TEAM ATR

(ALL TERRAIN RACERS)

ORIENTAL INSTITUTE OF SCIENCE AND TECHNOLOGY

Bhopal

CALCULATION REPORT

Submitted to,

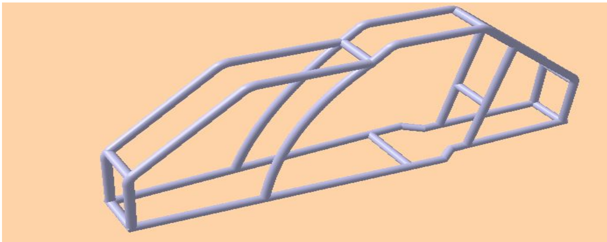
QUAD BIKE DESIGN CHALLENGE

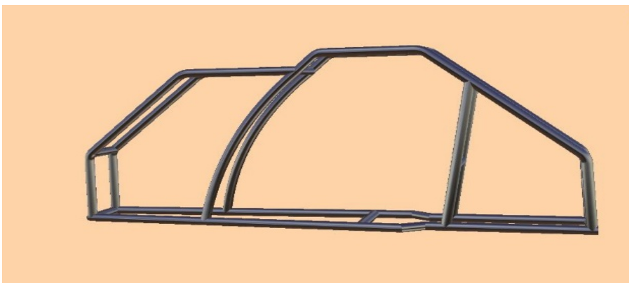
Technical Specifications:

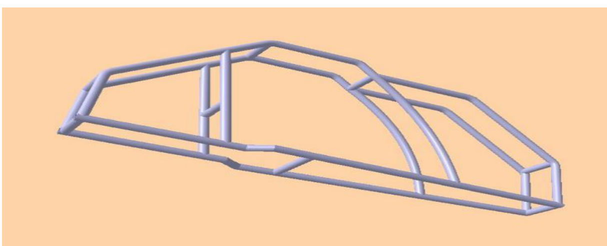
Wheel base	1066.8 mm
Front Wheel track	1016 mm
Rear Wheel track	965.2 mm
Static Ride Height	9”
C G Height	13”
Curb Weight	140 Kg
Weight Distribution	55:45

Max. Speed	50 Kmph
Grade ability	38°50”
Max. Accn.	8.017 m/s^2
Stopping Distance	4.22 m
Transmission Efficiency	90%
Gear Ratio	3.75

Frame Design







MATERIAL	1080 STEEL	4130 STEEL	4130 STEEL
OUTTER DIAMETER	25.40mm	25.40mm	31.75mm
WALL THICKNESS	2.04mm	2.04mm	1.69mm
BENDING STIFFNESS	3791.1 Nm^2	3791.1 Nm^2	3635.1 Nm^2
BENDING STRENGTH	391.3Nm	467.4Nm	487Nm
WEIGHT PER METER	1.486 kg	1.486 kg	1.229 kg

ROLL CAGE DESIGN SPECIFICATIONS:

Type	Space Frame
Material	Normalized AISI 4130 Chrome-Moly. Steel
Mass of Roll cage	12 kg
Length of Roll cage	50 inches
Width of Roll cage	8” (max.) 5” (min.)
Height of Roll cage	26”
Total length of pipes	18 m

FEA of Roll cage-

For AISI 4130 alloy steel –

Young's modulus-205 GPa

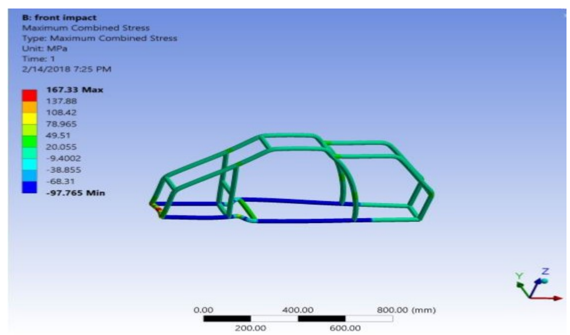
Poisson's ratio- 0.27-0.29 (say0.28)

For all the analysis, weight of the vehicle is taken to be 160kg

Front Impact Analysis

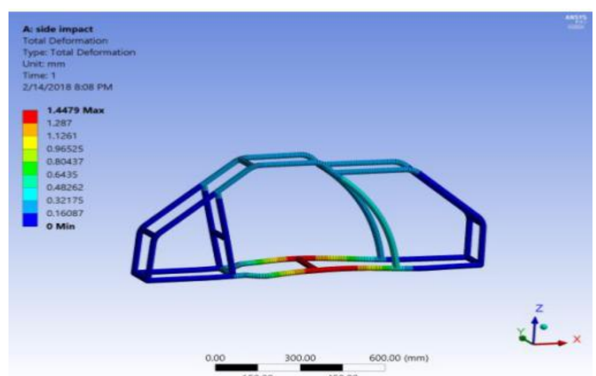
The impact test or crash test is performed assuming the vehicle hits the static rigid wall at top speed of 50 kmph. The collision is assumed to be perfectly plastic i.e, vehicle comes to rest after collision.

Front Impact	**6G (15303.6)**
Max. Deformation	**1.36 mm**
Max. Stress	**150.331 Mpa**
Factor of Safety	**3.05**



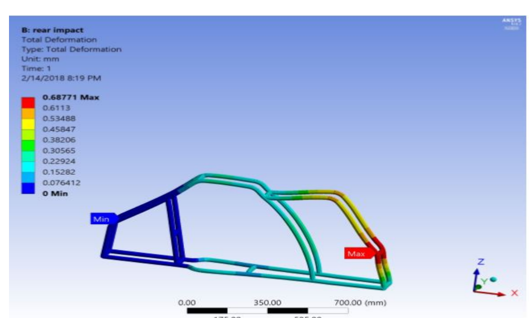
Side Impact Analysis

Side impact	**3G (7651.8 N)**
Max. Deformation	**0.95 mm**
Max . Stress	**206.1 Mpa**
Factor of Safety	**2.23 (>2 Design is Safe)**



