ISSN (O): 2393-8609

International Journal of Aerospace and Mechanical Engineering

Volume 3 – No.1, February 2016

DESIGN AND FABRICATION OF A TADPOLE HYBRID TRIKE

Gomish Chawla
B.Tech Automotive Design,
University of Petroleum and
Energy Studies, Dehradun
cgomish@gmail.com

Parmjeet Kaushik
B.Tech Automotive Design,
University of Petroleum and
Energy Studies, Dehradun
pjparamjeetkaushik1995@gmail.com

Rajat Singhal
B.Tech Automotive Design,
University of Petroleum and
Energy Studies, Dehradun
singhal403@gmail.com

ABSTRACT
The large majority of today's cars and trucks travel by using internal combustion engines that burn gasoline or other fossil fuels. The process of burning gasoline to power cars and trucks contributes to air pollution by releasing a variety of emissions into the atmosphere. Emissions that are released directly into the atmosphere from the tailpipes of cars and trucks are the primary source of vehicular pollution.

The principle objective of this research is to conceive, design, build and compete with a small electric as well as human powered tricycle. It should have a seating capacity of 2 riders in front and back position. The vehicle follows a tadpole structure; the design of which has been derived from passenger two rider bicycle. The target was to convert this simple design into a vehicle that can meet the standards of current available options. For this we started modifying the dimensions first of all. We fixed the dimensions considering all human ergonomic factors. Then we started making the changes according to the placement of various electric equipments and interference of various moving parts. We analyzed our design in all respect using the CAD modeling and analysis tools. The basic parameters were then decided based on various design related mathematical calculations and making some real life assumptions.

Keywords
Pollution, Emissions, Hybrid, Steering, Suspension

1. INTRODUCTION
Vehicular pollution has grown at an alarming rate due to growing urbanization in India. The air pollution from vehicles in urban areas, particularly in big cities, has become a serious problem. The pollution from vehicles has begun to tell through symptoms like cough, headache, nausea, irritation of eyes, various bronchial and visibility problems. The main pollutants emitted from the automobiles are hydrocarbons, lead/benzene, carbon monoxide, sulphur dioxide, nitrogen dioxide and particulate matter. The main cause of vehicular pollution is the rapidly growing number of vehicles.

Several measures are taken by the government like implementing ODD/EVEN policy to reduce the number of vehicles on the road. All these measures suggest that the time has come to shift from conventional petrol/diesel run vehicles to some innovative vehicles like human powered vehicles and battery operated vehicles.

As the government is trying to promote the use of Electrical vehicles instead of Petrol or Diesel Engines, this vehicle can easily be used for use in daily life. Effi-Cycle is a special kind of cycle moves with higher efficiency or we can say a cycle functioning most efficiently, normal bicycle has an efficiency of maximum 60%, & increase in the magnitude is almost impossible, but this particular efficycle consists of three wheels like conventional rickshaw, but the speed of efficycle can be achieved in the range up to 28-30 kmph. Along with manually driven, one DC motor is mounted here to run the cycle by electrical energy. A Rheostat is installed to adjust the RPM of motor through charging the resistance in the supply of current in the motor. Shock absorber is provided to withstand huge shock and vibration, which the system will receive during movement.

2. DESIGN METHODOLOGY
a) **Wheel Base and Track Width**: Wheel base is the distance between the centers of front and rear wheels. Track width is the distance between the front axle and the rear axle of a vehicle. Track width plays an important role as it controls the amount of lateral weight transfer during cornering. Wheelbase of the vehicle was finalized based upon the constraints in the dimensions. The main target was to keep the wheelbase and track width to an optimum value as it should have a minimum turning radius as well as optimum weight transfer should take place with the chosen track and wheelbase values. After much iteration the wheelbase and tread width was finalized as 965.2 mm (38”) and 889 mm (35”).

