m/sec |
| Impact time | 0.3sec |
| Impact force | 5856N |
| Force applied members | CLC |
| Fixed members | Lower members |

DISPLACEMENT



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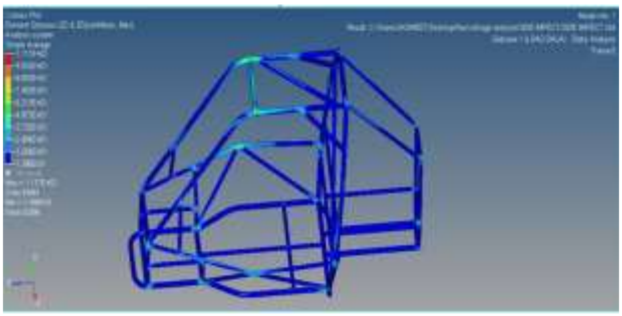


**Table -9**

| | |
|---|---|
| Max.Stress | 111.4 |
| Max.Deformation | 0.34 |
| Factor of safety | 4.1 |

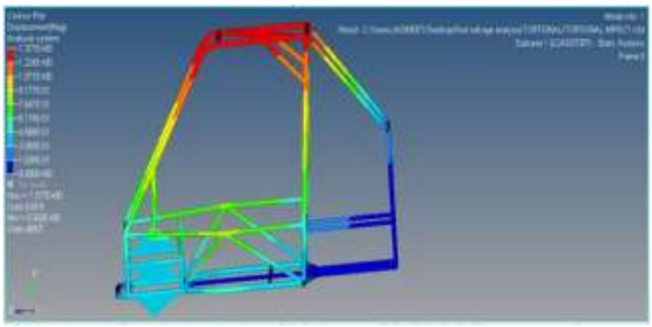
### 3.5. TORSIONAL IMPACT FORCE

The frame should be stiff enough to sustain dynamic suspension loads. When the vehicle is negotiating a bump there might be a case of alternating bumps on left and right wheels. Considering the left wheel is having the upward travel (jounce) and the right wheel is having the downward travel (rebound) the spring forces will act in the opposite direction composing a couple on front of the vehicle. This couple tries to produce a torsional stress in the frame. For the worst case scenario the diagonally opposite wheels are having the opposite wheel travel i.e. front right wheel is having the vertically upward travel and at same time rear left wheel is having the vertically downward travel producing a couple diagonally. This couple is responsible for the torsional stresses in the vehicle. Applying a load of 2.5g = 5856 N.

**Table -10**

| | |
|---|---|
| Vehicle speed | 15.66m/sec |
| Impact time | 0.3sec |
| Impact force | 5856N |
| Force applied members | Wishbone Mounting |
| Fixed members | Rear member |

DISPLACEMENT



STRESS

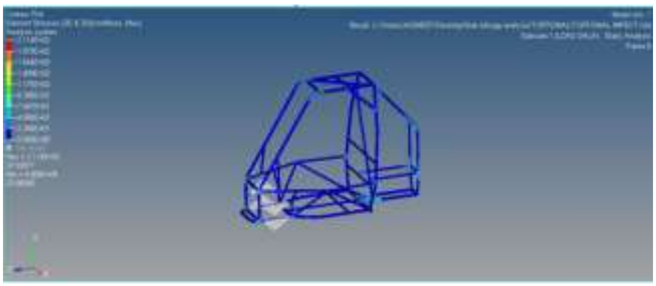


**Table -11**

| | |
|---|---|
| Max.Stress | 211.4MPa |
| Max.Deformation | 1.3mm |
| Factor of safety | 2.17 |

Torque=2.5*230*9.8*0.19=1070.65N-m

Angle of twist=(180/π)*1.3/381=0.19degree

Torsinal stiffness=T/Angle=5631.57N-m/degree

**4. RESULTS AND DISCUSSION**

Stress plots and deformations of critical elements undergoing different loads during the impact tests were analyzed using ANSYS and HYPERWORKS. This paper helps to understand the vital components of designing. As mentioned above the yield strength of the material used is 460 MPa. The maximum stress values of various impact tests have been determined and the factor of safety of the vehicle can be easily found. Safety is of utmost concern in every respect; for the driver, crew & environment. Considerable factor of safety (FOS) is applied to the roll cage design to minimize the risk of failure & possible resulting injury. This FOS value implies the safe value of applied loads and deformations.

**5. CONCLUSIONS**

**Table -12**

| Case | Total Applied Force(N) | Max. Stress (MPa) | FOS | Max. Deformation (mm) |
|---|---|---|---|---|
| Front Impact | 9000 | 386.2 | 1.18 | 2.7 |
| Rear Impact | 9000 | 387.5 | 1.14 | 3.2 |
| Side Impact | 5856 | 361.5 | 1.23 | 1.1 |
| Front Roll Over | 5856 | 111.7 | 4.11 | 4.5 |
| Torsion | 5856 | 211.4 | 2.17 | 1.3 |

The use of finite element analysis was invaluable to the design and analysis of the rollcage of an off-road vehicle. The analysis was helpful in finding out the maximum deformation, Von Mises stress and the factor of safety for five different impact tests. The findings from the finite element analysis and the actual failure will allow future designers to integrate a solution to this problem into their design from the beginning of fabrication. The following table shows the various loading conditions, deformations, maximum stress values and factor of safety for various test conditions.

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