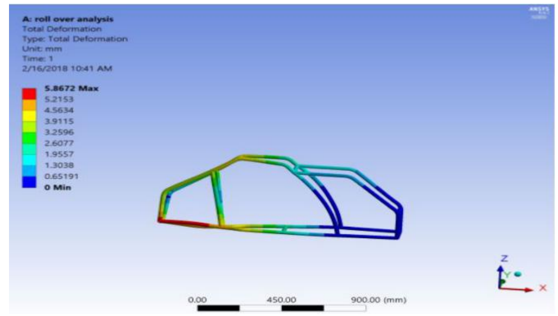
Rear Impact Analysis

Rear impact	**3G (7651.8 N)**
Max. Deformation	**0.95 mm**
Max. Stress	**56.196 Mpa**
Factor of Safety	**3.23 (>2 Design is Safe)**



Roll Over Impact Analysis

Roll over Impact	3.5G (8927.1 N)
Max. Deformation	0.30 mm
Max. stress	80.63 Mpa
Factor of safety	3.05 (> Design is Safe)

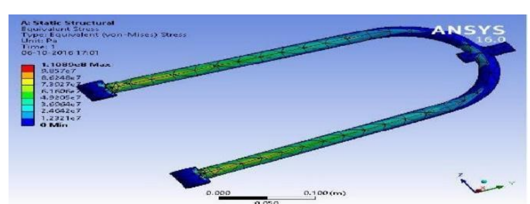


Suspension Design:

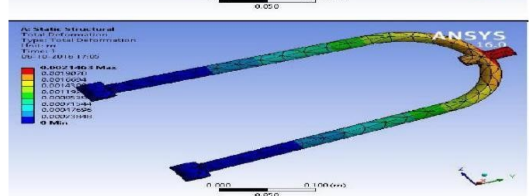
WHEEL GEOMETRY	
Camber Angle	30
Caster Angle	70
Toe-in	20
KPI	30
Ride Height	9”
Scrub radius	50.2 mm

DESIGN CONSIDERATIONS	
Un sprung mass of vehicle	70 kg
Static Stability Factor (Front)	1.10
Static Stability Factor (Rear)	1.03

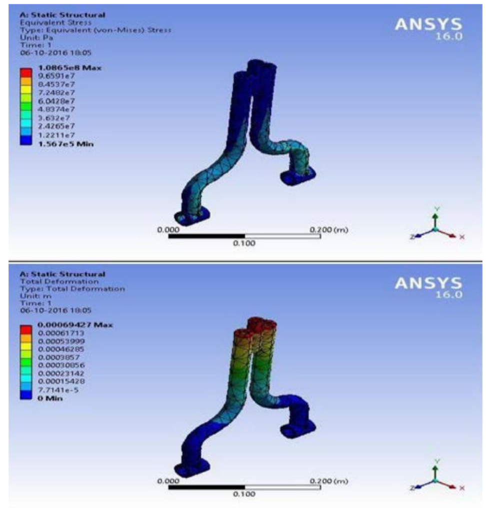
WISHBONE ARMS :



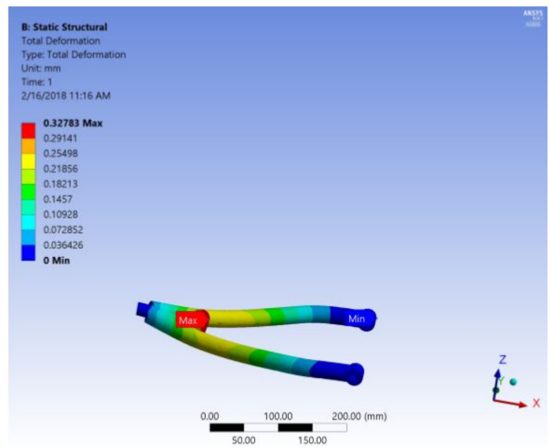
Front Upper Arm FEA



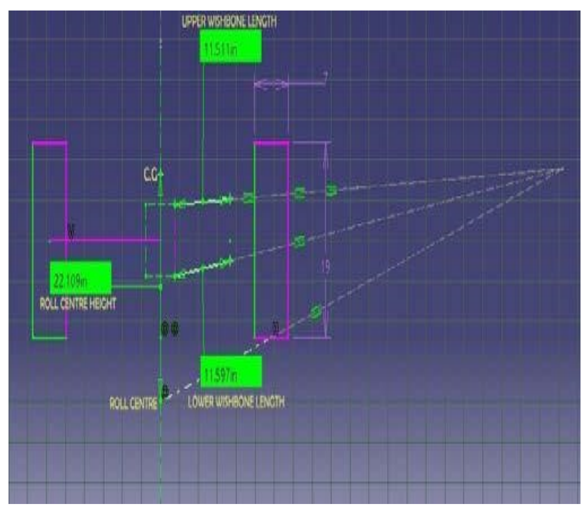
Rear Upper Arm FEA



Front & Rear Lower Arm FEA



Wishbones length Calculation in Catia V5



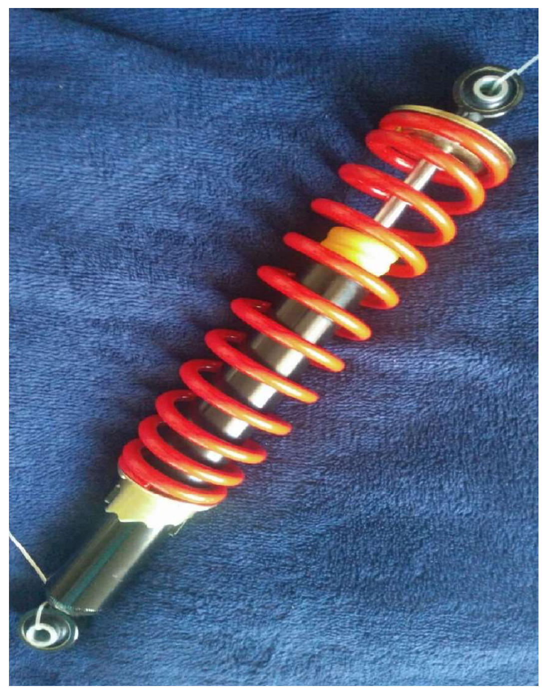
SHOCK ABSORBERS:

All the suspension is equipped with custom-made shock- absorbers which allows the automatic preload adjustment in order to keep the optimal vehicle trim. The shock absorber is completely self-adopting so no HMI is needed. Less un sprung weight which helps to reduce the overall weight of the quad bike and thus provide faster acceleration.

