BAJA 2012- DESIGN REPORT

Team Name:

MECH MUSKETEERS

Registration ID: 63000

Introduction:

Sri Krishna College of Engineering and technology is ready to roll-out its first All Terrain Vehicle fabricated by 25 students and guided by our Faculty Advisor. The car can hit a top speed of 45 kmph in any terrain condition and provides good driver ergonomics. The car weighs around 375 kg making it a lighter and a safer car to drive.

Technical Specifications:

Engine:

- Make: Briggs & Stratton
- Displacement: 305 cc - OHV engine
- Max Torque : 18.6 Nm @ 2600 rpm
- Max Power: 10 hp @ 4000 rpm

Drive:

- Make: Mahindra Alfa Champion
- Spec: 4 Speed Forward Transmission + 1 reverse

Suspension:

- Spec: Double wishbone for both front and rear.

Wheels:

For both front & rear tyres, the following specifications are used.

- 22 inch- Outer Dia
- 10 inch- Rim
- 8 inch- Tyre width

Brakes:

- All Wheel Disc Brakes.
- Hydraulically operated.
- Stopping Distance-10.2m

Steering:

- Spec: Manual Rack & Pinion.
- Type: Two Wheeled Steering.

Dimensions:

- Vehicle Length: 2500 mm
- Overall Width: 1337 mm
- Wheel base: 1780 mm
- Overall Height: 1512 mm

Weights:

- Gross Vehicle Weight: 375 kg
- Roll-cage: 62 kg
- Engine and Coupler: 30 kg
- Transmission accessories: 40 kg
- Suspension components: 40 kg
- Brakes and Tyres: 65 kg
- Steering: 18 kg
- Body & Electrical: 50 kg
- Miscellaneous(incl. driver): 70 kg

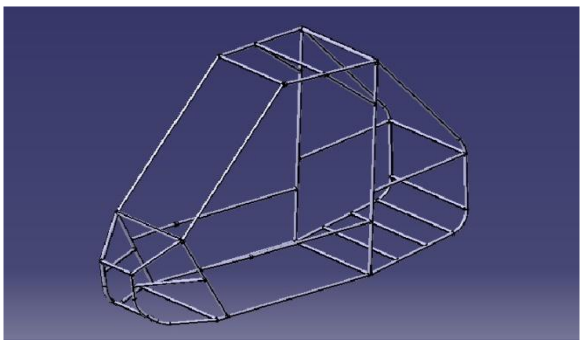
ROLL- CAGE DESIGN & DRIVER ERGONOMICS:

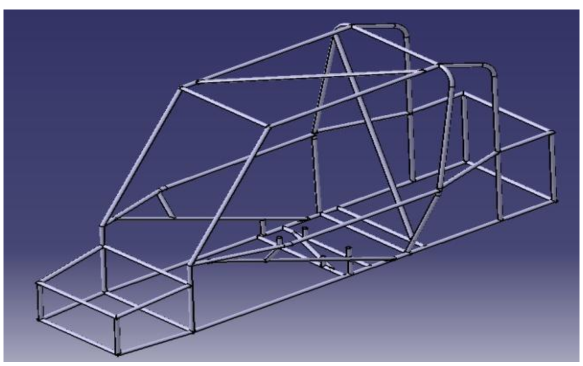
Design consideration:

- ✓ Safety
- ✓ Ergonomics

The roll- cage was finalized after much iteration.

Some of the previous attempts made prior to obtaining the final roll-cage are shown below.

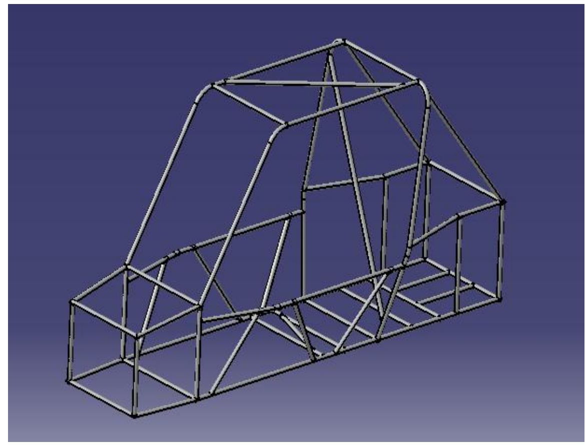




The final roll-cage is obtained after considering many factors.

