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Stress Analysis on Sae Supara Car Using Fea

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Abstract:** The STUDENT FORMULA competition challenges teams of university under graduates to conceive design, fabricate, develop and compete with small formula style vehicles. The team concentrated primarily on high-performance, reliability, safety, ergonomics, manufacturability, serviceability and cost. The first main design goal is to keep the roll cage as light as possible. The key points to be considered while designing the roll cage are Driver's safety, comfort, Structural strength for rough terrain. For reduction of weight, carbon fibre is best suited but it is expensive and provides more stiffness. The three samples ASTM 106 GRADE B, chrome moly 4130, 4140 are tested.ASTM 106 GRADE B has good tensile strength whereas weldability is poor and weight is high. 4130 tubes are having good tensile strength and weldability than 4130 pipes.4130 tubes fails at high temperature and results in castrophic due to welding whereas 4140 is best suited due to the ability to withstand high temperature TIG welding and possess good tensile strength and light in weight. The front and rear roll hoops which are required to be made from steel tube will be integrated into the chassis and will also provide additional support for the suspension and spring mounts. The body will protect the driver from external exposure. The team uses a 499cc, four-cylinder Royal Enfield engine to provide a broad powerband.The race focuses on acceleration rather than top speed and this engine will provide the low-end torque. Independent suspension for both front and rear is used to increase the comfort and performance. H type circuit is used for braking. Reverse Ackermann geometry said to have favourable natural steering characteristics because the steer torques increase linearly with steer angle. Hence it is unanimous choice for the steering geometry. With high-rate impact research and testing improvements in an ergonomic driving position and improvements in the integration of the suspension, the overall result will be an increase in reliability and drivability of the car.

1. ROLL CAGE

The type of frame used is a Space frame type commonly termed as roll cage. It should withstand all loads under the off-road condition. The key points considered while designing the roll cage are as follows: Driver's safety, comfort Structural strength, Stiffness for rough terrain, Ease of manufacture and less weight.

2. MATERIAL ANALYSIS

The important parameter considered is that the material of roll cage should contain at least 0.1% carbon. The three materials sample ASTM 106 GRADE B, Chrome moly 4130, 4140 were collected and tested for the carbon content, yield strength, tensile strength, weight, cost, and availability.

Table 1 Properties of materials

Properties	ASTM 106 GRADE B	CHROM MOLY 4130	CHROM MOLY 4140
Density(Kg/m$^{3)}$	7800	7800	7700-8300
Tensile stress(MPa)	415	550	655
Yield point(MPa)	240	360.06	415

Then the material was tested for manufacturing ability. It includes welding and bending. TIG welding was selected as it has high tensile strength. Some members were subjected to bending, as bending reduces stress and gives aesthetic look for the roll cage. So, the unique characteristic of the material which is high strength and less weight made it suitable for our Requirement. In this, ASTM 106 GRADE B has more weight when compared with other materials .4130 has good tensile and yield point whereas weldabilty is poor and fail at high temperature.4140 has good weld ability when compared with other materials and it is chosen as material for roll cage.

3. DESIGN

The first primary safety standard focused on designing was maintaining a minimum of 6 inches vertical distance from the driver's head to the bottom of the RHO and a 65mm clearance between the rest of the body and the vehicle roll cage.

4. BRAKES

4.1 Methodology

The braking system in our vehicle is designed in order to lock the four wheels when the brakes are applied considering the longitudinal dynamic weight transfer during the deceleration of the vehicle.

4.2 Design

To get effective braking we have decided to use hydraulic disc brakes on all the four wheels. Tandem master cylinder has been installed since they have high performance, easy replacement, and comparatively less weight than other available options. For biasing we have installed flow control valve. Fixed callipers are used for their advantage over the floating callipers since equal distortion of the pads is possible with the first. Brake rotor of 190 mm dia. is modelled & material selected is AISI 304 due to its corrosion resistive property.

We have used H-type Circuit and fixed single piston calliper of diameter of 27 mm. We have used TVS GRILING master cylinder of Bore 19mm. For brake lining we have used steel tube of 10 mm diameter. The braking fluid is Dot 4 is used for its higher boiling point than Dot 3 making the fluid less likely to boil.