CALCULATIONS:

FRONT SUSPENSIONS

Arm length (d2) = 398 mm
Length of A arm up to suspension mounting (d1) = 304.6 mm
Motion ratio = shock travel/wheel travel = d1/d2 =
Motion Ratio (MR) = 0.701
Spring rate (K) = G x d^4 / 8 D^3 n
G=81370 N/mm^2, N=10, **D**=60 mm, d=10 mm
K= 47.08 N/mm
Wheel Rate (WR) = (MR) ^2 * K * ACF
= (.701) ^2 *47.05 *cos38.9
WR = 18 N/mm



Suspension Freq (SF) = 187.8{(WR/ sprung wt)} ^1/2/ (60)
Spring Wt = 33.75* 9.81
SF = 187.8{(18/33.75*9.81*.2248)} ^1/2/ (60)
SF = 1.539 Hz

Front Ride Rate (Krf) = 4*(3.14) ^2*(SF) ^2*Wf
Krf = 61458.3

Rear ride rate = 4*(3.14) ^2* (SF) ^2* Wir
= 4* (3.14) ^2* (1.539) ^2 * 82.5 *9.81
Krr = 7714.2 * 9.81 = **75676.302**

REAR SUSPENSIONS

Arm length (d2) = 297.18 mm
Length up to suspension (d1) = 165.1 mm
Motion ratio (MR) = .55

Spring Rate (K) = 47.08 N/mm

Wheel Rate (WR) = 13.06 N/mm

Suspension Frequency = 0.677

Roll Moment at front = (hf-Rcf)*Mf*g
= (393.7-152.5)*67.5*9.81
= **159.716 Nm**
Front roll rate factor (F¢sf) =

3.14*(tf)^2*Wf left * Wr right /180(Wrf+Wrr)
3.14*(tf)^2*Wr/360   (tf = 40"0

Front roll rate factor = 466170.8 N-mm-deg roll

Roll rate at front = Roll Moment/ F¢sf
= **0.3426 degree/g**

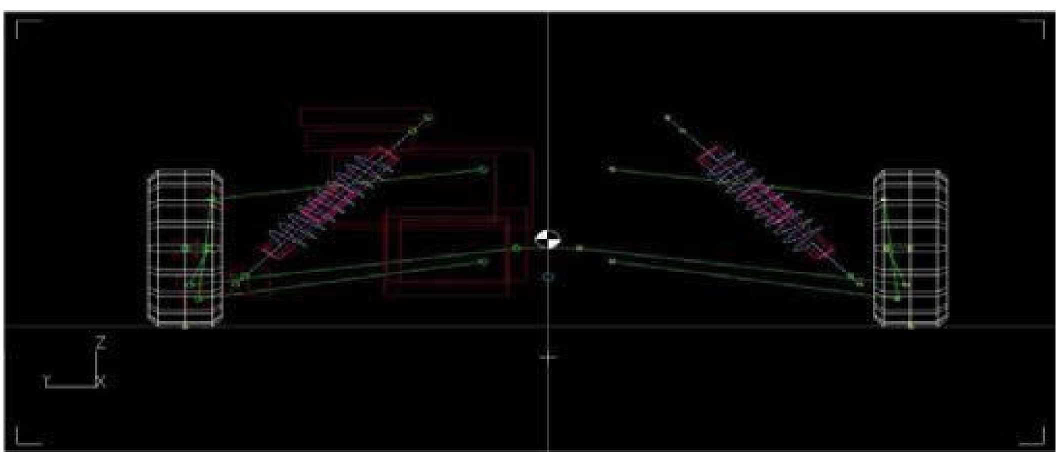
Rear roll rate factor = 3.14* (tr)^2* Wr/360 (tr=39") **F¢R= 541632.292 N-mm-degroll**

Roll moment at rear = (hr – Rcr)*Mr*g
= (419.1-152)*82.5*9.81
= 216170.07 Nm

Roll rate at rear = 216170.7/541632.292
= **0.39 deg/g**

Coil rate = Wheel rate * (Suspension leverage)^2
= 18 * (1/.71)^2
= **35.70 N/mm**

Suspension and Wheel geometry:



STEERING SYSTEM:

Wheelbase(L)	42”=1.066m
Front Wheel Track	38”=0.965m
Rear Track Width	36”=0.914m
Weight Distribution	55:45
Total Weight	140kg+60Kg (Driver)
Turning Radius	2.41m
Static Weight on Front Wheel	110.5 Kg
Static Weight on Rear Wheel	90 Kg
Axle Length	914.4mm
Mechanical Trail	25.5mm
Scrub radius	50.2mm
Turning Velocity	5 m/s
Steering Arm Length	140mm
Front Tyre width Radius of Tyre Radius of Steering	 190.5mm 292.1mm 342.9 mm
Rear Tyre Width Radius of Wheel Radius of Steering	254 mm 279.4mm 342.9m
Load on Front Wheel Load on each Front Wheel	110.5Kg 55.25 Kg
Tripod Radius Tripod Height	80 mm 75.4 mm
Inner Turning angle Outer turning angle	32.62^0 22.63^0

ACKERMANN CALCULATION:

Ackermann Angle (φ3)

= $\tan^{-1}$ (Axle Length / (2 x Wheel base))

= $\tan^{-1}$ (914.4 / (2*1066.8))

= 23.19

1.3. ACKERMANN PERCENTAGE:

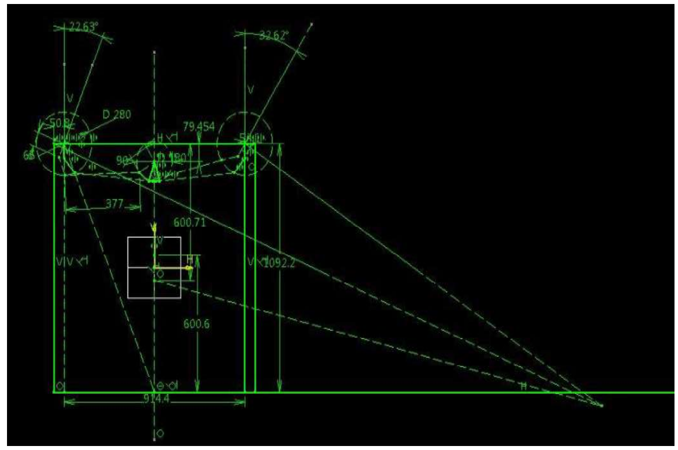
Ackermann Percentage is calculated from referring to the CREO model of the Steering system; for error. [Error = 10.03 mm] Ackermann Percentage