Table 1. Technical Specifications of the Vehicle

S.NO.	PARAMETERS	ESTIMATED DATA
1.	TOP SPEED	11.11 m/sec.
2.	TURNING RADIUS	2.204 m
3.	STOPPING DISTANCE	4.07 m
4.	WHEEL BASE	965.2 mm
5.	TRACK WIDTH	889 mm
6.	CENTRE OF GRAVITY	0.314 m above ground 0.434 m right of front axle
7.	SELF WEIGHT OF CHASSIS	8 Kg.
8.	MOTOR & BATTERY WEIGHT	30 Kg.

ISSN (O): 2393-8609
International Journal of Aerospace and Mechanical Engineering
Volume 3 – No.1, February 2016

9.	AIR RESISTANCE	2.96 N
10.	ROLLING RESISTANCE	39.50 N
11.	GRADE RESISTANCE	286.84

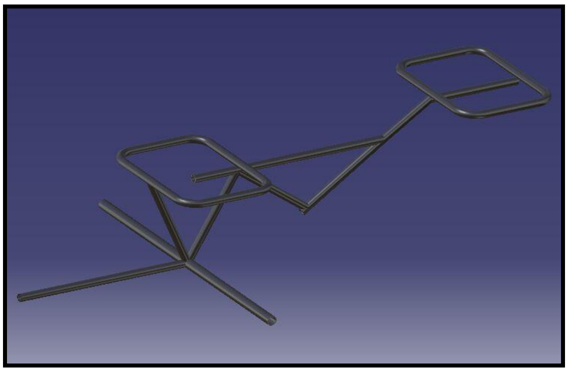
3. DESIGN AND FABRICATION OF FRAME

The goals for the frame design include:

1. Making a compact design.
2. Light weight and high power to weight ratio.
3. Low center of gravity.
4. Increase ground clearance.
5. Increase driver comfort.
6. Provides safety to the driver during collisions.

After much iteration the frame was finalized and was modeled on NX Unigraphics.

First iteration:



Final frame:

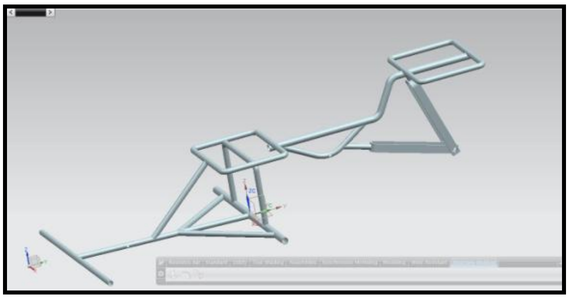


Fig. 1. Frame iterations

3.1 FRAME MATERIAL SELECTION

The selection of material plays a very crucial role in order to achieve strength, desired weight, safety and endurance of the vehicle. To make an optimal material selection extensive study of materials was done on the basis of mechanical strength, chemical properties, cost and availability was done. The challenge was to stike a trade-off between all the parameters. After a detailed market survey AISI 1018 was selected as the material for the frame.

Table2. Bending Strength and Bending Stiffness values

	D_o= 1" t= 2mm	D_o= 1.25" t = 1.5 mm
Bending Stiffness	2078.32 N/m^2	3350.79 N/m^2
Bending Strength	291.331 Nm	375.814 Nm

3.2 ANALYSIS OF FRAME

Simulation of Load Analysis was also performed using Finite Element Method (FEM) based upon the load carried in the static and dynamic modes and the results showed that the chassis was able to sustain all the loading conditions like Front Impact and vertical loadings.1D meshing is done on CATIA V5 analysis module.

Front Impact: To calculate the impact force Impact equation was used. The rate of change of momentum for a vehicle of a mass 74 kgs. was assumed to hit the vehicle with an oncoming velocity of say 40Kmph i.e. 11.11 m/sec. In case of elastic collision with impact duration of 0.3 sec, the impact force obtained is:

$$F= (\text{mass X velocity})/\text{Impact time} =$$

$$F = (74 \text{ X } 11.11)/ 0.5 = 2740.466 \text{ N} = 2800 \text{ N}$$

The chassis should be designed such that it should transmit fewer forces to drivers in case of collision as safety of driver is a main concern. Keeping this in mind an attenuator was designed which will act as a crash cushion intended to reduce the damage to chassis, drivers in case of a collision. Impact attenuators are designed to absorb the colliding vehicle's kinetic energy.