- ➢ Proper stress distribution
- ➢ Compactness and weight reduction
- ➢ Easy construction

The Roll-cage constructed for our vehicle is shown in the following image.



Material properties and selection:

Mild Steel (AISI 1018 steel) having

O.D 25.4 mm and I.D 19.1 mm.

- Yield strength : 365MPa
- Poisson ratio : 0.31
- Elasticity modulus : 205GPa
- Weight of roll cage : 62kg
- Number of welded joints : 65
- Number of bends : 8
- Welding type : TIG Welding
- Max bend radius : 15cm

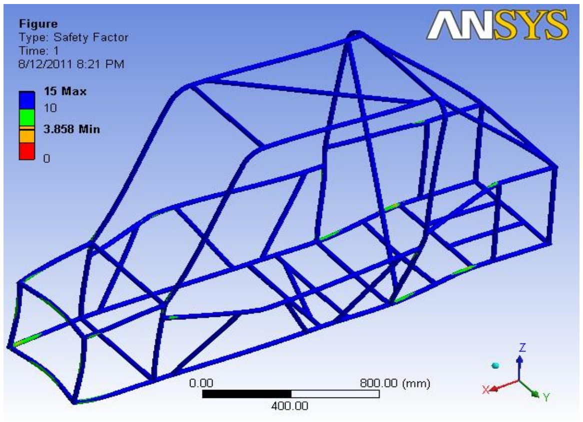
Weight Distribution:

Static Load:

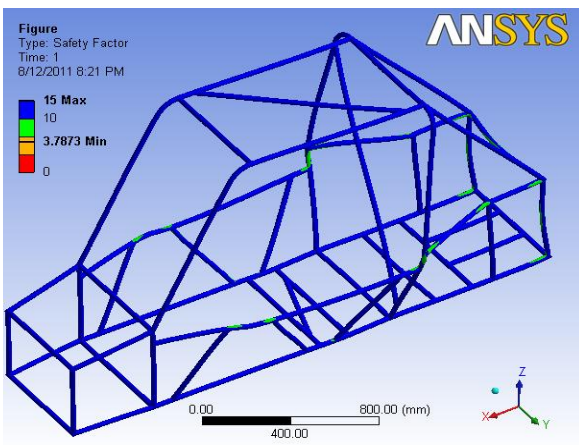
- At front = 1260 N
- At rear = 1878 N
- Deflection = 4.8 mm

Analysis report for Roll-cage:

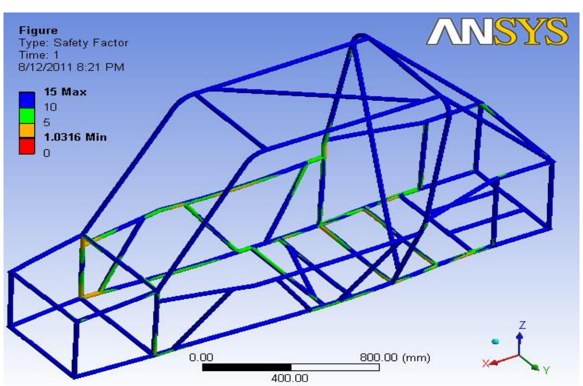
FRONT IMPACT LOAD: F=10050N



REAR IMPACT LOAD: F=12500N

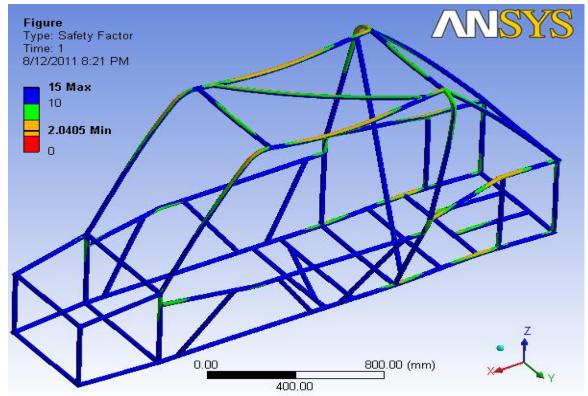


SIDE IMPACT LOAD: F=10000N



TOP IMPACT LOAD: F=10000N

Considering roll-over, the Ansys report is obtained as follows.