= {(1092.2 + 10.03)/1092.2} x 100

= 1. x 100

= 100.93 % (*Over steer)*

DYNAMIC CONDITION:



Turning Radius Centre of Gravity
=2.414m
Turning Radius Inner Wheel = 2.026 m
Turning Radius Outer Wheel =2.839mm
Height Centre of Gravity = 330.2mm
Tie-Rod Angle top view (ϕ1) = 50
Tie-Rod Angle front view (ϕ2) = 1
Ackermann Angle (ϕ3) = 23.1

I. Cornering Force -
= (Turning Velocity) ^2 /
(Turning Radius Centre of Gravity x
g)
= 5^2 / (2.414x 9.81)
= 1.05N

II. Weight transfer at cornering -
= (Cornering Force x Height C.G. x Front Axle
Load) / Track width
= (1.05 x330.2 x 103.5) / (1066.8)
= 46.40 kg

III. Weight on Inner Wheel -
= (Load on Inner Wheel - Weight transfer at
cornering)
= (51.75- 46.40)
= 5.35kg

IV. Weight on Outer Wheel -
= (Load on Outer Wheel + Weight transfer at
cornering)
= (51.75+ 46.40)
= 98.15 kg

V. Lateral Force on Inner Wheel -
= (Weight on Inner Wheel x Turning Velocity2) /
Turning Radius Inner Wheel
= (5.35 x 52) / 2.026
= 66.016N

VI. Lateral Force on Outer Wheel -
= (Weight on Outer Wheel x Turning Velocity2) /
Turning Radius Outer Wheel
= (98.15 x 52) / 2.839
= 864.3N

VII. Moment due to Lateral Force - A. Moment
Inner Wheel
= (Lateral Force on Inner Wheel x Radius of
Wheel x tan (caster angle))
= (66.016 x 292.1 x tan (7))
= 2367.68 N-mm

B. Moment Outer Wheel
= (Lateral Force on Outer Wheel x Radius of
Wheel x tan (caster angle))
= (864.3x 292.1 x tan (7))
= 30998.43 N-mm

Moment at Kingpin due to Lateral Force
= Moment Inner Wheel + Moment Outer Wheel
= 2367.68+ 30998.43
= 33366.1N-mm

VIII. Self-Aligning Torque –

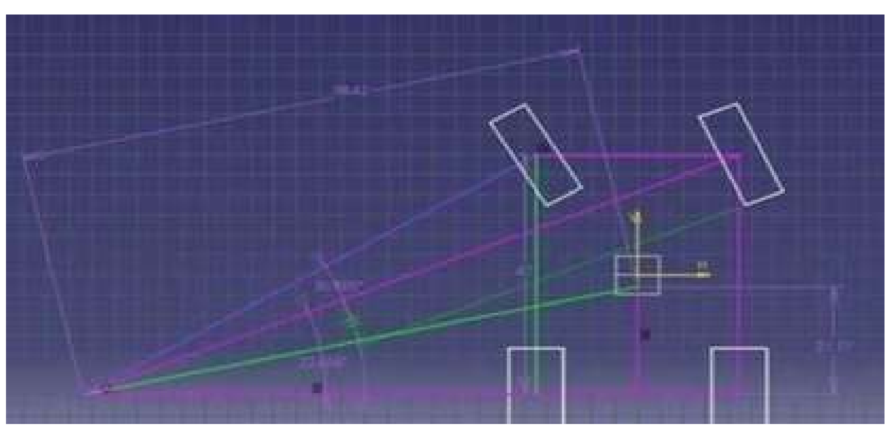
= lateral force*cos(caster)*mechanical trail
=930.3*cos7*(1.41*25.4)
=33069.98Nmm
IX. Net Moment at Kingpin -
= Moment due to Self-Aligning Torque + Moment due to Lateral Force
= 33069.98+ 33366.1
=66436.08 N-mm
X. Perpendicular force at Steering Arm -
= Net Moment at Kingpin / Steering Arm Length
= 66436.08 / (25.4*5.5)
= 288.34N
XI. Force along Tie-rod at arm end -
= Perpendicular force at Steering Arm / [cos (ϕ1+ϕ3) x cos (ϕ2)]
= 288.34/ [cos (5.00+22.714) x cos (1)]
= 325.76N
XII. Force along Tie-rod at tripod end -
= Force along Tie-rod at arm end / tripod efficiency
= 325.76/0.9
= 361.96N
XIII. Horizontal force at tripod end -
= Force along Tie-rod at tripod end / [cos (ϕ1) x cos (ϕ2)]
=361.76//[cos(5)*cos(1)]= 363.4N
XIV. Actual Horizontal force at tripod end –
= Horizontal force at tripod end / tripod efficiency
= 363.47 / 0.9
= 403.86 N
XV. Moment at Steering Column -
= Actual Horizontal force at tripod end x Radius
= 403.47 x 90
= 36347.4 N-mm
XVI. Steering Effort -
= Moment at Steering Column / Radius of Steering
= 36347/342.9
= 106N

