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1Analysis of Formula Racing Car Frame Using Ansys

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ABSTRACT: *SAE Supra India organizes the undergraduate racing completion for 2011 in which teams are challenged to design considering the various circumstances and to fabricate the created design in the camps itself. This paper's sole focus is the design and analysis for a chassis which has to sustain the racing environment. As chassis plays a vital role in a race car but can be called as the back bone of a good race car. Good designs allow a light, stiff and extremely safe chassis to be produced at a reasonable manufacturing cost. The work shown in this research paper was taken participation by Black Hawk SAE Supra team. This paper introduces several concepts of frame's load distributions such a lateral, longitudinal vertical and horizontal torsion and consequent deformation modes. .Various studies were conducted upon the understanding the relation of the machine elements with the driver (Ergonomics).Ergonomics considers factors such as Drivers visibility, seat inclination, thermal isolation etc. The chassis design was carried out on CAD software Pro-Engineers. Design model was prepared using anthropometric parameters of tallest driver as 95th percentile male was selected to SAE rules book and previous design knowledge. Static and dynamic load distributions were calculated analytically followed by extensive study of various boundary conditions to be applied during diverse FEA (Finite Element Analysis) test which was carried out in Ansys. Stress distributions, lateral displacements during static, dynamic and frequency modes were analysed and found considerably high factor of safety as 3.85.*

INDEX TERMS: *FAE(Finite Element Analysis)*

I. INTRODUCTION

SAE (society of automotive engineers) has conduct the competition in which student build, design, and compete with a small formula race car .These compensation help in providing the educational experience that analogous to the type of project work they will face in work force ,it also help the student to participate in group work ,project management and finance have been incorporated in the rules of SAE. The SAE competition is consisting of static and dynamic event where they are judge on the performance of vehicle. The main philosophy behind the impact test is that to assure the driver safety in the survival cell, the survival cell should be strong enough to absorb the force and to distribute the force from front to the back without large deflection to the chassis. The chassis should be strong enough to absorb the energy when front, back, side, torsional are the load which occur during the impact test should be distributed progressively. The introduction of the various frame design concept and provide analytical and the experimental both. The various loading condition are also describe below. These paper is consist of various test whish are conduct on the chassis which give the detail description are documented below. Which are such as front impact test, side impact test, roll over test, torsional test these are the test which are conducted. The paper has also provide the detail description of the material which is used while design of the vehicle these has widen the structure strength and modelled111 the design to inculcate more driver comfort ,safety the structure is in the truss form which help to reduce the energy in structure. The mode of load distribution and the concept were taken from the various books and the reference.

II. METHODOLOGY

The design process of the chassis consisted of many steps, from the initial assignment to the task of chassis design to the start of construction. These steps are; to identify the restriction, determine the required performance criteria, research design techniques and methodology, use CAD and modelling software to design chassis and lastly start construction. Throughout these steps, choices must be based on achieving the targets set down to met performance requirement for condition the car will and can be reasonably expected to be subjected to under racing conditions. For example designing a rear air foil on a FSAE car that can only produce more down force than it own weight at speed greater than the car is expected to travel in competition is a futile exercise.

DESIGN CRITERIA

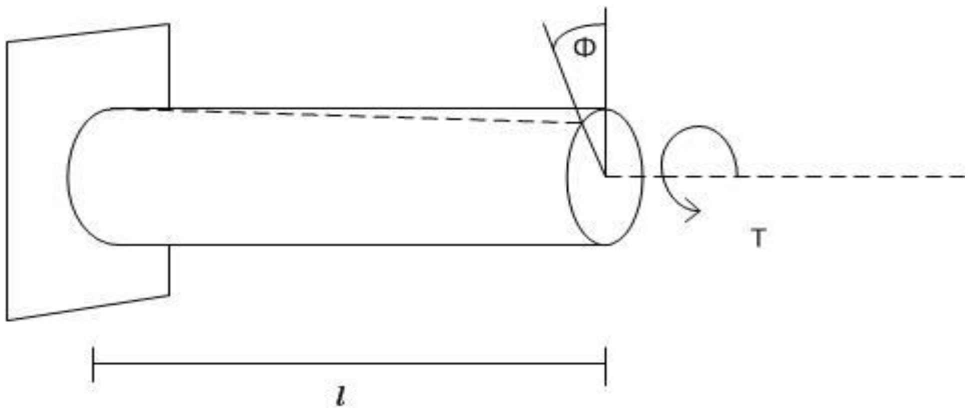
The decisions made in the various design steps so far that have shaped the design criteria. Firstly, the choice to use a space frame design that abides by the standard rules outlined in the SAE 2014 rules book. Secondly, the required performance criteria have been identified as weight and torsional stiffness, two properties that are generally inversely proportional to one another. One downfall of the decision to use hub motors is the increased of un-sprung mass, which will increase to forces on the chassis when the wheels are subjected to vertical acceleration (bumps) (Smith, 1984), thus the FSAE will require large torsional stiffness than normal FSAE cars.

TORSIONAL STIFFNESS

In order to design a car of maximum torsional stiffness the basis or generalized equation for torsion must be examined. Figure below is a basic shaft constrained at one end and an applied torque T at the other, with Φ denoting the resultant twist of the shaft.

Equation 5.1 is the simple formula that relates this angle of twist to the applied torque, with J representing the shafts polar moment of inertia, G representing the shear modulus of the material and *l* being the length of the shaft.

$$T = \Phi JG / l \qquad 5.1$$



Simple Torsion of Shaft

This equation can then be rearranged to express torsional stiffness

$$T/\Phi = JG / l \qquad 5.2$$

This expression displays that torsional stiffness in proportional to both the polar moment inertia and material shear modulus, whilst being inversely proportional to the length. The stiffness of the chassis can be helped to be maximized, by using these key relationships and placing them in the context of the chassis.

1. Length – relates to the wheelbase of the car, and as it was decided to run the minimum wheelbase allowed under the rules this relationship as already been utilized.