Driver Ergonomics:

Our major constrain was ergonomics and we have given due importance to it and have ensured our drivers are comfortable in the vehicle. The comparison for the values we have given and those mentioned in the rule book is given below.

Part	Parameters	Values	Constrains
cockpit	Distance between helmet to RHO	20cm	15.2cm
	Distance between helmet to FBM	55cm	30cm
	Distance between seat to RHO	106cm	104.1cm
	Distance between seat to ABC	70cm	nil
	Distance between arm to SIM	10.16cm	7.62cm
	Angle between FBM and RHO	32.13deg	<45deg
Firewall	Angle of inclination	10 deg	<20 deg
	Distance between seat and firewall	10cm	nil

Vehicle performance:

The following lists the vehicle performance target.

Parameters	Performance
Max speed	42 km/hr
Max Acceleration	4.83 m/s^2
Stopping distance	10.42 m
Deceleration	6.53 m/s^2
Gradeability	57.21%
Turning Circle Dia	8.2 m
Ground Clearance	262.55 mm

SUSPENSION DESIGN:

Design consideration:

- Better traction and handling.
- Vehicle Comforts.
- Roll centre and its impact.
- Cornering force.
- Manufacturing aspects
- Weight transfer

➢ Based on the above requirements and the comparison of the different types of independent systems, for both the front and rear of our vehicle, we have opted to use **Double Wishbone system with unequal and unparallel arms.**

➢ Maruti knuckle was chosen owing to its compatibility, cushioning effect and it is modified to mount the double a-arms. In the front, the suspension has to interface with the steering and braking, the arms are attached to the wheel knuckle mounting points by ball and socket joint. Similarly ball joints are used in the rear with optimized motion.

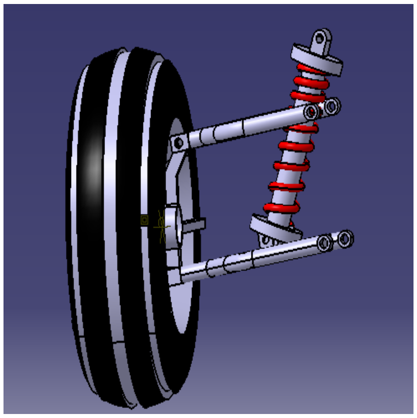
➢ In order to suit the needs of large travel and ease of tuning, we have chosen the coil spring- shock absorber unit of unicorn. It has provisions to vary the stiffness to match the roll stiffness which changes with the position of the roll centre.

Parameter	Double Wishbone	Mac-Pherson strut	Trailing Arm
Degree Of freedom	3	2	3
Wheel Alignment	4	2	1
Roll Center Adjustability	4	3	2
Mounting	3	4	2

Target specification:

Wire dia (d)	12mm
Coil dia (D)	54mm
No. of active Coils (i)	6
Total no. of coils (n)	10
Force acting on the Coil (F)	750 N
Length of the Coil (l)	340mm
Pitch of Soft Coil (p)	28mm
Modulus of Rigidity (G)	$8.1*10^4$ N/mm^2
Percentage Weight Transfer	18.875%

		LENGTH	INCLINATION
FRONT	UPPER	267	3.22
	LOWER	300	5.74
REAR	UPPER	250	4.12
	LOWER	282	6.5



Calculation:

Shear Stress acting on the Coil $\tau = (8kPD)/\Pi d^3$ = **80.6N/mm²**

Deflection $y = (8PD^3 i)/Gd^4$ = **3.42mm**

Spring Rate $K = P/y$ = **220N/mm**

Energy stored in spring $E=p*y/2$ = **1282.5 N mm.**

Parameter	Camber	Caster	Toe - in
Front Left Wheel	-2°	3	2mm
Front Right Wheel	-2°	2	2mm
Rear Wheel	-2°	0	.5mm