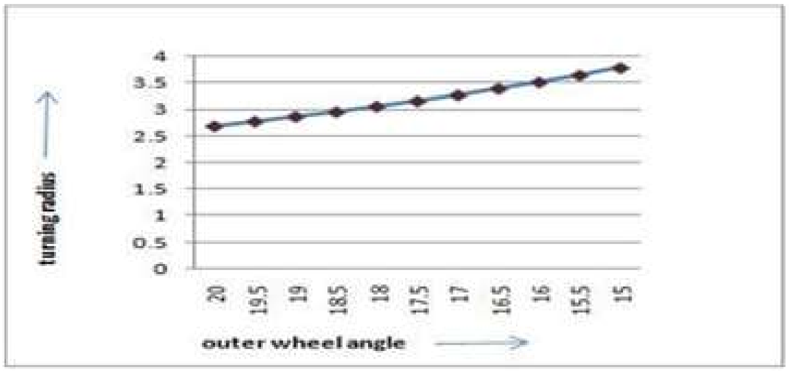
<u>Cornering Stiffness:</u>

For front, C.S=42.18 N/degree
For Rear, C.S=27.071N/degree

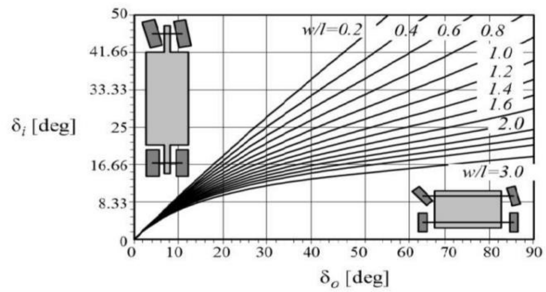
<u>Turning Radius</u>

Turning Radius Drawing in Catia V5





Effect of the w/l on the Ackermann condition for the front wheel steering vehicles:

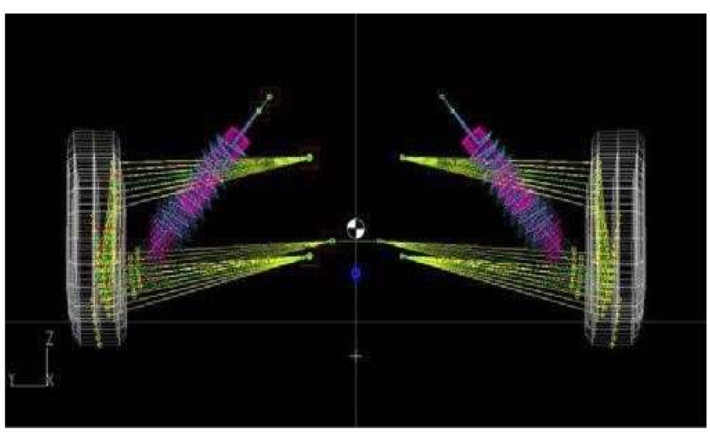


BUMP AND ROLL STEER

Steer with ride travel is very common in all terrain scenarios steer with ride travel is undesirable because if the wheel steers when it runs over a bumps or when the car rolls in a turn the car will travel on a path that a driver did not select intentionally.

Ride/Bump and roll steer are a function of the steering geometry. If the tied rod is not aimed at the instant axis of the motion of the suspension system, then the steer will occur with ride because the steering and suspension are moving about different centers.

If the tie rod is not of the correct length for its location, then it will not continue to point at the instant axis when the suspension travelled in ride.



Bump rolls & Steer Simulation in Lotus

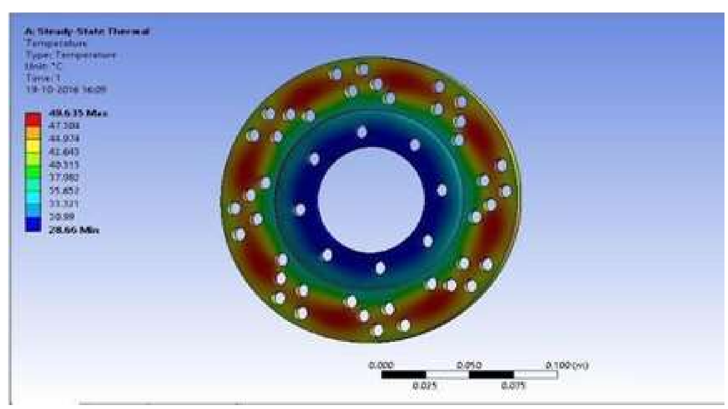
DIFFERENTIAL:

An open differential is a type of differential that allows its two output shafts to rotate at different speeds while cornering. In our ATV we used a differential instead of single shaft drive because of certain dynamic advantages it provided while cornering and while riding through non-uniform terrains. The torque transmitted by an open differential will always be equal at both wheels.

BRAKING SYSTEM:

The braking system is composed of disc brakes on both front and rear wheels. A rotor disc & caliper assembly is mounted to satisfy the braking requirements of our quad bike such as terrain of the track, speed limits, driver ergonomics and other rulebook constraints.

Disc Analysis



Calculations:

The total weight of the vehicle along with an average weight of driver (60 kg) was estimated to be 200 kg. The weight distribution for the quad bike was estimated to be approximately 55:45 from the front to the rear. The static weight distribution of the vehicle is 110kg at the front and 90 kg at the rear.

Rear Braking:

a) Known and assumed Parameters:

1. Total weight of vehicle = 200kg

2. Radius of Tire = 0.2794m

3. Weight distribution factor:

Front wheels = 0.55

Rear wheels = 0.45

4. Master cylinder diameter = 0.024m=24.00mm

5. Caliper cylinder diameter = 0.0255m=25.5mm

6. Rotor Disc Diameter = 0.2m=20.0cm=200mm

Effective diameter of rear disk = 0.16m=16.0cm=160mm

7. No of disc used = 1

Assumed Parameters:

1. Paddle Force = 200N

2. Paddle ratio = 6

b) Calculating the actual braking force (Fr) and braking torque (Tr):

- Force transmitted to the piston of Tandem Master Cylinder= Paddle force* Paddle ratio = 200*6 = 1200 N
- Area of piston in master cylinder = π*0.024*0.024/4=4.52*10^(-4)m2
- Area of caliper piston= π *0.0255*0.0255/4 = 5.107*10^-4 m2
- Pressure generated=force transmitted/area of master cylinder piston =(200*5)/(4.52*10^-4)=28.54 *10^5 N/m^2

Force at caliper= pressure generated* area of caliper piston= (28.54*10^5*5.107*10^-4*2) = 2711.6N

- Total braking force by calipers on the disc =2711.68 *1= 2711.68N
- Total braking force acting on discs (Fr) = 2711.68 * 1 =2711.68N
- Braking torque at disc= total braking force* distance from center of disc where the effective pressure acts= 2711.68*0.08
- **Tr (generated) = 216.93 Nm**

c) Decelerations of vehicle:

- Decelerations of vehicle = Fr / Weight of vehicle = 2711.68/200 = 13.55 m/sec^2

d) Static load on wheels:

- Load on front wheel = weight distribution factor on front wheel * mass of vehicle *g= 0.55*200*9.81 = 1079.1 N
- Load on rear wheel = weight distribution factor on rear wheel * mass of vehicle*g = 0.45*200*9.81 = 882.9 N

e) Relative centre of gravity (X):

- X = Vertical distance of C.G from ground / wheel base = 22 / 42 = 0.5238

f) Dynamic axle load:

- Dynamic load transfer: (CG height/wheel base)*(mass of vehicle)*Decelerations= 0.5238 *200*13.55 =1220.376 N
- Dynamic load on rear axle= static load+ load transfer = 882.9 + 1220.376 = 2103.276 N
- Dynamic load on rear wheel= load on axle /2= 2103.276/2 = 1051.63 N
- Frictional force on rear wheel= dynamic load*coefficient of friction between road and tires = 1051.63*0.65 = 673.56N
- Braking torque required at rear wheel= Frictional force on rear wheel* rolling radius wheel = 673.56 * 0.2794 = 188.19Nm
- **As, the Tr (generated) = 216.93 Nm >Tr (required) = 188.19 Nm**

  Our design is safe

g) Stopping distance:

- For Speed of 40km/hr Stopping Distance is,

$V^2=u^2+2as$

$S=(v^2-u^2)/2a$=speed^2/(2*deceleration)= (11.11*11.11)/(2*13.55) = 4.55 **m**

But, the actual stopping distance depends upon the driver's reaction time, his applying force and hence for reaction time of 1sec, another 1 m of distance is covered by tire,

Hence the actual stopping distance will be= 4.55 +0.7=5.25m

The stopping distance may vary from driver to driver.

h) Stopping time:

Theoretical:

We have t = v/a = 11.11 / 13.55 = 0.81sec

Where, v - Initial velocity

a - deceleration

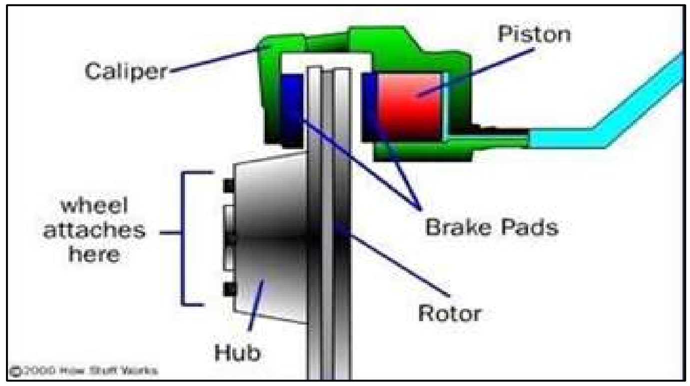
Hence, t = 0.81sec

The above time is when there is no slip of tires, i.e. the coefficient of friction is 0.65 (dry earth).

The above stopping time is theoretical; the actual time depends upon the response time of the driver, the surface of road, tire grip etc.

As per, thinking time used in the Highway Code, an additional time of 0.6sec,

t = 0.81+ 0.6= 1.41 sec



Front Braking:

a) Known and assumed Parameters:

Known Parameters:

1. Total weight of vehicle = 200kg

2. Radius of Tire = 0.292m

3. Weight distribution factor:

   Front wheels = 0.55

   Rear wheels = 0.45

4. Master cylinder diameter = 19.05mm

5. Caliper cylinder diameter = 25.5mm = 0.0255m

6. Rotor Disc Diameter = 200mm=0.2m=20Cm

Effective diameter of front disk = 0.18m

7. No of disc used = 2

Assumed Parameters:

1. Paddle Force = 150N

2. Paddle ratio = 5

b) Calculating the actual braking force (Fr) and braking torque (Tr):

- Force transmitted to the piston of Tandem Master Cylinder= Paddle force* Paddle ratio = 150*5= 750 N
- Area of piston in master cylinder = π*0.0195*0.0195/4=2.986*10^-4m2
- Area of caliper piston= π *0.0255*0.0255/4= 5.107*10^-4 m2
- Pressure generated=force transmitted/area of master cylinder piston=750/(2.986*10^-4)= 25.11*10^5
- Force at caliper= pressure generated* area of caliper piston= (25.11*10^5*5.107*10^-4) = 1282.36N
- Braking force provided by caliper= force at caliper*coefficient of friction between caliper and disc = 1282.36*0.5 = 641.18 N
- Total braking force by both calipers on the disc =641.18*2= 1282.36N
- Total braking force acting on both discs (Fr) = 1282.36 * 2 =2564.73N
- Braking torque at disc= total braking force* distance from center of disc where the effective pressure acts= 2564.73*0.09=230.82
- **Tr (generated) = 230.82 Nm**

c) Decelerations of vehicle:

- Decelerations of vehicle = Fr / Weight of vehicle = 2564.73/200=12.823m/sec^2

d) Static load on wheels:

- Load on front wheel = weight distribution factor on front wheel * mass of vehicle *g= 0.55*200*9.81 = 1079.1 N
- Load on rear wheel = weight distribution factor on rear wheel * mass of vehicle*g = 0.45*200*9.81 = 882.9N

e) Relative centre of gravity (X):

- X = Vertical distance of C.G from ground / wheel base = 22 / 42 = 0.523

f) Dynamic axle load:

- Dynamic load transfer: (cg height/wheel base)*(mass of vehicle)*Decelerations

Dynamic load transfer: (22 / 42)*200*12.823= 1314.9N

- Dynamic load on front axle= static load+ load transfer =882.9 +1314.9 = 2197.8N
- Dynamic load on front wheel= load on axle = 2197.8/2 =1098.9N
- Frictional force on front wheel= dynamic load*coefficient of friction between road and tires = 1098.9*0.65 =714.285 N
- Braking torque required at front wheel= Frictional force on front wheel* rolling radius wheel = 714.285* 0.292 = 208.5Nm
- As, the Tr (generated) = 230.82Nm >Tr (required) = 208.5 Nm