5.4.1 Improvements

This basic flow chart was modified slightly along the way to improve speed, with the addition of Pro-e simulations FEA to replace the need for using Ansys modelling at each iteration. As to analyse a new model in Ansys would take a number of hours to input and setup, whereas Pro-e Simulation was already interfaced with Pro-e and thus took no time at all the setup and run the FEA. This did however limit the options available when performing the FEA as the program does not allow for mesh refinement or type selection, element selection or complex loading conditions, a down side that will be discussed later.

5.4.2Chassis design

We have compare the two chassis using the FEA a new iteration was created as shown in the figure. The below two figure have the slightly different design technique to achieve the performance technique .the strength of the chassis is increased by incorporate many triangular structure section there where many different

iteration which was made before the final design was made. The below figure show the frame before the iteration is done.
The FEA is done on the old frame by using the ansys as a tool and the result which was obtained is shown below. As the method of analysis was done in the three stages such as the front impact test ,side impact test., rear impact test. The below figure provide the detail information of the changes which are done in the old frame and the new frame, the various view of the frame is provided.

III. CALCULATIONS

[1] Front impact – In this case, the front of the car, disregarding the impact attenuator is considered to collide with a stationary object in a head-on collision at maximum speed with an impact time of 0.4 sec.
[2] Rear impact – In this case, another car is considered to collide head-on with the rear of the car at maximum speed with an impact time of 0.8 sec.
[3] Side impact – In this case, a sideways impact into an obstruction is considered at the maximum speed with an impact time of 0.6 sec.
[4] Rollover impact – In this case, overturning or rollover of the chassis is considered and the effect of self-weight is considered as an impact load.
[5] Torsional rigidity - The torsional rigidity of the frame is determined by applying an equal and opposite bending moment on the chassis and quantifying the angular displacement.

Front Impact test
Assumptions made-
- Car travelling at 27.77m/s rams into stationary mass longitudinally.
- Crash impulse of 0.4 s
- Force distribution ratio = 70-30
- 70% on bulkhead members and 30% on frontal cross members

Such distribution is assumed keeping in mind that that the cross members are--
[1] Welded to support the impact attenuator and
[2] Prevent the longitudinal penetration of impact attenuator and of any broken part from the front.
[3] Form triangulated structure to increase the stiffness of the frame members of front bulkhead.
[4] The cross members are not bonded to any other member in the longitudinal direction and hence tend to form

cantilever type structure when load is applied.
The total force acting on the front bulkhead was calculated using following relations-
[1] Final velocity(v) = initial velocity(u) + acceleration(a)*time(t)
[2] Total force(f)1 = mass(m)*acceleration(a)
[3] Force[f2]= stiffness[k]*deformation[x] (at node level)
[4] Stress = force/area
[5] Acceleration = 69.44 m/s2 (retarding)

Total force acting on the body = 400*69.44 N = 27776.47 N
By doing the time independent static analysis of structure for frontal impact, we are able to observe the result for-
1. Total deformation in the body
2. Stress induced

Rear Impact Test -
Assumptions-
- Vehicle travelling at 27.77m/s crashes into a stationary vehicle
- Crash impulse = 0.8
- Acceleration=-34.71m/s^2(retardation)
- Force applied =400 x 34.71= 13444.44 N

The entire energy transfer will be in the form of kinetic energy and potential energy.
Side Impact Test-
Assumptions-
- Car travelling at 27.77m/s rams into a stationary vehicle.

- Crash Impulse- 0.6

In case of any side or lateral collision the maximum amount of forces are transferred to the between them. The entire energy transmitted is stored in the form of-

Potential energy ,which causes the deformation and induces the stresses in body and 2. Kinetic energy, which causes the body to have some lateral motion after collision.

Due to kinetic energy of the body, the body motion ceases after comparatively larger duration. This increases the stopping time of the vehicle thus reducing the effects of impact upto some level.

The formulae used for the force calculation are same as above.

Acceleration = -46.283m/s2 (retarding)

Force = 400*46.283 N

= 18512.56N

By doing the time independent static analysis of structure for frontal impact ,we are able to observe the result for-

[1] Total deformation in the body

[2] Stress induced

IV. MATERIAL SELECTION

Material selection where done according to the stress induced in chassis;

AISI 1018

Material specification as follows-

Outer Diameter. Pipe 1 =25.4mm

Thickness on pipe1 =2.88 mm

Outer Diameter. Pipe 2 =50.8mm

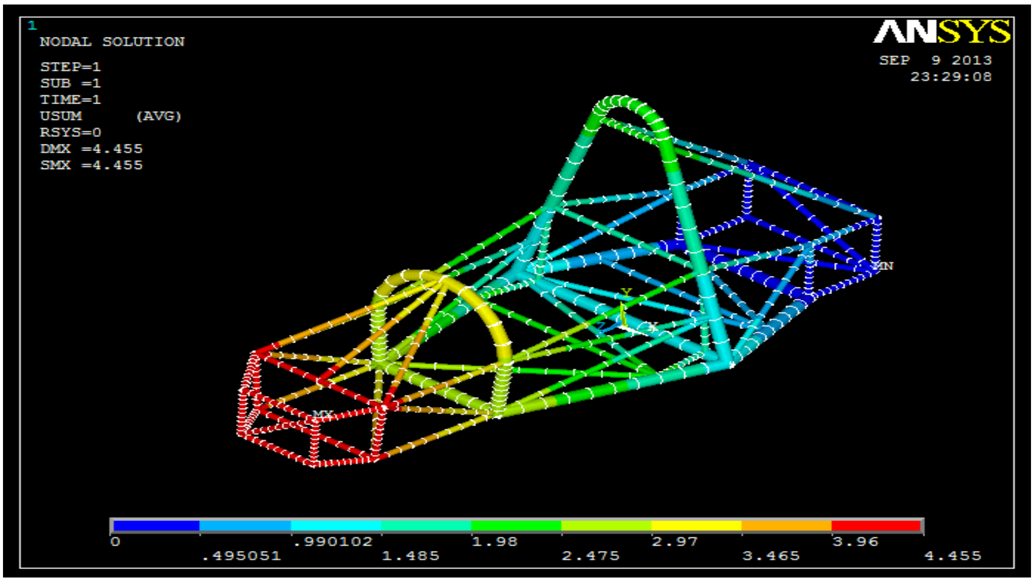
Thickness of pipe 2= 3.9mm

MATERIAL	**AISI**
MATERIAL UTS	1018 440 MPa
Carbon contain	0.18%
Modulus of Elasticity	205 GPa
Poisson's ratio	0.29
Thickness Roll hoop Other element	0.145 0.113