- **Sprung mass = 267 kg.**
- **Unsprung mass = 108 kg.**

$W'_{front} = W_{front} + (d*h/g*l)*W_{total}$

Total weight of the vehicle, W_{total} = 3678.75 N

Static weight on the front axle, W_{front} = 1471.5 N

Wheel base, l = 1.780 m

$W'_{rear} = W_{rear} - (d*h/g*l)*W_{total}$

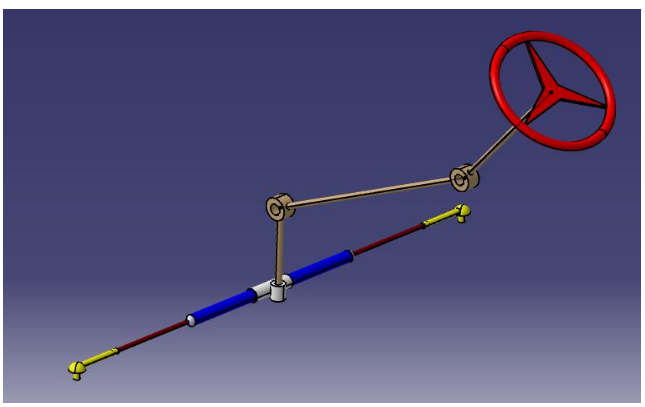
Static weight on the rear axle, W_{rear} = 2207.25 N

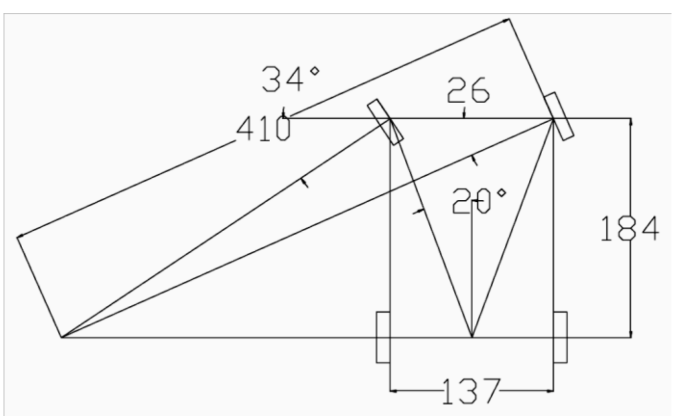
	Front	Rear
ANGLE OF INCLINATION	54	70
SPRING COIL DIA	54mm	54mm
SPRING WIRE DIA	12mm	12mm
NO. OF COILS	10	10
FREE LENGTH	210mm	210mm
LOAD	750N	2207.25
STIFFNESS	225N/mm	225N/mm
SHEAR STRESS	80.8 N/mm²	237.2 N/mm²
ENERGY STORED	396 J	473.4 J
STATIC DEFLECTON	3.2 mm	9.1 mm

STEERING:

Rack and Pinion steering is chosen for the following reasons
1) Ease of fabrication and lightness
2) Wide range of ratios
3) Good response with less free play

STEERING SYSTEMS	RACK AND PINION	RECIRCULATING BALL	WORM AND SECTOR
Steering parameters	4	4	3
Steering Effort	4	3	2
Weight	5	2	3
Linkages	5	3	2
Friction	4	5	2





Steering calculation:-

- Wheel track – 1370 mm
- Wheel base –1830mm
- Distance between two pivot points = 1222mm
- inner lock angle θ = 33.6°
- Steering Ratio = 17.5:1
- Steering wheel diameter = 381mm
- ø-outer lock angle = 26.4°
- Ackermann Angle = 19.88°
- Turning Diameter = 8.2 m
- Turning Radius = 4.1m
- Steering lock to lock = 3.27 turns

Ackermann Relation

cotø-cot θ =c/b

cot(26.4) - cot(33.6) = 0.5

1370 / 1830 = 0.61

Vehicle turning radius:-

Rif = b/sin -(a-c/2)= 2.5m

Rof = b/sin +(a-c/2)=4.1m

Rir = b/tan -(a-c/2)=1.94m

Ror = b/tan +(a-c/2)=3.55m

Steering effort =weight of the vehicle /steering gear ratio

Steering effort (E)=3924/17.5=224.22N

BRAKING:

Design Considerations:

- Light in Weight
- Easy Bleeding and Maintenance
- Enough braking force to stop the vehicle
- Good anti fading property and weather resistance

BRAKE TYPE	DISC	DRUM	CABLE
Anti-fading	5	3	2
Environment resistance	5	1	2
Cost	3	4	5