Our design is safe.

g) Stopping distance:

- For Speed of 40km/hr Stopping Distance is, $V^2=u^2+2as$

  $S=(v^2-u^2)/2a$=speed^2/(2*deceleration)

  = (11.11*11.11) / (2*12.823) = 4.812m

But, the actual stopping distance depends upon the driver's reaction time, his applying force and hence for reaction time of .6sec, another 1m of distance is covered by tire,

Hence **the actual stopping distance will be=4.812+1=5.812m**

The stopping distance may vary from driver to driver.

h) Stopping time:

Theoretical:We have t = v/a = 11.11 / 12.823 = 0.866sec

Where, v - Initial velocity a - deceleration

Hence, t = 0.866sec

The above time is when there is no slip of tires, i.e. the coefficient of friction is 0.65 . The above stopping time is theoretical; the actual time depends upon the response time of the driver, the surface of road, tire grip etc.

As per, thinking time used in the Highway Code, an additional time of 0.4sec, **t = 0.866+ 0.4= 1.26sec**

DRIVE TRAIN:

SHIFTER TRANSMISSION (MANUAL GEARBOX)

The shifter transmission has high output and power transfer. The power is more easily controlled on with the gear shifter. Therefore, we have decided to use the shifter transmission. We are using the stock shifter transmission that comes with engine LIFAN 167FMM.

Calculations:

Transmission calculations:

Rolling resistance
F-rolling = c*weight of vehicle
= 0.050*230*9.81
=112.81 N
Where, F-rolling- Frictional / Rolling resistance
c- Rolling resistance coefficient c = 0.050(car tire dry earth)
c= 0.03 for car tire on tar / asphalt
Trolling – Rolling Torque
R – Wheel Radius

Trolling = Fr * R
= 112.81 * 0.2794
= 31.5 Nm

Maximum peak Torque of Engine – 16 Nm

Maximum Torque at rear axle = Max peak torque of engine * efficiency of engine * sprocket ratio * Transmission efficiency
= 16 * 0.92 * 3.75 * 0.97
=53.54 Nm

ENGINE SPECIFICATIONS:

The engine specifications below are specified as :

Engine	LIfan 167 MN
Displacement	229.00 cc
Bore X Stroke	67 mm X 65 mm
Compression Ratio	9:1
Power	15.5 bhp @ 7000 rpm
Torque	16 Nm @ 6000 rpm
Idle Speed	1420 rpm +/- 100 rpm
Starter	Electric & Kick
Fuel	Petrol
Cooling	Air Cooled
Lubrication	Forced & Wet Sump

Maximum Speed of Vehicle:

Rated rpm provided by the throttle controller = **rpm**
Final Gear Ratio of vehicle = 3.75
Losses in transmission system = 0.03

Efficiency of engine = 0.92
Circumfrence of tire = 2* π * 0.275
= 1.72 m

Velocity of vehicle (considering zero drag) = rpm of engine * circumfrence of tire * Final gear ratio
= 6000 * 0.92 * 1.5 / (3.75*3.33*0.96)
= 813 m/min
= 48.78 km/hr

Calculations at different rpm:

1) Engine RPM : 1000 rpm Wheel diameter: 0.558 m (22")
   Primary reduction = 3.33
   Engine shaft rpm = 1000 / 3.33
   = 300.30
   Power shaft rpm = 300.30 / 3.75
   =80.08 rpm
   Speed (kmph) = power shaft rpm * π * wheel dia 8 * 60 / 1000
   = 80.08 * 3.14 * 0.558 * 60 * 10^-3
   = 8.4 kmph

2) Engine rpm : 1800 rpm Wheel diameter: 0.558m (22")
   Primary reduction = 3.33

   Engine shaft rpm = 1800 / 3.33
   = 540.54
   Power shaft rpm = 54.54 / 3.75
   = 144.14 rpm
   Speed = 80.08 * 3.14 * 0.558 * 60 * 10^-3
   = 15.15 kmph

3) Engine rpm : 3200 rpm Wheel diameter: 0.558 m (22")
   Primary reduction = 3.33
   Engine shaft rpm = 3200 / 3.33
   = 960.96
   Power shaft rpm = 960.96 / 3.75
   = 256.25 rpm
   Speed (kmph) = 256.25 * 3.14 * 0.558 * 60 * 10^-3
   = 26.9 kmp

4) Engine rpm : 4500 rpm
   Wheel diameter: 0.558 m (22")
   Primary reduction = 3.33

   Engine shaft rpm = 4500 / 3.33
   = 1351.13
   Power shaft rpm = 1351.13 / 3.75
   = 360.36 rpm
   Speed (kmph) = 360.36 * 3.14 * 0.558 * 60 * 10^-3
   = 37.88 kmp

5) Engine rpm : 6000 rpm
   Wheel diameter: 0.558 m (22")

Primary reduction = 3.33

Engine shaft rpm = 6000 / 3.33
= 1801.80
Power shaft rpm = 1801.80 / 3.75
= 480.4 rpm
Speed (kmph) = 480.4 * 3.14 * 0.558 * 60 * 10^-3
= 50.51 kmp

Torque excerted on the wheels:

The maximum engine torque = 16 Nm
Transmission efficiency = 90% = 0.9

Drive torque (Nm) = engine torque * combined gear ratio * transmission efficiency

Combined gear ratio = primary reduction * gear ratii * reduction at each engine gear ratio

Calculations:

1 Drive torque =16.33*3.75*2.769*0.9 =497.92 Nm
2 Drive torque =16.33*3.75*1.882*0.9 =338.42 Nm
3 Drive torque =16.33*3.75*1.450*0.9 =260.73 Nm
4 Drive torque =16.33*3.75*1.130*0.9 =203.1 Nm
5 Drive torque =16.33*3.75*0.960*0.9 =172.62 Nm

Vehicle tractive effort / drive torque formula:

Drive force = drive torque / Wheel radius

Calculations:

1) 497 / 0.279 = 1781.36 N
2) 338.42 / 0.279 = 1211.4 N
3) 260.73 / 0.279 = 934.5 N
4) 203.1 / 0.279 = 727.9 N
5) 172.62 / 0.279 = 618.70 N