Properties of material

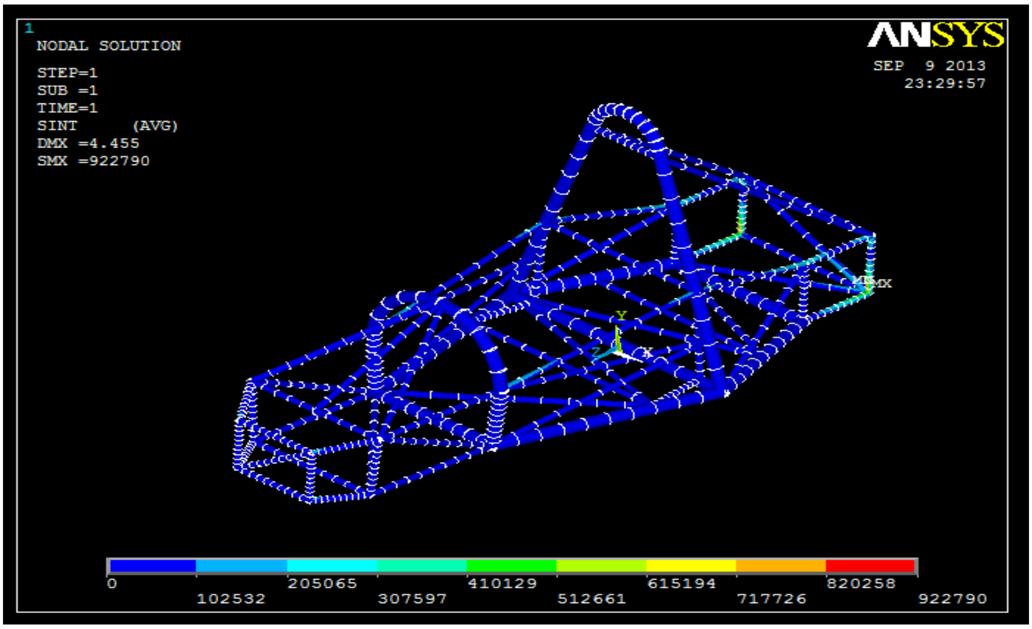
V. RESULT AND DISCUSSION

Old Chassis Analysis-
Front impact test-
Displacement vector sum-



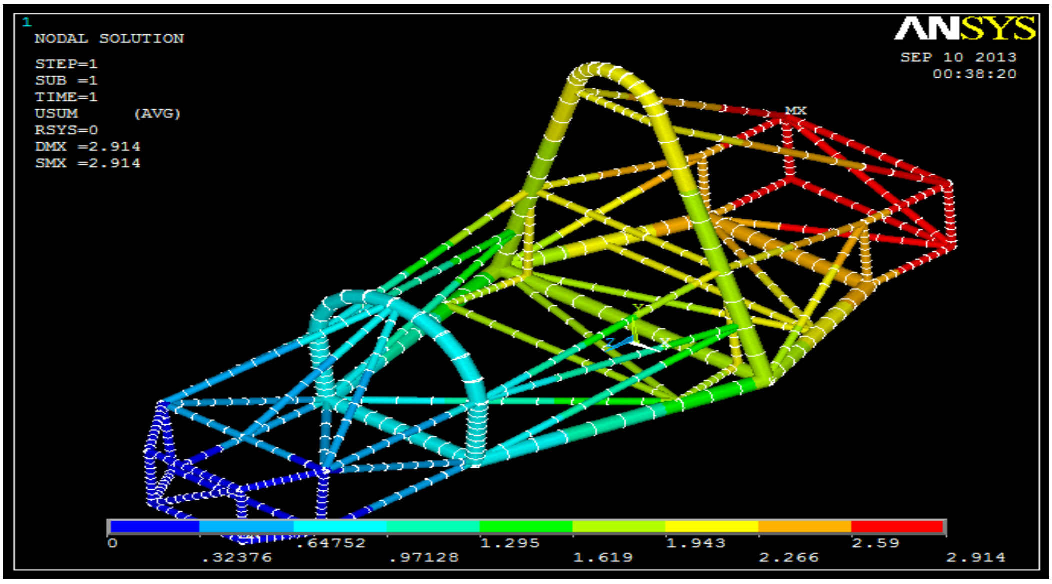
Old Chassis Front Impact test Displacement vector sum Diameter

Stress Intensity-



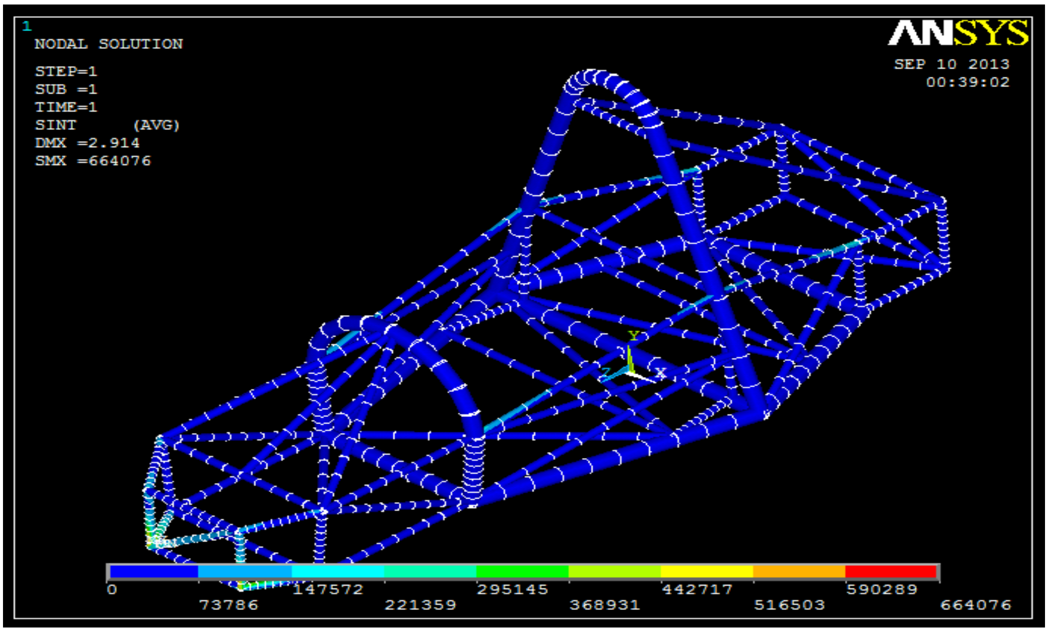
Old Chassis Front Impact test Stress Intensity