5. SUSPENSION

An off roader suspension should be more flexible as it should arrest the entire upcoming shock from the rugged surface while the vehicle is in dynamic motion. Selection of suspensions was based on the criteria of their degree of freedom, roll centre adjustability, and ease in wheel alignment parameters. We have positioned our roll centres at 200 mm and 230 mm above the ground in the front and rear respectively. These values allow us to minimize jacking forces while maintaining acceptable values for roll. We have provided Nose dive type roll axis (higher roll centre in rear than front) to minimize vehicle roll. The control arms have been kept of optimum length, so as to attain desirable wheel travel, camber gain and also to minimize the tendency of body to roll and stabilize the vehicle during cornering.

5.1 Suspension Control arm

Independent suspension for both front and rear is used in order to increase the comfort and performance in our vehicle. Therefore a pair of control arm is used for each wheel. The Front lower and rear upper control arms are of 30 mm Outer diameter and 3 mm thickness which takes most of vertical load exerted by the vehicle weight with a bending strength of 673.85 N-mm. The other Control arms are of 25.4 mm O.D and 3 mm thickness, which has a bending strength of 455.29 N-mm.

5.2 Shock Absorbers

Gas shocks and coil-over shocks were both considered for use on the vehicle. Gas shocks were found to be significantly lighter than coil shocks however; coil-over shocks were selected because of their superior ability to respond after impact.

5.3 Specification

Table 2 Specification

Gross vehicle weight (GVW)	**350 kg**
Tyre	145*75*R12 mm
Centre of gravity	216.3 mm
Track width (F/R)	1500 mm
Longitudinal wheelbase	1810 mm
Caster angle	0 degree
Camber angle	0 degree
Wheel travel front	Jounce:1.2inch rebound:1.2inch
Wheel travel rear	Jounce:1.5inch Rebound:1.5inch

6. STEERING

The fundamental mechanism of steering system is to control the direction of the vehicle. The stability of control in sharp turns and bumpy road with quick response play a vital factor in steering for an ATV. These essentials are enacted in the design without compromising.

6.1 Steering Geometry

Reverse Ackermann geometry said to have favourable natural steering characteristics because the steer torques increase linearly with steer angle. Hence it is unanimous choice for the steering geometry.

6.2 Steering Gear Box

Larger feedback, and a direct 'steering feel' are more precise in Rack-and-pinion steering over the other steering mechanism. Also a small degree of movement with the steering wheel brings immediate results on the road. Other steering systems tend to have some play in the steering wheel when travelling straight down the road. The rack-and-pinion system is implemented, proven easy to service, which contributes to a lower cost of ownership.

6.3 Specification

Table 3 Specification of suspension

Track width	1500 mm
Wheel base	1810 mm
Kingpin centre to centre distance	1390 mm
Ackermann angle	30 degree
Turning radius	3.96 mm
Gear ratio	6:1
Steering arm length	375mm
Steering force	600 N

7. POWER TRAIN

The objective of the drive train is to optimize the power delivered to the wheels regardless of the vehicle speed for the various competition conditions.

7.1 Engine

The engine used in our car is obtained from Royal Enfield 500 cc as per rule book parameters not to exceed 610 cc. The specifications of the engine are:

- Type Single Cylinder, 4 stroke, Twin spark
- Displacement 499cc
- Bore x stroke 84 x 90mm
- Compression Ratio 8.5:1
- Maximum Speed 5250 rpm
- Maximum Power 27.bhp
- Maximum torque 41.3Nm
- Gearbox 5 Speed constant mesh

7.2 Transmission

The shifter transmission power is more easily controlled on with the gear shifter and desired gear can be chosen at any time. And it is tested in many vehicles besides it has high output also. The chain sprocket is used for transmission from engine to driving shaft.

7.3 Gear ratio

Table 4 Gear ratio and speed

Gear	Gear ratio	Speed Km/hr
1st	3.06:1	29
2nd	2.01:1	45
3rd	1.52:1	59
4th	1.21:1	74
5th	1:1	90

8. FINITE ELEMENT ANALYSIS

After completing the design of the Roll cage, Finite Element Analysis (FEA) was performed using ANSYS 14.0 (WORK BENCH) to ensure expected loadings do not exceed material specifications. Ex=3.65 N/m^2 and PRXY=0.3 was used as per properties. Standard loads as per Europe National Car Assessment Programme (ENCAP) were applied on the key points and the results were obtained. For Frontal Impact, Side impact and Roll over results obtained were safe for the impact. From the results of analysis we conclude that Von-Misses stresses are in safe factor. Hence, the design is safe enough to proceed further for fabrication.