The constraint was to maintain the weight of the chassis as low as possible without compromising on safety. So the attenuator made from Coca-Cola cans was designed and its efficiency was verified by performing Front Impact Analysis in CATIA V5.The results verified that it transmits less amount of shocks to passengers.

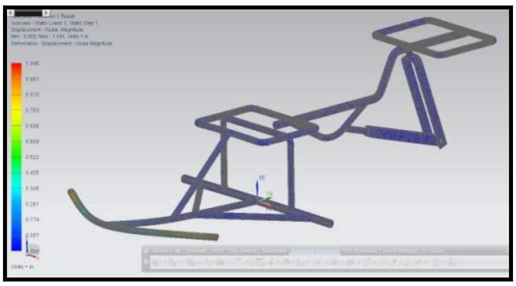


Fig. 2. Front Impact Test without attenuator

ISSN (O): 2393-8609

International Journal of Aerospace and Mechanical Engineering

Volume 3 – No.1, February 2016

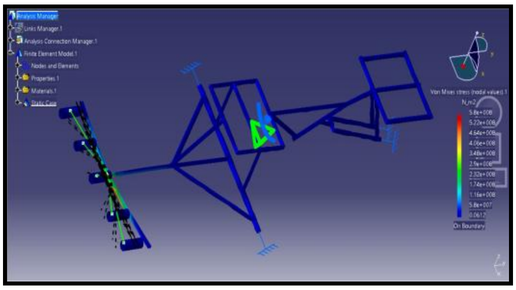


Fig. 3. Front Impact with attenuator

Vertical Loading: Vertical Loading equal to 3g force is being acted upon the chassis.

The optimum value of Factor of Safety should lie between 3 and 5.

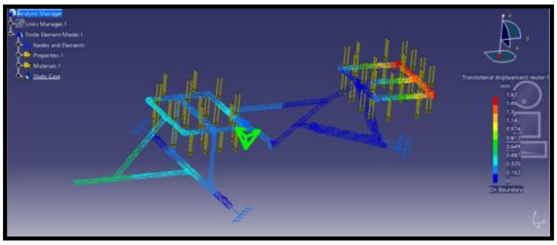


Fig. 4. Static Loading Stress Distribution

FOS: 3.55

The results of CAE indicated that design of frame was successful as it was only Light Weight but could withstand all the tests which ensured driver safety and reliability of the frame.

4. POWER TRAIN

The powertrain is the heart of a vehicle as it provides the driving force to run the vehicle. Powertrain was very critical to design. A lot of insistent study was done which brought out the final design after numerous iterations. Following are the design considerations put together for the design:

1. Maximize Power to Weight Ratio
2. Reliable and durable powertrain
3. Less driver fatigue
4. Optimum compromise between max. speed and acceleration
5. Efficient and compact power train

The vehicle is powered by both human and electric power. The drivers can power the vehicle using the two crank wheels installed at the optimum location in the prescribed wheelbase. These two cranks transmit the power to an idler which ultimately drive the rear wheels through two freewheel.

For power accumulation the concept of common hub has been used. As it can be seen, the front driver pedals the front sprocket which helps in rotating the common hub shaft. At the same time, the rear driver pedals the middle sprocket which in turn also rotates the common hub shaft. The power of two drivers is accumulated at the common hub and then transmitted to rear wheel via the middle storage sprocket. The sprocket sizes have been finalized by optimizing the pedal rate, pedal force and power input through much iteration.

4.1 FOR MOTOR DRIVE:

Furthermore, the motor (rpm = 1500, power = 400 watt) will be placed just above the rear sprocket. The motor will be fitted with a gear which will be meshed with a gear of different size attached to rear sprocket. Since the max speed of rear wheel of trike is 250 rpm the motor rpm has to be brought down (to get torque).