Rear Impact Test-
Displacement vector sum-



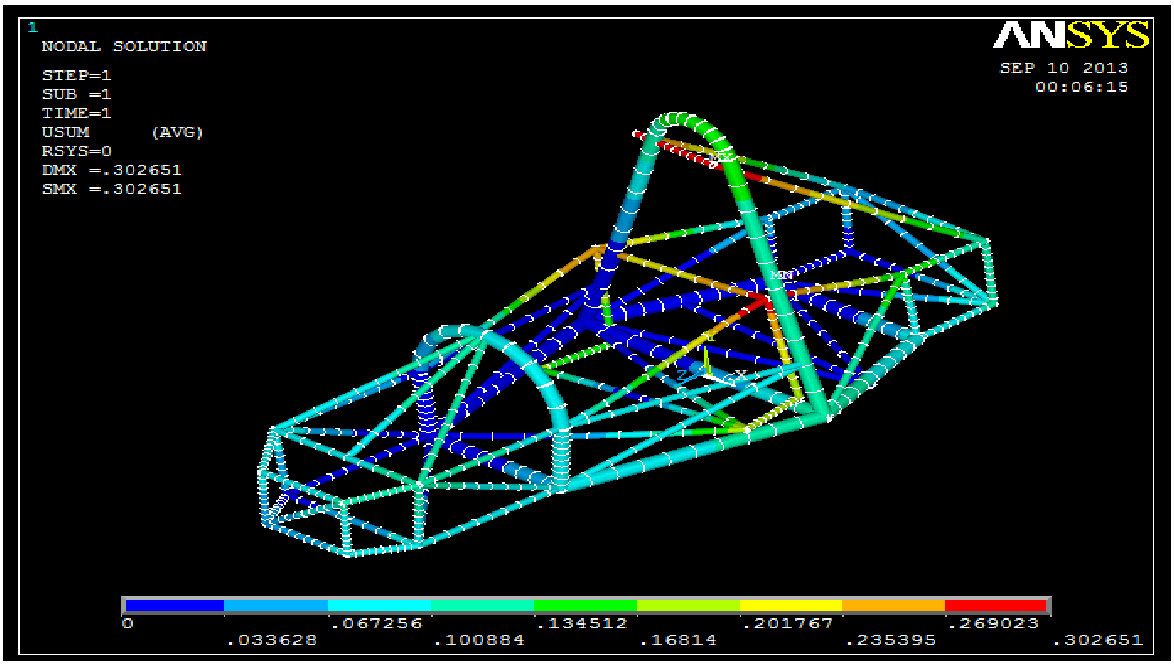
Old Chassis Rear Impact Test Displacement vector sum Diameter

Stress Intensity-



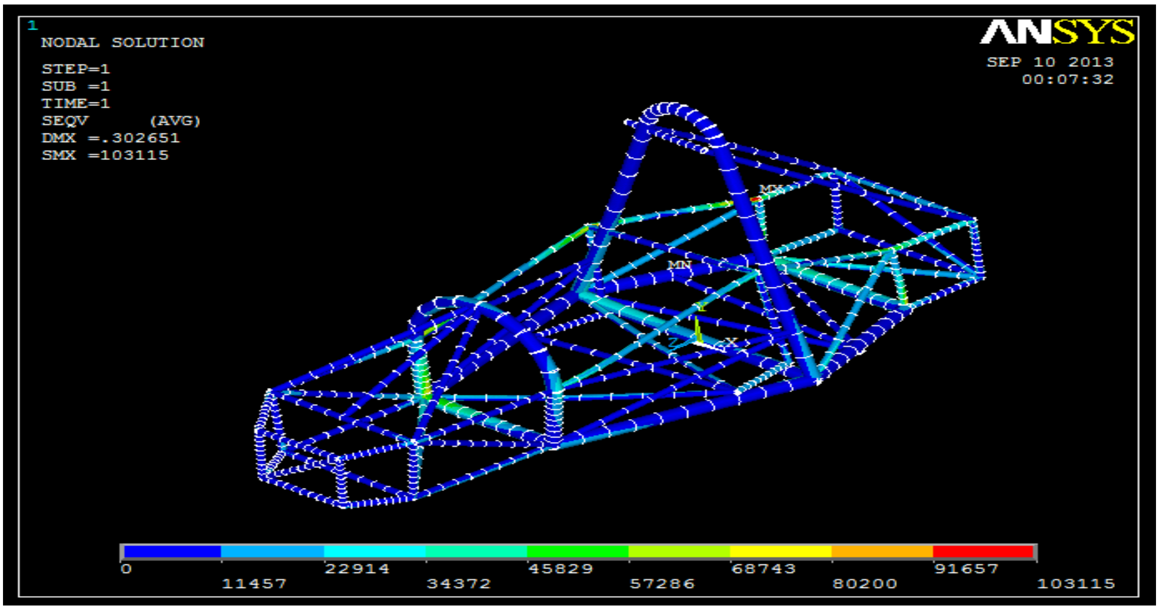
Old Chassis Rear Impact Test Stress Intensity