8.1 Analysis

Analysis of ASTM 106 GRADE B

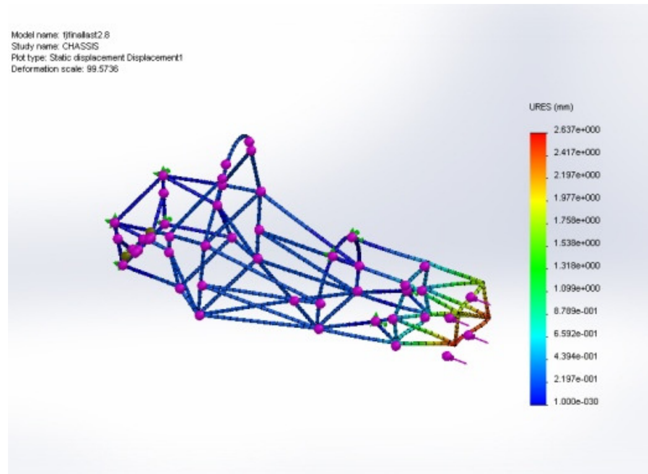

Fig. 1 Front impact of ASTM 106 GRADE B

Table 5 Stress and displacement of Front impact of ASTM 106 GRADE B

Load applied (N)	Max stress (MPa)	Displacement (mm)	F.O.S
8584	136	2.637	1.74

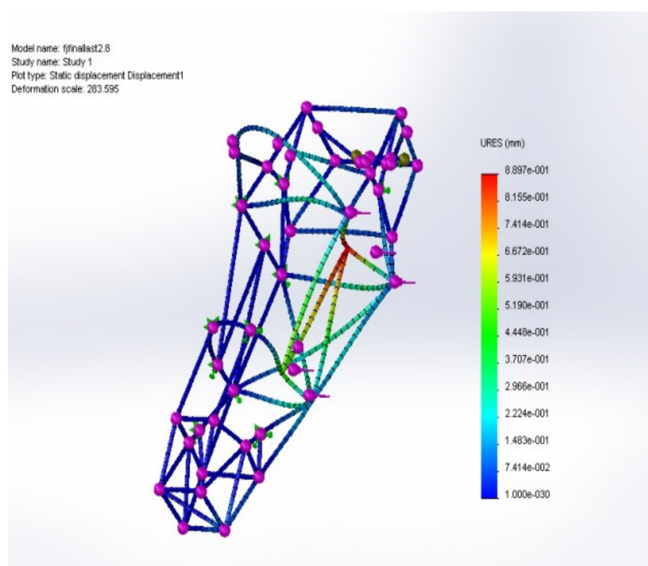

Fig. 2 Side impact of ASTM 106 GRADE B

Table 6 Stress and displacement of Side impact of ASTM 106 GRADE B

Load applied(N)	Max Stress (MPa)	Displacement (mm)	F.O.S
8584	209	$8.89*10^{-1}$	1.15

Analysis of Chrom moly 4130

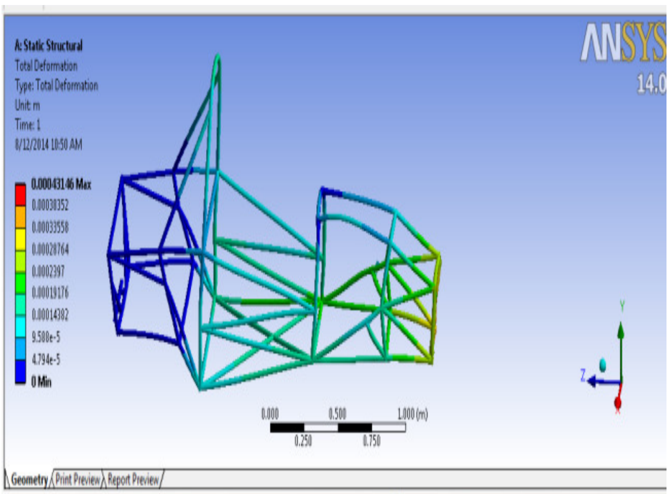

Fig. 3 Front impact of Chrom moly 4130

Table 7 Stress and displacement of Front impact of Chrom moly 4130

Load applied (N)	Max. Stress(MPa)	Displacement(mm)	F.O.S
8584	240.6	$4.31*10^{-3}$	1.49