A gear reduction of 6:1 is to be done. The minimum gear size which can be manufactured easily is 8 teeth. So the other gear will have 48 teeth. Hence, the motor will be fitted with 8 teeth gear while the rear sprocket will be fitted with 48 gear teeth.

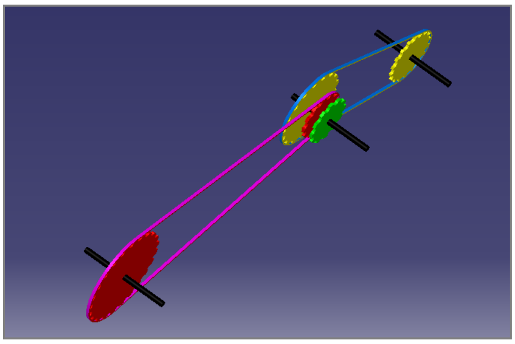


Fig. 5. Power Train Arrangement

5. STEERING GEOMETRY:

The steering considerations while designing the steering system were:

1) Less Steering Effort.
2) Minimum Turning Radius.
3) To achieve pure rolling.
4) To minimize bump steer.
5) To obtain straight line stability.
6) Optimum steering response.

Keeping in mind all these aspects, the chosen steering design included a Knuckle (Linkage type) steering geometry rotated with the help of an Ambassador-water body bearing situated at the apex of the apex of the knuckle and the dimensions were iterated using "Peter Eland Knuckle Spreadsheets" so as to achieve pure rolling with minimum steering effort.

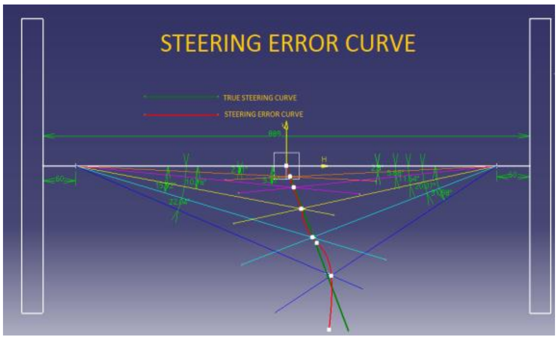
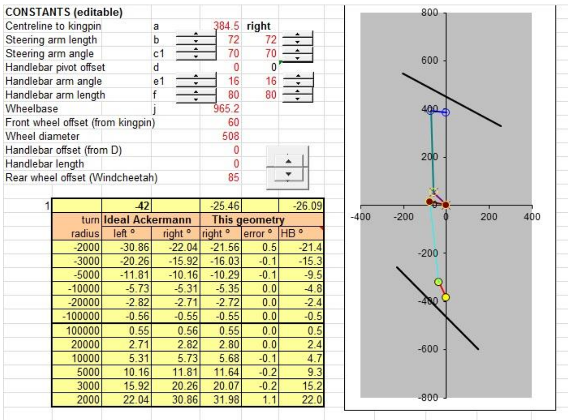


Fig.6. Steering Error Curve

ISSN (O): 2393-8609

International Journal of Aerospace and Mechanical Engineering

Volume 3 – No.1, February 2016



CONSTANTS (editable)			
Centreline to kingpin	a	384.5	right
Steering arm length	b	72	72
Steering arm angle	c1	70	70
Handlebar pivot offset	d	0	0
Handlebar arm angle	e1	16	16
Handlebar arm length	f	80	80
Wheelbase	j	965.2	
Front wheel offset (from kingpin)		60	
Wheel diameter		508	
Handlebar offset (from D)		0	
Handlebar length		0	
Rear wheel offset (Windcheetah)		85	