Side Impact Test-
Displacement vector sum-



Old Chassis Side Impact Test Displacement vector sum Diameter

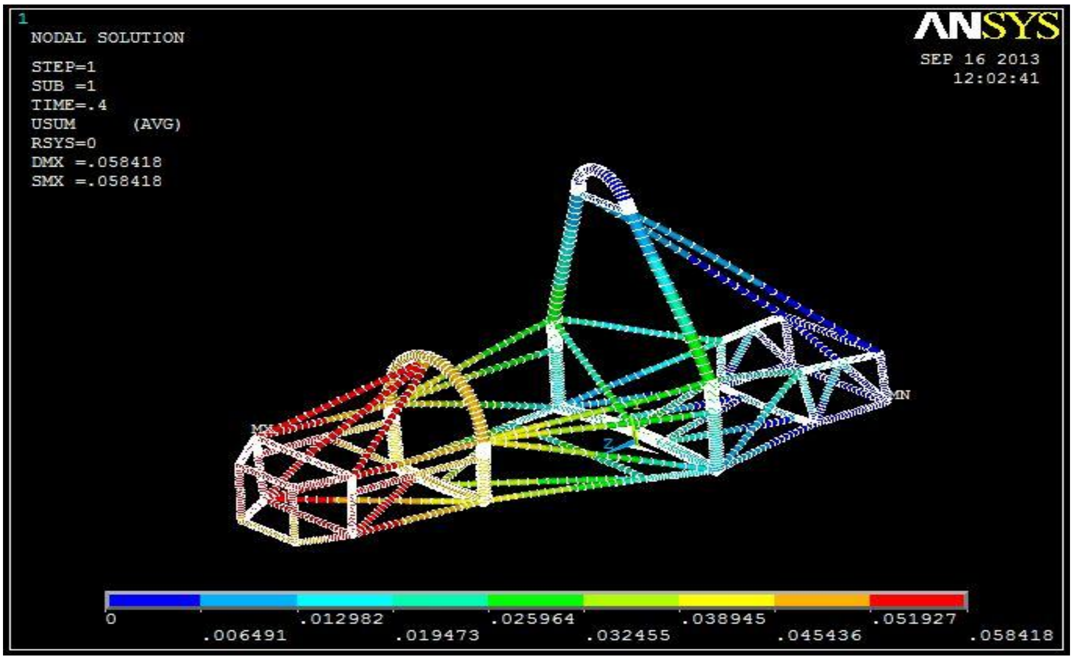
Stress Intensity-



Old Chassis Side Impact Test Stress Intensity

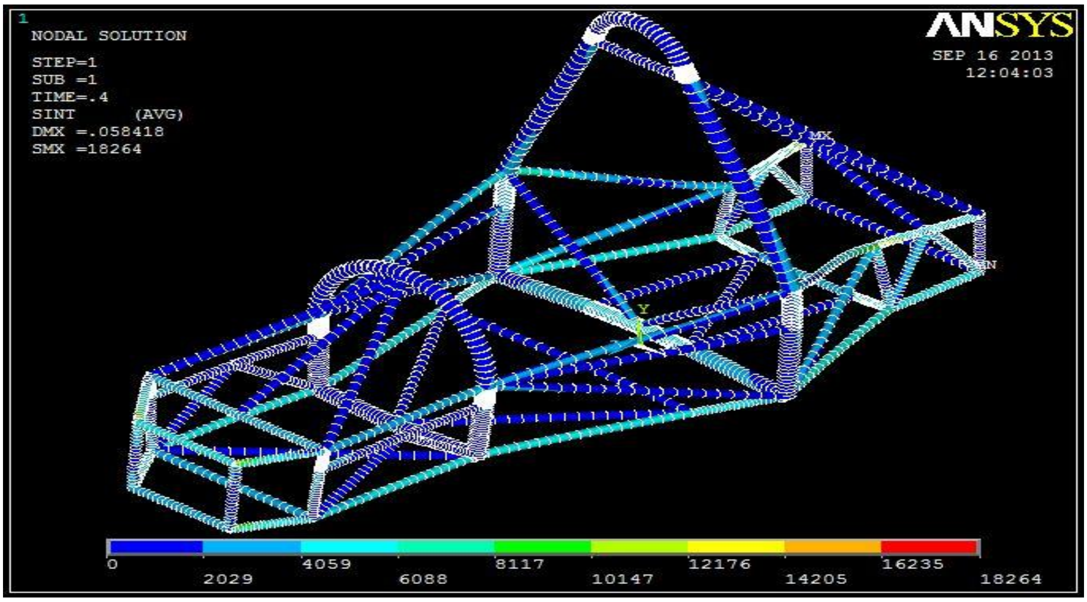
New frame Analysis -
According to analysis done on old chassis few modification where done in chassis so that the stress should get distributed among the members and also weight where also reduced, thus the following is the modified chassis and analysis shows following result as shown below-

Front Impact-
Displacement vector sum-



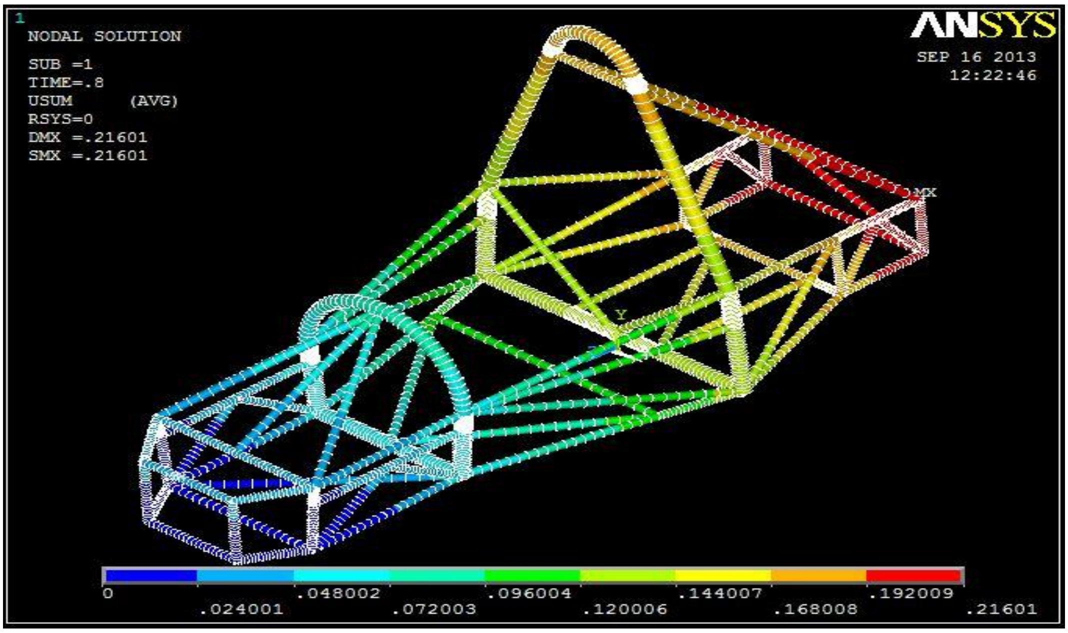
New frame Analysis Front Impact test Displacement vector sum Diameter