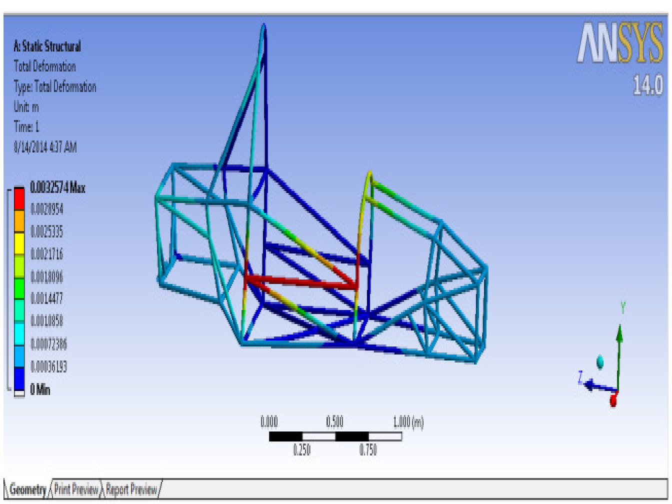

Fig. 4 Side impact of Chrom moly 4130

Table 8 Stress and displacement of side impact of Chrom moly 4130

Load applied(N)	Max Stress (MPa)	Displacement (mm)	F.O.S
8584	130	$3.25*10^{-3}$	2.3

Analysis of chrom moly 4140

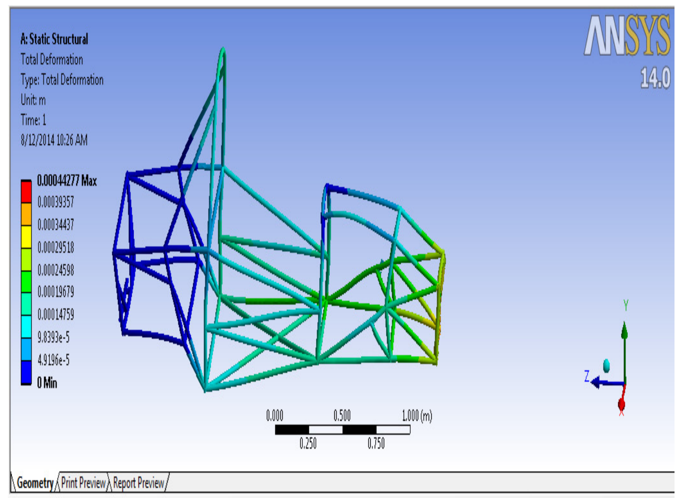

Fig. 5 Front impact of Chrom moly 4140

Table 9 Stress and displacement of Front impact of Chrom moly 4140

Load applied (N)	Max. Stress(MPa)	Displacement (mm)	F.O.S
8584	129	$4.42*10^{-4}$	2.79

Side impact of Chrom moly 4140

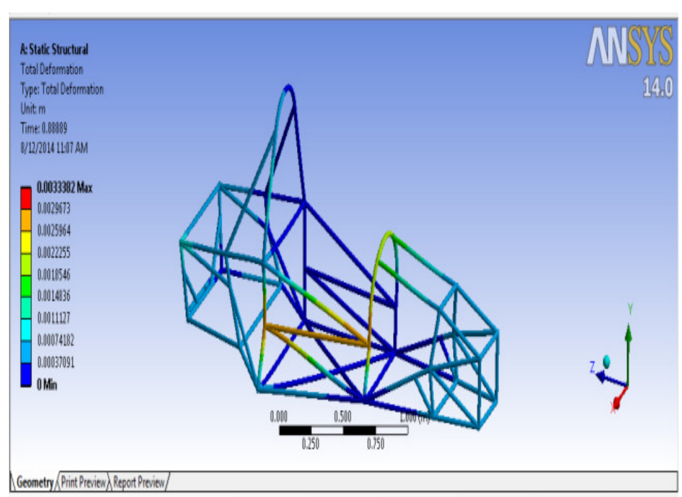

Fig. 6 Side impact of Chrom moly 4140

Table 10 Stress and displacement of side impact of Chrom moly 4140

Load applied (N)	Max. Stress (MPa)	Displacement (mm)	F.O.S
8584	100.1	$3.33*10^{-2}$	3.59