1	-42		-25.46		-26.09
turn	Ideal Ackermann		This geometry		
radius	left °	right °	right °	error °	HB °
-2000	-30.86	-22.04	-21.56	0.5	-21.4
-3000	-20.26	-15.92	-16.03	-0.1	-15.3
-5000	-11.81	-10.16	-10.29	-0.1	-9.5
-10000	-5.73	-5.31	-5.35	0.0	-4.8
-20000	-2.82	-2.71	-2.72	0.0	-2.4
-100000	-0.56	-0.55	-0.55	0.0	-0.5
100000	0.55	0.56	0.55	0.0	0.5
20000	2.71	2.82	2.80	0.0	2.4
10000	5.31	5.73	5.68	-0.1	4.7
5000	10.16	11.81	11.64	-0.2	9.3
3000	15.92	20.26	20.07	-0.2	15.2
2000	22.04	30.86	31.98	1.1	22.0

Fig.7. Peter Eland Spreadsheet

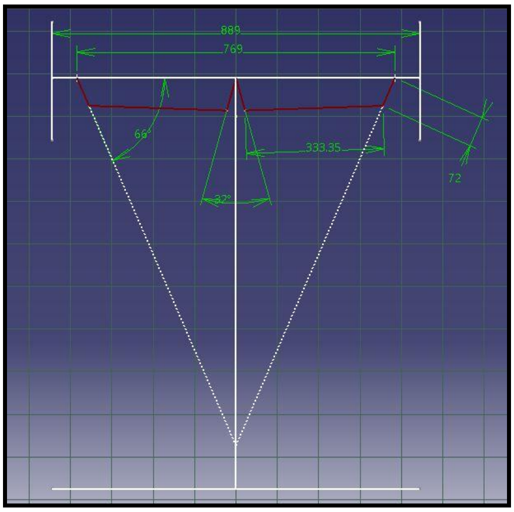


Fig 8. Ackermann Geometry

The other main objective i.e. 'Pure Rolling' was also achieved to a great extent with the help of Peter Eland spreadsheet which provided errors that could be iterated as many times as desired. Thus, finally a pure rolling curvature was obtained up to 2.2 meter of turning radius and after that, the Ackermann percentage started increasing up to 111.7% at the tightest turn. The most innovative part of the steering system was designing and fabrication of adjustable tie rod length so the driver can set the steering dynamics according to the steering conditions.

6. SUSPENSION SYSTEM

After much research about the design of various common suspension systems like Double Wishbone, Macpherson Strut, Trailing Arms etc., the SLA Double Wishbone Suspension system was finalized. C-type suspension design was used as compared to conventional A-Arm suspension as former is compact compared to latter as well as less stress is induced in C-Arm Suspension. The wishbones were manufactured using AISI 1018 tubing as to make it stronger as well as lighter and were connected to the chassis using needle bearings.

Maximum Suspension travel was designed to be 32mm in bump as well as rebound. No suspension was used at the rear wheel to make the trike light weight as well as to reduce the overall cost.

The suspension dynamics plays an important role as it accounts for maintaining the optimum contact patch as well as provide comfort to the passengers during bump. The ride frequency was assumed to be 2Hz.Now the main challenge was to reduce this frequency from 2Hz to a lesser value so to make a comfortable ride. The angle of the spring was inclined to 15 degrees from the vertical so as to account for a correction factor of 0.939.The ride rate was calculated as 7.03 N/mm and spring rate as 16.03 N/mm. After designing the suspension parameters the frequency was reduced to 118 cpm compared to 120 cpm initially.

Lotus Suspension Analysis software was used to analyze the suspension hard points so as to have an optimum camber and toe change curves during bump and rebound conditions. The maximum camber change was calculated as 0.765 degrees in Rebound and -1.485 degrees in Bump.