Stress Intensity-



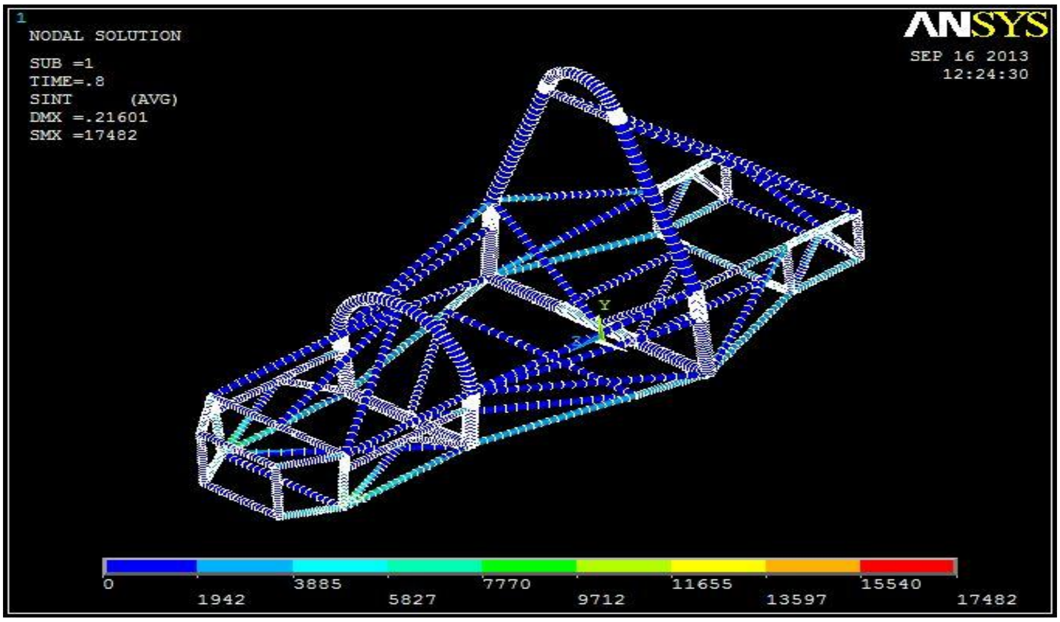
New frame Analysis Front Impact test Stress Intensity

Rear Impact Test-
Displacement vector sum-



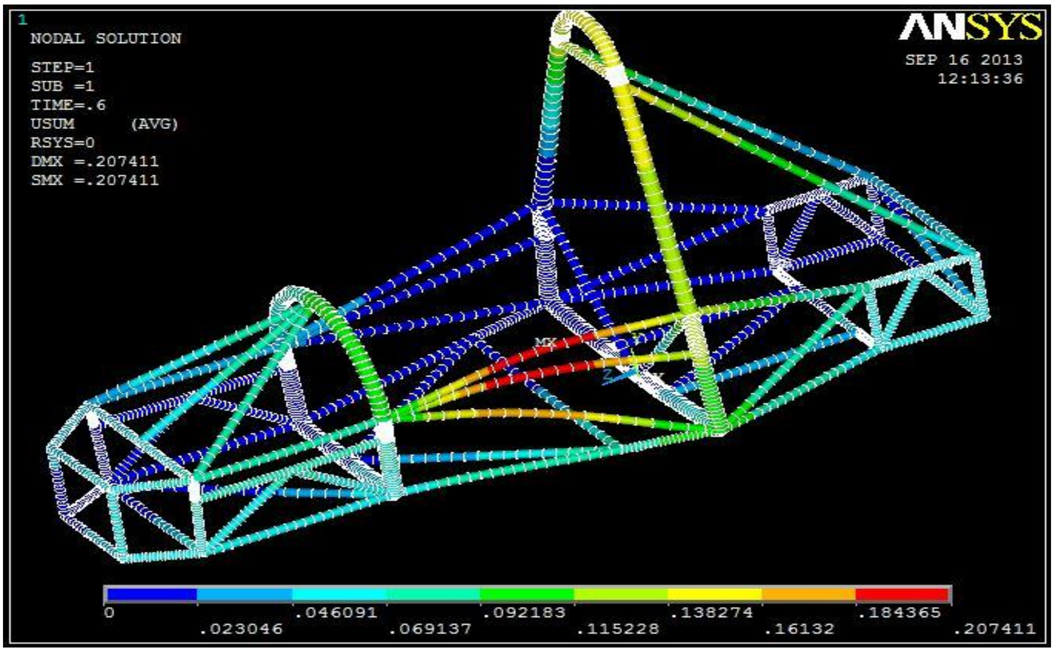
New frame Analysis Rear Impact Test Displacement vector sum Diameter