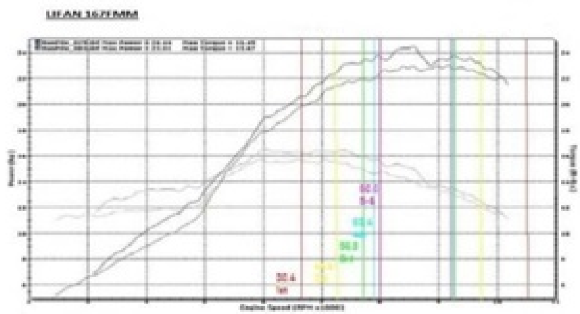
Grade ability

Drive force = mg sin ϴ m = 230 kg g = 9.81 m/s^{-2} ϴ = sin^{-1} (Drive force / mg)

Calculation

1) ϴ = sin^{-1}(1781.36 / (230 * 9.81)) = 42□
2) ϴ = sin^{-1} (1211 / (230 * 9.81)) = 32□
3) ϴ = sin^{-1} (934.5 / (230 * 9.81)) = 24□
4) ϴ = sin^{-1} (727.9 / (230 * 9.81)) = 18.82□

5) $\Theta = \sin^{-1}$ (618 / (230 * 9.81)) = 15.89□



Engine Torque Curve

d) Sprocket Calculations:

Pitch of chain = p = 14.8 mm
Centre distance = a = 584.2 mm

z1 = no. of teeth on driving sprocket = 12
z2 = no. of teeth on driven sprocket = 45

Sprocket ratio = 45 / 12 = 3.75

Velocity = v 13.52 m/s

(n1) = driving sprocket speed = 6000 / (3.33*0.96) rpm
= 1876 rpm
Chain speed = v= z1*p*n1 / 60000
= 12*14.8*6000/60000
=17.7m/s
Chain tension = p1 = 533.33 N
Chain width = b1 = 11mm roller
Diameter = d1 = 10mm

NO of links = Ln2 (a/p) + (z1+z2)/2 + (z2-z1/2
π)*(p/a) = 2(584.2/14.8) + (12+45)/2 + (45-12+2
π)*(14.8/584.2) = 109

Length of chain (L) = L*P = 109*14.8 = 1613.2mm = 1.6 m
Power to be transmitted (KW) = (2 πnT)/60000 =
10KW

From table,
Service factor = Ks = 1.4
Single chain K1 = 1

For 12 teeth (driving) = K2 = 0.76

KW rating of chain = (KW to be transmitted) * Ks /
(K1*K2) KW rating of chain

= 10*1.4/1*0.76 = 18.42 KW

PCD of driving sprocket = D1 = P/sin(180/Z1)

=14.8/sin(180/12) = 57.18mm

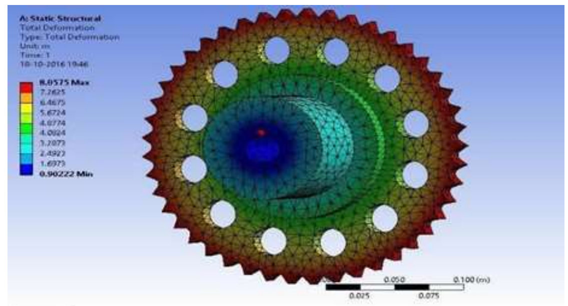
PCD of driven sprocket = D2 = P/sin(180/Z2)

=14.8/sin(180/45) = 212 mm

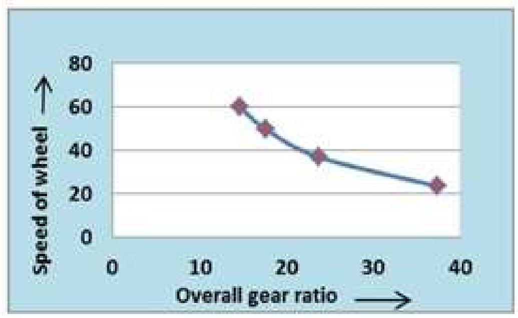
Do mean = D1+P(1-1.6/17)-D1

= 57.18+14.8(1-1.6/17)-10 = 70.58 mm

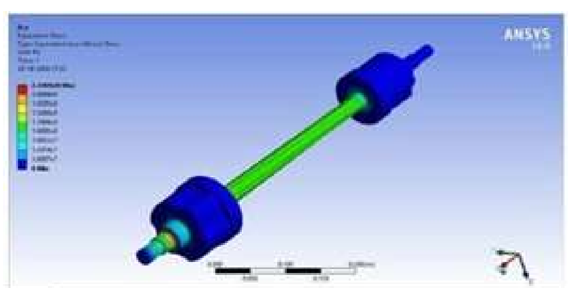
Tooth width = 0.90*b1 = 0.9.*11 = 8.2 mm



Sprocket FEA



Speed of Wheel to Gear Ratio



Drive Shaft FEA

DRIVER'S SAFETY & ERGONOMICS:

Dimension Number	Dimension	Description
1	Age (year)	
2	Weight (kg)	Total mass (weight) of the body
3	Stature	Vertical distance from the floor to the highest point of the head (vertex).
4	Shoulder (biacromial) breadth	Distance along a straight line from acromion to acromion
5	Hip Breadth, sitting	Breadth of the body measured across the widest portion of the hips
6	Shoulder height, sitting	Vertical distance from a horizontal sitting surface to the acromion
7	Elbow height, sitting	Vertical distance from a horizontal sitting surface to the lowest bony point of the elbow when it is bent at a right angle with the forearm horizontal
8	Buttock-popliteal length (seat depth)	Horizontal distance from the hollow of the knee to the rearmost point of the buttock
9	Lower leg length (popliteal height)	Vertical distance from the footrest surface to the lower surface of the thigh immediately behind the knee, bent at right angles
10	Upper hip bone height, sitting	Distance from floor to the uppermost point of the left hipbone. The hipbone is traced by palpating [11, 16].
11	Lowest rib bone height, sitting	Distance from floor to the bottom of the lowest left rib. The lowest left rib is traced by palpating [11, 16].

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