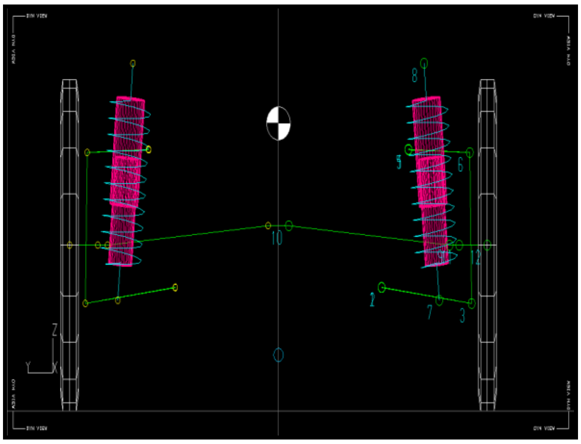


Fig9. Lotus Suspension Analyzer

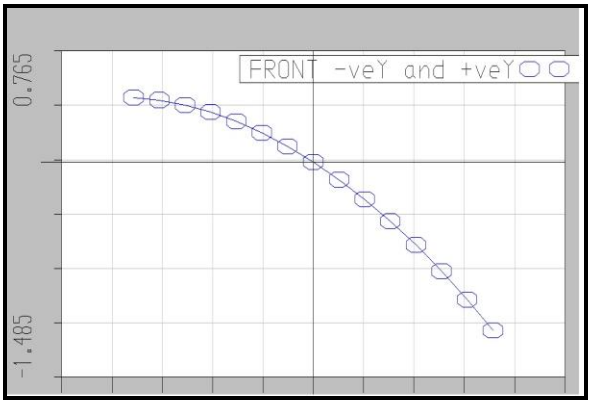


Fig.10. Camber change curve

Also, simultaneously with the iterations of pure rolling and Ackermann principle, we iterated with bump steer conditions with the help of Lotus analyzer to attain least toe change with max of 2 inches of wheel travel. Thus we attained minimal toe change leading to conditions of no bump steer. So, to put it in a nut shell we have iterated Ackermann theory with Peter Eland's Spreadsheet and also with Lotus Analyzer to find the best suited geometry for steering which can fulfill all the design considerations and can finally lead us to a very strong and effective compromise between various elements giving excellent stability to the vehicle and driver.

ISSN (O): 2393-8609

International Journal of Aerospace and Mechanical Engineering

Volume 3 – No.1, February 2016

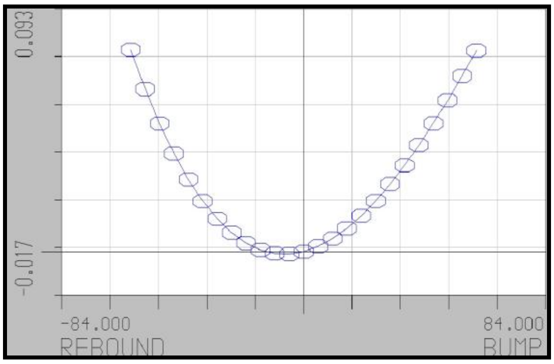


Fig.11. Bump Steer curve

7. BRAKING SYSTEM

The main focus while designing the brakes of the cycle was not only on brakes efficiency but also on the braking efficiency. Following are the design considerations kept forward while designing & assembly of braking system:

1) Effective braking in all conditions.
2) Less driver fatigue,
3) Simple and reliable braking system
4) Adequate braking force.

The brake actuated by wire was used instead of hydraulic brakes to reduce the weight of the vehicle.

Following were the specifications of the braking system:

Table3. Brake parameters values

Parameters	Values
Static rear axle load	39.22
Static axle load distribution	0.53
Braking Force	235.44 N
Total possible braking force on axle	356.359
Maximum temperature	59 degrees

Thermal analysis were performed for a temperature of 59 degrees. And the results showed the disc inducing a maximum stress of 0.000188 N/mm^2 with a deflection of 0.029mm.

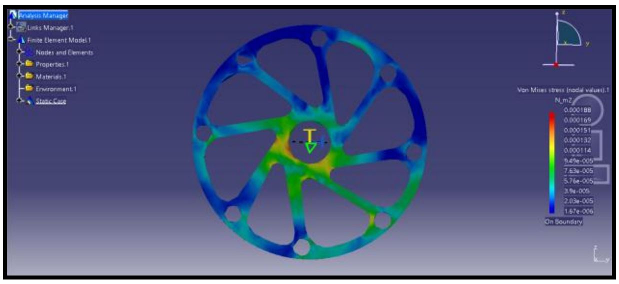


Fig.12. Thermal Analysis

8. SAFETY FEATURES

1) PVC insulated wires routed within the hollow rods of the frame.
2) Clearance between each and every moving parts from the driver.
3) Use of proper seat belts.
4) Kill switch is provided in case of emergency.
5) Side transparent protection from dust and wind
6) Insulated casing for battery and utility box.
7) Use of proper helmet and gloves for the driver.
8) Fairing for the protection from rain and debris.