Stress Intensity-



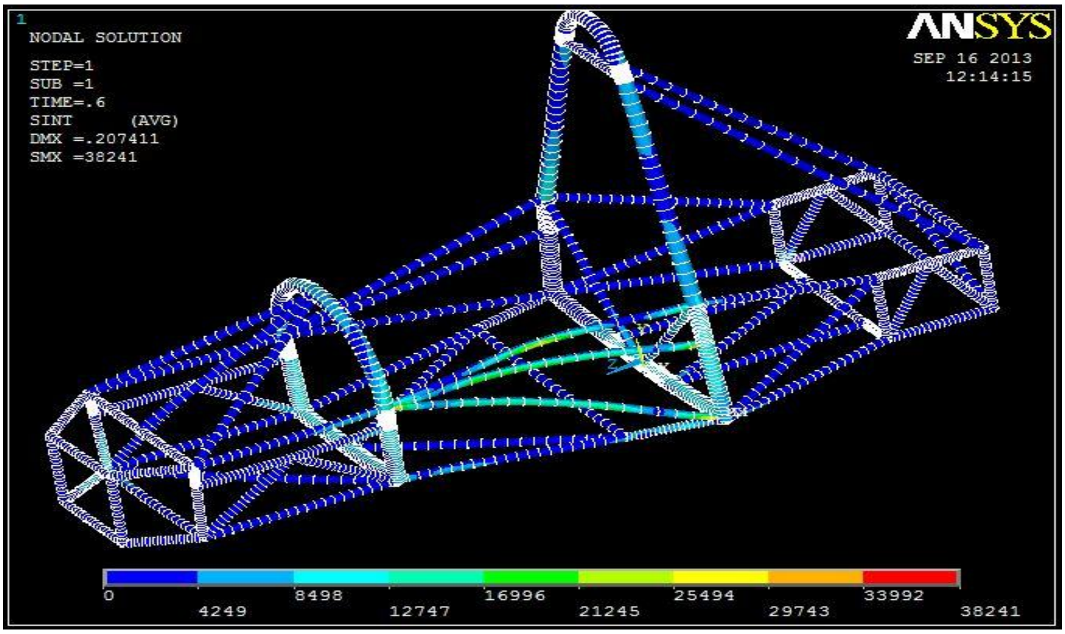
New frame Analysis Rear Impact Test Stress Intensity

11Side Impact Test-
Displacement vector sum-



New frame Analysis Side Impact Test Displacement vector sum Diameter

Stress Intensity-

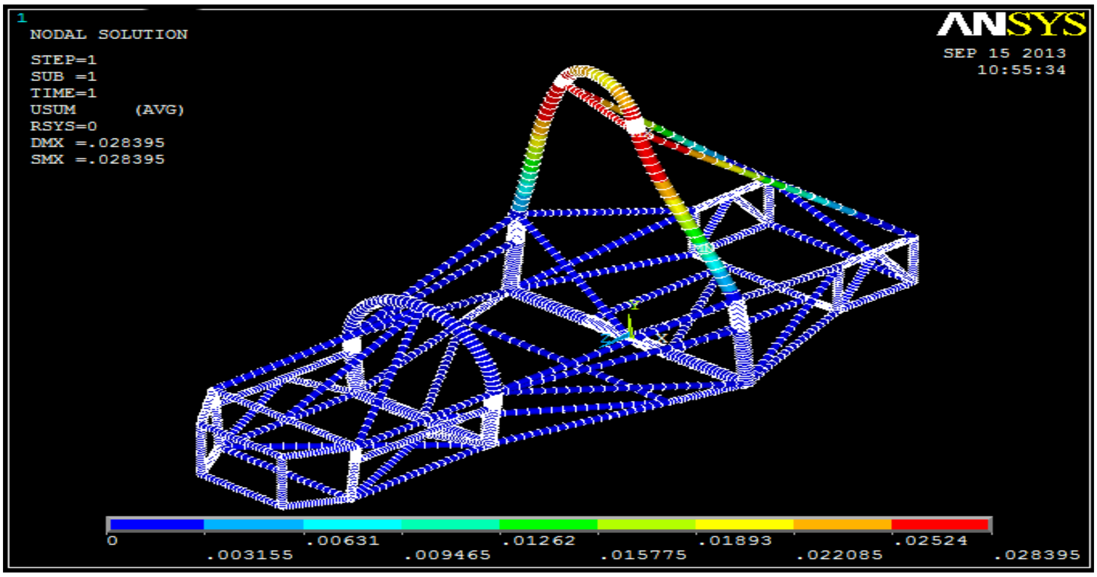


New frame Analysis Side Impact Test Stress Intensity

Roll over test-
This test is done to check the strength of main roll hoop when the vehicle overturn, when any vehicle overturn the total weight of vehicle fall on the top most point of chassis in the direction positive x or negative x.

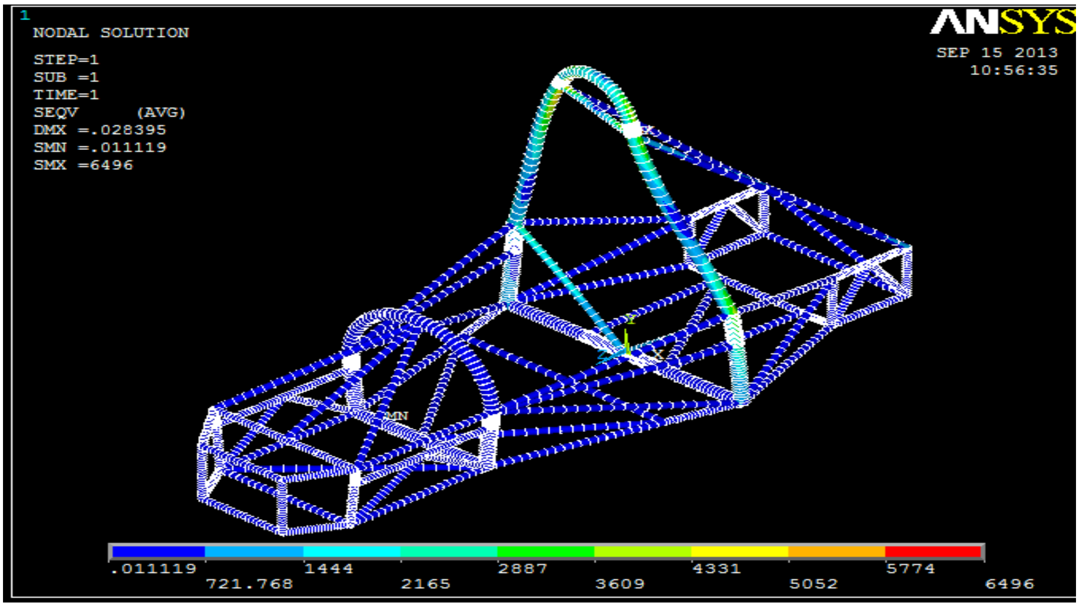
Thus we have applied force in positive x direction at the top most point of chassis (i.e at top point of main roll hoop).