Upright

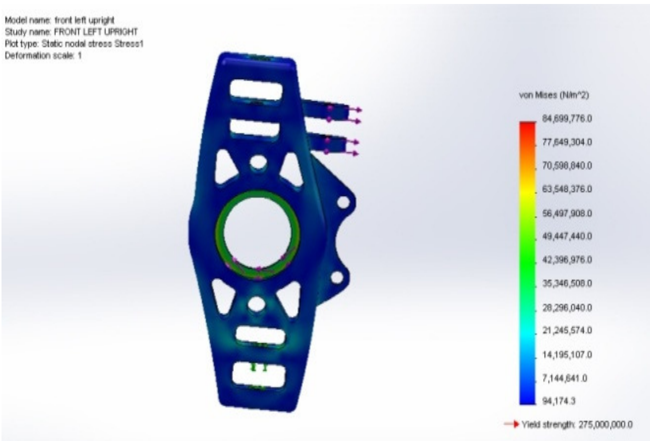

Fig. 7 Upright

Table 11 Stress and displacement of upright

Load applied (N-m)	Max stress (MPa)	Displacement (mm)	F.O.S
750	275	$5.204*10^{-2}$	3.246

Hub

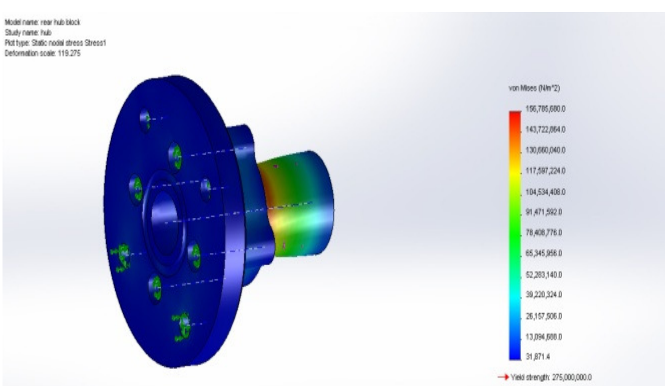

Fig. 8 Hub

Table 12 Stress and displacement of hub

Load applied(N)	Max stress (MPa)	Displacement (mm)	F.O.S
750	275	$1.13*10^{-1}$	1.753

Disc

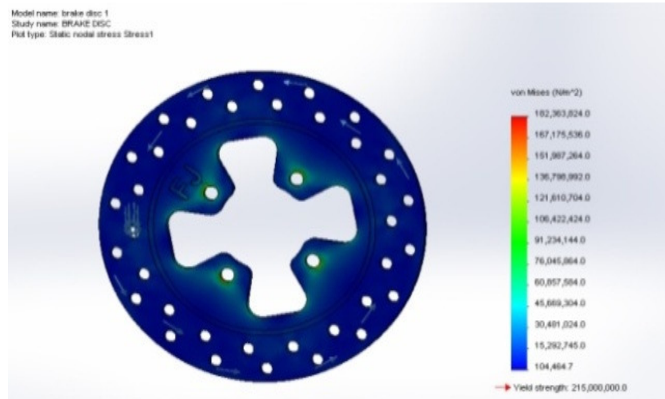

Fig. 9 Disc

Table 13 Stress and displacement of disc

Load applied(N)	Max stress (MPa)	Displacement (mm)	F.O.S
58500	182	1.856	1.178

9. RESULT AND DISCUSSION

The major factor considered for designing of the roll cage are weight, weldability, cost and manufacturability. The material ASTM 106 GRADE B has more impurities and weight is high when compared with 4130 and 4140. Chrom moly 4130 is light in weight, show less deformation in analysis, posses good tensile and yield strength and it is the widely used material for roll cage. But weldability is poor since it fails at high temperature.Chrom moly 4140 is light in weight and posses good tensile and yield strength than 4130.But the deformation of 4140 is high than 4130.On considering the weldability criteria which is more important in manufacturing of roll cage since it has to be welded at many points of the roll cage.4140 has good weldability than 4130 which makes it a better choice for the material of roll cage.4140 does not fail at high temperature and used as material for roll cage .Since it is light in weight, the mileage of the vehicle is high and gives better performance, reliable and cost of manufacturing is less.