Selection Criteria

Weight Transfer:

Static 40 % Front and 60 % rear distribution

Dynamic Front: 146 kg
Rear: 254 kg

Brake Calculation

W = Weight of the Vehicle = 3924 N
μ = coefficient of friction =0.8
g = acceleration due to gravity, m/s2 = 9.81 m/s2
h = height if the c.g from the ground = 0.42m
b = wheel base =1.830 m
M= Mass of the vehicle= 400kg
U= speed of the vehicle = 42Km/hr = 11.66m/s
ρ=Density of cast iron = 7800 kg/cubic m
c=Specific heat of cast iron= 0.46 kj/kgK

Weight Transfer:

$$Wt = \frac{\mu h}{b} W$$

Wt = 0.8 * 0.42*400*9.81/1.83

= 720.4 N

Deceleration of vehicle:

MFDD = ug
=0.8×9.81
=7.848 m/s2

Average Deceleration:

$$a_{ave} = \frac{v}{((v / a) + 0.3g)}$$

= (11.66)/ ((11.66/0.8) + (0.3*9.81))

= 6.53 m/s2

Stopping Distance:

$$S = \frac{U^2}{2 * a_{avg}}$$

S= $(11.66^2)/(2*6.53)$

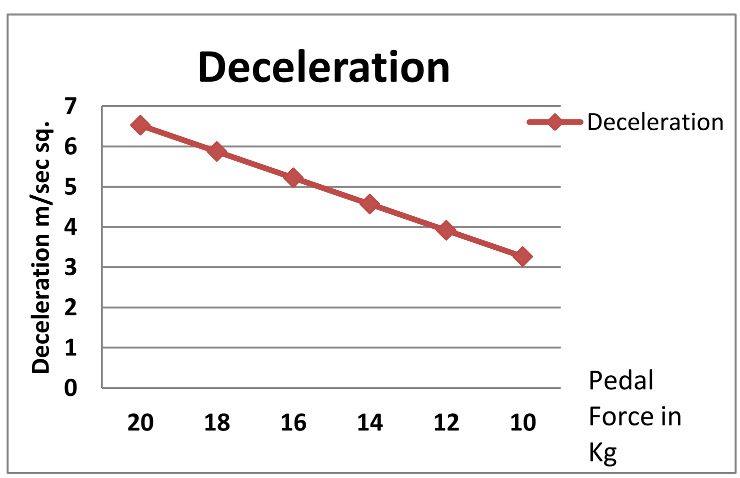
S= 10.42m

Braking Force Applied:

$$F = \frac{\text{Weight of the driver}}{4}$$

F = 80/4 = 20 kgf

Pedal Force in Kg	Deceleration in m/s2
20	6.530174
18	5.877156
16	5.224139
14	4.571122
12	3.918104
10	3.265087



Brake Temp Analysis:

Brake Power Produced = Kinetic Energy + Potential Energy + Rotational Energy

$= \frac{\text{Mass of Vehicle}*\text{Velocity}^2}{2} + 0 + 0.3*\text{Kinetic Energy} =$

$\frac{400*11.666^2}{2} + 0 + 0.3*KE$

= 185.029 KW

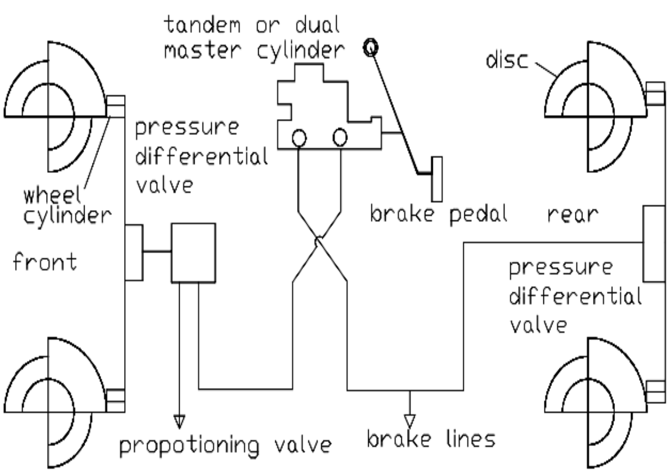
Average Temperature rise per stop:

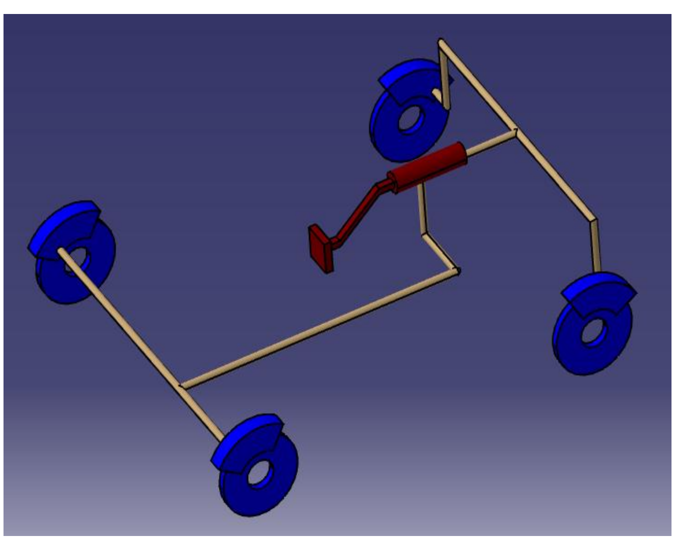
$$\Delta T = \frac{P.t}{\rho.c.V}$$

ΔT = (185.029*0.1)/(7800*0.46*volume of disc)

= 25.5℃

Model and Layout of Braking System:





POWER TRAIN:

After several iterative studies on the market availability of various gear boxes we chose the Mahindra 3 wheeler alfa champion gear box. The decision matrix is thus provided.

Parameter	Mahindra-Alfa (manual)	Piaggio-Ape (manual)	CVT
Torque	4	5	5
Top Speed	5	4	5
Acceleration	5	5	4
Cost	5	4	3
Serviceability	5	5	3

Alfa champion gear box is a constant mesh gear box. Specifications are given below.

Gear Box type	**Constant mesh**
Ist gear ratio	**31.88 : 1**
IInd gear ratio	**18.98 : 1**
IIIrd gear ratio	**11.59 : 1**
IVth gear ratio	**07.77 : 1**
Rev gear ratio	**55.08 : 1**

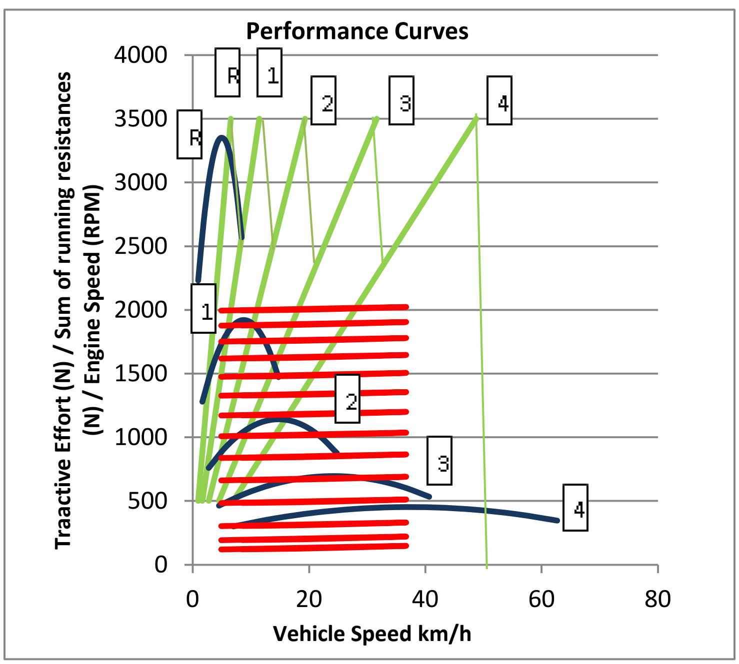
To obtain the vehicle performance we assumed and calculated various values. Assumed values are based on industrially followed standards.

Max Torque(Nm)	18.6
@ RPM	2600
Radius of rear wheel(m)	0.2731
Drag Coefficient	0.5
Rolling coefficient	0.032
Frontal Area(m^2)	0.95
Wt of the vehicle(kg)	375
Trans. Efficiency %	90

The following vehicle performance parameters are calculated for various gears and tabulated below.