Calculation-
The following shows the result of analysis done on chassis-
Displacement vector sum-



Roll Over test Displacement vector sum

Stress intensity-



Roll Over test Stress intensity

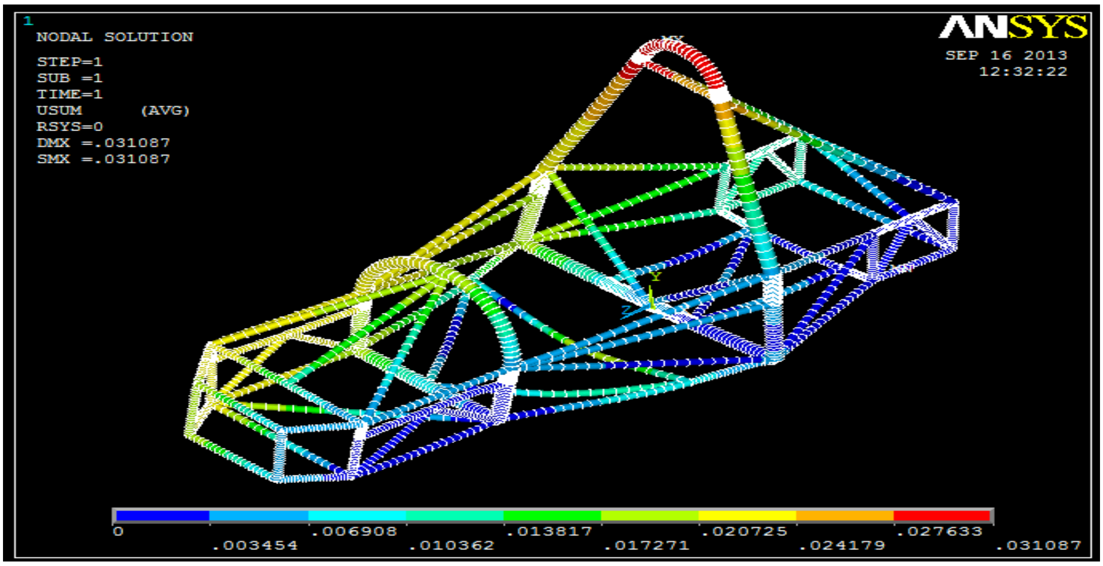
Torsional-

Rear suspension mounting points of the frame were fixed and loads were applied in the front suspension spring mounting as shown in the figure X. Maximum displacement obtained from the results and torsional rigidity was found using the following formula-

K=FL/tan^-1(dy1+dy2)/2L

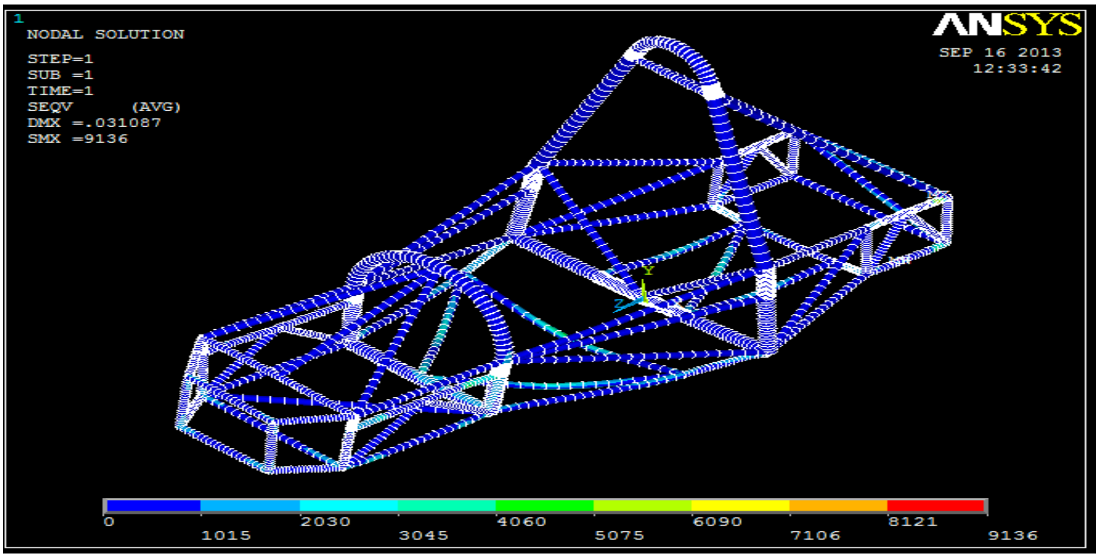
A couple force of 2000N is calculated value for torsional rigidity analysis.

Displacement vector sum-



Torsional test Displacement vector sum

Stress intensity-



Torsional test Stress intensity

VI. COMPARISON BETWEEN NEW AND OLD CHASSIS-

From the above analysis in Ansys software the following result where coded.
Factor of safety--Factor of safety can be defined as the ratio of maximum stress sustained by the material to the stress measured induced during loading, thus

Factor of safety=Ultimate stress/Maximum stress(induced)

FEATURES	**OLD CHASSIS**	**NEW CHASSIS**
Weight	110kg	90kg
Factor of safety		
Front impact	Break down	3.49
Side impact	Break down	2
Rear impact	Break down	3.65

Table 7.3.1- Comparison between New and Old chassis

VII. CONCLUSION

The essential aim of the project was to design a car for the SAE supra and to study the various forces acting on the frame while racing . There are two way of analysis of the frame one is by physical mode of analysis and another by software mode of analysis. The physical mode is not economical so we have considered the software mode. In software mode the frame is analysis on the Ansys software and The result of ANSYS is quit reliable as compare to other software . The various test taken on the frame are front impact test, side impact test ,etc. the result of the test were compared with the result range in the rule book of SAE Supra The new frame model is compared with the old frame model and the iteration were done and getting to reduce total deflection in frame. The selection of the material is an important factor in the design of the frame as we have used the material AISI 1018 steel to manufacture frame which has the high stiffness and can sustain the various load acting on in during the various test done on the frame. The new frame of SAE Supra which was taken for analysis by using ansys we get best result and done successfully.

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