10. SAFETY AND ERGONOMICS

Driver's safety and comfort was Primary factor considered while designing and selecting the entire design. Driver will be rugged up with 5 point harness seat belt along with neck resistant. Two kill Switch and Fire Extinguishers used

11. ACKNOWLEDGEMENT

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Wheel assembly

Fig. no4.1 Wheel assembly

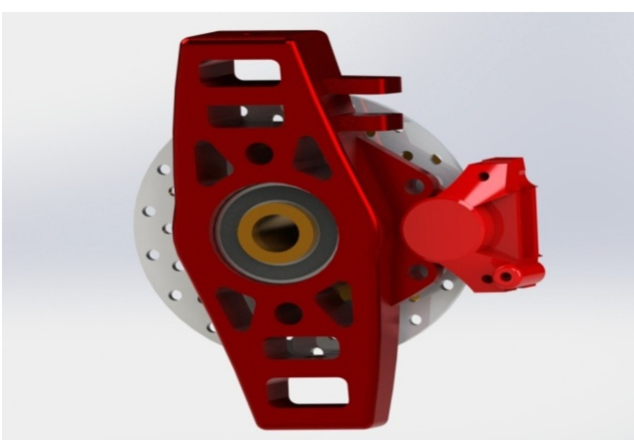

Fig. no.2.1 Disc assembly

Brake circuit layout

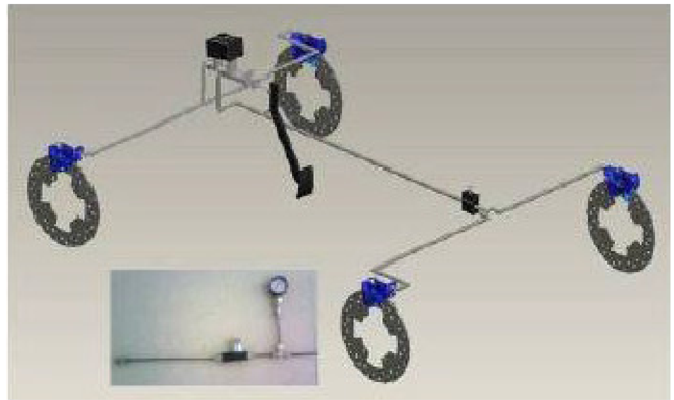

Fig. no.2.2 Brake circuit layout

Pedal force vs acceleration ciruit

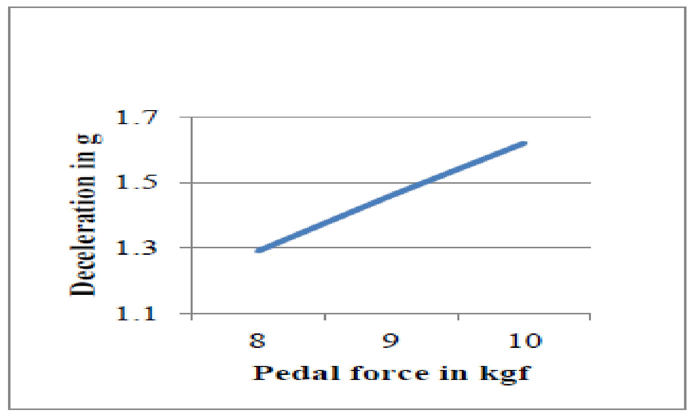

Fig. no.2.2 Pedal force vs acceleration ciruit

Steering wheel assembly

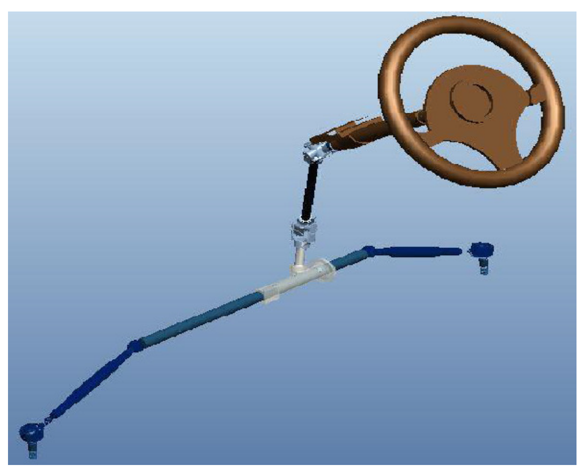

Fig. no.4.2Steering wheel assembly