Max. Parameters / Gears	1^{st}	2^{nd}	3^{rd}	4^{th}
Torque at wheel **-Tw (Nm)**	527.31	313.04	190.84	123.88
Tractive Force**- Fz (N)**	1930.8	1146.2	698.78	453.59
Velocity **- V (km/h)**	9.81	16.53	27.12	41.78
Wheel **RPM**	95.54	160.43	263.16	405.41
Gradeability**- p (%)**	57.21	29.79	15.69	09.06
Acceleration - **a (m/s^2)**	4.83	2.73	1.52	0.83

Vehicle Performance



Engine speed Vs **Vehicle Speed**

Tractive effort Vs **Vehicle Speed**

Sum of resistances Vs **Vehicle Speed** @ **varying Gradeability (**0 to 60% upwards)

Formula Used:

Velocity (m/s) **v** = $(0.06 * \eta_{mot} * U) / G_r$

Tractive Force (N) $\mathbf{F_z}$ = $(2\pi * M_{mot} * \eta * G_r) / U$

Gradeability (%) **p** = $[\{F_z/(9.81*G_z)\} - f_r] * 100$

Rolling Resistance (N) $\mathbf{F_r}$ = $9.81 * G_z * f_r * \cos\alpha$

Air Resistance (N) $\mathbf{F_L}$ = $0.6 * C_w * A * v^2$

Climbing Resistance (N) $\mathbf{F_s}$ = $9.81 * G_z * \sin\alpha$

Acceleration (m/s^2) **a** = $[F_z - \{F_s+F_L+F_r\}] / G_z$

Where,

$\mathbf{G_r}$ = Gear ratios (final reduction)

$\boldsymbol{\eta}_{\mathbf{mot}}$ = Engine Speed (RPM)

U = Tyre Rolling Circumference

$\boldsymbol{\eta}$ = Efficiency (90%)

$\mathbf{M_{mot}}$ = Engine Torque (Nm)

$\mathbf{G_z}$ = Vehicle Weight (kg)

$\mathbf{f_r}$ = Coefficient of rolling resistance (=0.15)

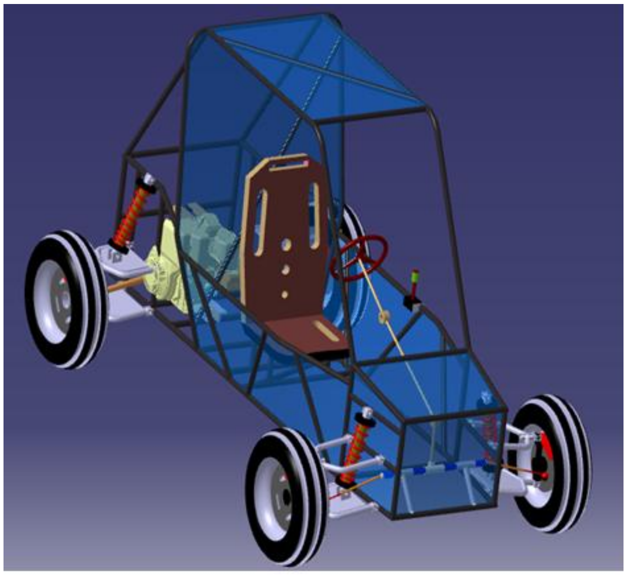
$\boldsymbol{\alpha}$ = Angle of Gradient (deg)

A = Frontal projected area (m^2)

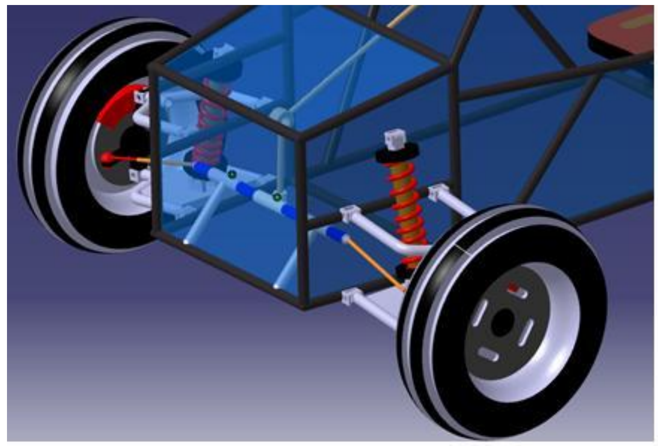
$\mathbf{C_w}$ = Drag Coefficient (=0.5)