9. ERGONOMICS

The ergonomics of a human powered vehicle plays a very important role as a optimum ergonomic position is desired by the driver in order to transmit the maximum power to the cranks in order to achieve maximum power. A mock test was conducted by setting up a test bench similar to the seats, and driver and various parameters like steering column height, angle of backrest were found.

✓ Rider's line of sight:
a) Wide front
b) Clear left and right peripheral vision

✓ Handle bar:
a) Not hindering front vision.
b) Maintaining the proper arm angle.
c) Comfortable recumbent seats making appropriate posture Pedals.
d) Maintaining proper angle between calf and thigh.
e) Kill switch

10. INNOVATION

The innovation adopted in our vehicle has been termed as 2-Speed Direct Drive Train. In this the vehicle will have a forward motion while pedaling forwards as on conventional cycles (one gear) and would also have a forward motion while pedaling backwards (on another gear).The advantage of this innovation includes it is compact and light – weight as well as we can shift from one gear to another it can be shifted just by pedaling backwards. It can be used in hilly areas such as Dehradun, Shimla etc. so that the driver can just pedal backwards and get more torque thus easily the vehicle can climb up the hills.

11. CONCLUSION

Through this paper, we aimed to design a vehicle with integration of both electronics as well as mechanical models and also to present it aesthetically and ergonomically strong. With a very light and strong frame, pure rolling steering, efficient braking system and optimum power to mass ratio the trike easily fulfills all the static and dynamic tests put through. Thus the vehicle is built with effective compromise between each and every section to attain best possible stability, speed, acceleration, response, safety and feel. The vehicle was designed and tested in the national event 'SAE NIS EFFI-CYCLE 2015' where it could clear all the Static and Dynamic Tests in 1st attempt and obtained an All India Rank-4 with Best Innovation Award as well as the Most Light Weight Vehicle Award.

This vehicle was made for serving the humanity. Such light weight vehicles can be modified according to the Motor Vehicle Rules and can be used even in universities, tourist spots, recreational purposes etc. We think this research can be an alternative to the ODD-EVEN policy which aims at reducing pollution in the NCT of DELHI. We are confident that this research will be the future for hybrid automotive vehicles all over the world.

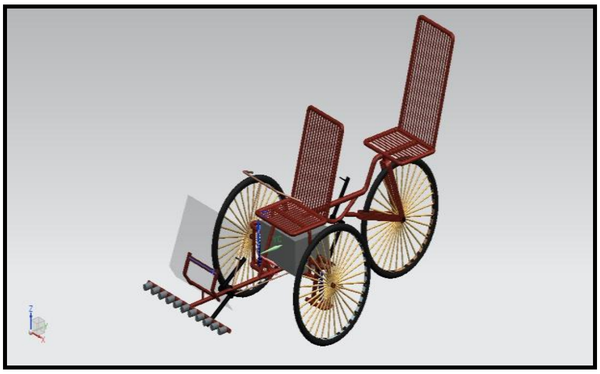


Fig.13. Isometric view of full assembly

12. ACKNOWLEDGEMENTS
We sincerely thank Mr. Sandeep Sharma, Technical Head, Aerosphere, Chandigarh who always motivated to carry this research work. His proper guidance led to the completion of this research. We would also like to thank our parents for their never-ending support.

13. REFERENCES
[1] SAE NIS Effi-Cycle Rule Book 2015
[2] Peter Eland's Spreadsheet
[3] Roark's Formulas for Stresses and Strains