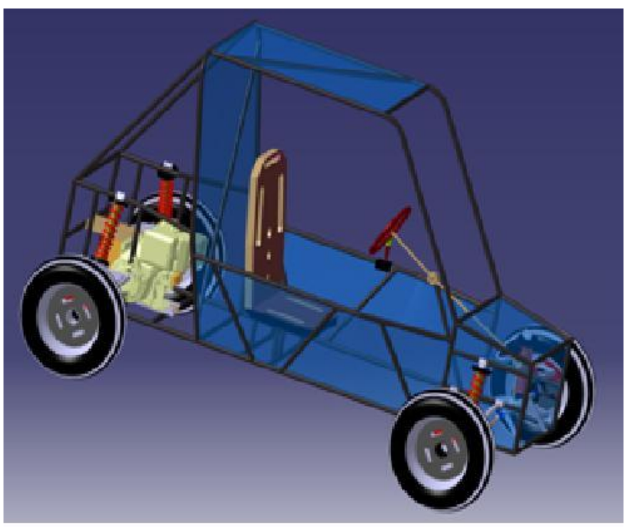
Full-Vehicle Design:

The entire 3-D view of the vehicle was designed using CATIA software. The Detailed views of the front and rear assemblies are also shown.

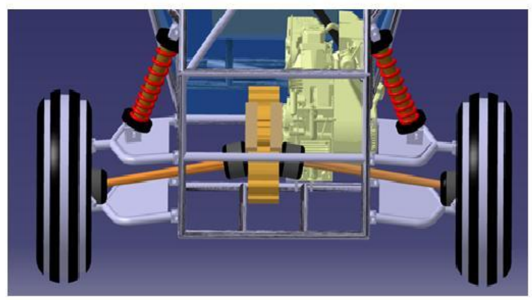


Front suspension & steering assembly:





Rear suspension & Power-train:



BODY PANELS:

In order to fabricate a light weight all terrain vehicle, after studying the various materials available in the market and by taking the cost consideration into account, we opted for using Aluminium for body panels.

- Aluminum is used because of its lightness and for the ease of riveting it with the roll-cage.
- Thickness of body sheet used for covering side impact members will be 0.6mm.
- Thickness of the sheet used to cover the firewall will be 1 mm.

SAFETY FEATURES IN THE CAR:

The building of our ATV mainly emphasizes on safety and a good driving experience. The safety features included in our car are listed as follows.

- Driver apparels (racing suits, Gloves, Neck Braces, Shoes) are SFI 3.3 rated and fire retardant.
- The seat which we use is a fibre glass racing seat.
- SFI rated 5- point latch and link harness safety belts are used.
- Engine and Driver separated by 1 mm thick firewall which ensures driver safety.
- Polypropylene Roll-bar paddings to ensure that the driver is protected from direct against the steel pipes.
- All constraints complying with rule-book to ensure safety in all conditions.
- Use of two Fire extinguishers one mounted one car for immediate driver safety.
- Proper maintenance of C.G and suspension design ensuring that the driver gets good safety and adequate speed during cornering also avoiding roll-over.
- Filleting of materials to avoid any contact with sharp edges.
- Use of all wheel disc brakes to obtain short stopping distance.
- Optimized usage of support members to protect the driver from crashes and roll-over as proven by the Analysis report.
- Usage of rubber mounting beds for engine to avoid vibrations.
- Usage of fibre-glass goggles and rated Helmets to protect the driver.
- Proper sealing of Electrical wires.

REFERENCES AND ACKNOWLEDGEMENTS:

- Automobile Mechanics by **N.K GIRI**
- Vehicle Dynamics by **THOMAS.D.GILLESPIE**
- Automotive mechanics by **G.B.S NARANG**
- Automotive Mechanics by **WILLIAM.H.CROUSE/DONALD ANGLIN**
- MECHANICAL SENSORS by **H.H.BAU/B.KLOECK**