Advances in Automobile Engineering

Tiwari et al., Adv Automob Eng 2017, 6:3
DOI: 10.4172/2167-7670.1000167

Research Article Open Access

Design of Efficycle-Human Powered Light Weight Hybrid Tricycle with Inbuilt Rear Wheel Steering and Use of Universal Joint in Front Axle

Abhay Tiwari*, Ishan Jaswal, Sulipt Das and Anshu Singh

Department of Mechanical Engineering, Chandigarh Group of Colleges, Technical Campus, India

Abstract

Any innovation or technology cannot be possible until and unless the work is not done by a team. In such a manner members of Team GARUD (participants of SAE-NIS 2015), who are highly motivated individuals are recklessly working towards the realization of this goal since its very inception. This paper provides in detail, about the design considerations, and methodology used in designing and developing it. The designing of the vehicle has done on Solid-Works 2014 while the design analysis has done on ANSYS-2014. Various lightweight approaches like a lightweight seat, wheel, steering have also adopted. The innovations include the use of rear wheel steering instead of conventional front wheel steering that meets the need of the market and can be produced by a fictitious firm effectively so, Human powered hybrid vehicle presents the new milestone in the realm of "Green technology".

Keywords: Effi-cycle; RWS: Rear Wheel Steering; UV Joints: Universal Joints; Green Technology; 2WF and 1WR (2 wheels in front and 1 wheel in rear); PMDC: Permanent Magnet DC; FEM: Finite Element Method; AISI: American Iron and steel Institute; CAE: Computer-Aided Engineering; OD: Outer Diameter; ID: Inner Diameter

Introduction

The main objective is to reduce the weight of the vehicle by selecting lighter material and equipment but stronger and optimize it for a lightweight vehicle. Now, it is a right time to develop alternate and green needs of transportation for a sustainable future. The secondary objective of the weight reduction is to maximize the use of the useful power available. Different technologies were analysed and based on the research factors such as turning radius, stability, handling, and ease of manoeuvring, tadpole design was adopted with 2WF and 1WR. The vehicle has an innovative tadpole design, which is ergonomically engineered and easy to manufacture. The vehicle provides the user with the best performance, easy maintenance, and safety, at very reasonable prices. The design was simulated and analysed on SOLID WORKS and analysis software, ANSYS, where we analysed it by various tests like front impact side impact, rear impact and rollover impact test [1].

Innovations

Using UV joints in front axle

It has very rarely seen that front suspension and front wheel drive have co-existed in an efficycle. However, to facilitate safe and effective power transmission, team GARUD has introduced the use of UV joints in front axle to provide the vehicle with both independent suspension and front wheel drive, so that it is convenient for the vehicle to climb uphill and simultaneously resist shocks. The UV joints in the front axle have the similar application as that of front axels of 4- wheeler (Figure 1).

Application of rear wheel steering

Eliminating the use of conventional front wheel steering which added a lot to the weight of vehicle and multiple stresses on the links. Team GARUD has devised a lot simpler and even much lighter alternative i.e., application of rear wheel steering, which a standard bicycle is steering without handles but a lever protruding from the stem and reaching to right drive from side. A peculiar advantage of this type of steering is that unlike conventional effi -cycle steering system, this steering is lever actuated (Figure 2).

Scope in automotive industry

UVB joints can be used in tricycle instead of wishbone to minimize their weight and simultaneously provide a base independent suspension.

Design Constraints

The geometry of the vehicle should be tadpole or delta. The vehicle must be dimension of 100" × 54" × 59" (inches) (L × B × H) for

Figure 1: UV joints.

Figure 2: Rear wheel steering system.

***Corresponding author:** Abhay Tiwari, Department of Mechanical Engineering, Chandigarh Group of Colleges, Technical Campus, India, Tel: 0172 398 4200; E-mail: abhaytiwari736@gmail.com

Received February 01, 2017; **Accepted** July 17, 2017; **Published** July 21, 2017

Citation: Tiwari A, Jaswal I, Das S, Singh A (2017) Design of Efficycle-Human Powered Light Weight Hybrid Tricycle with Inbuilt Rear Wheel Steering and Use of Universal Joint in Front Axle. Adv Automob Eng 6: 167. doi: 10.4172/2167-7670.1000167

maximum stability of the vehicle. The seating capacity of vehicle for must be 2 persons of height 6 feet and weight (both person) 115 kg at least. The battery rating must be 48V, 35 Ah. Motor should be PMDC of 370 watts, 1500 rpm, and 48V for efficient running of vehicle. Brakes must be functional, positive locking brakes on all wheels. The brakes should be disk brake and mounted to the wheels and not on the drive axel. There should be a clearance of minimum 3” between driver and any components of the vehicle in static and dynamic conditions. There should be a ground clearance of minimum 8” in the vehicle [2].

Design Methodology

Chassis/Frame design

The vehicle is totally depends on the best frame design and then it is only possible to fabricate the whole vehicle of the accurate dimension. As we know that, a tadpole trikes front ends exhibits less acceleration than the rear end when turning. This great speed and stability. Suspension system has designed under the assumption that the frame is a rigid body. Therefore, the FEM analysis of the complete frame was carried out with help of analysis software (ANSYS-2014) (Figure 3).

Material selection: Effi-cycle frame can be fabricated from various types of materials with varied cross section and sizes. The selection of material can matter a lot in reducing or increasing the weight of the vehicle. Use of lighter material available without compromising on strength and safety can prove beneficial. The range of material start from the thin and light alloy steels to aluminium and carbon fibres. Material such as AISI 4130, commonly known as chromyl, exhibits higher yield strength as compared to other carbon steel. Alternate materials like aluminium alloys (metals) are also the better option. Aluminium is almost 1/3 in weight of the same cross section of steel. But for better strength, we need to use higher diameter and more thickness of aluminium pipes, but still the weight of the required aluminium will be very low than steel [3].

Composites material like carbon fibres are the widely used in automobile application resistant but carbon fibres can be used resulting in ultra-light efficiency (Figures 4 and 5).

Use of different cross section: Material and cross section used for frame should be selected according to the loads acting on the different

Figure 3: 3D frame model.

Figure

Figure 4: Aluminium box- section and tubes.

Figure 5: Carbon fibre tube.

S.N.	Name	Density (kg/m^3)	OD (mm)	ID (mm)	Thickness (mm)	Weight (kg/m)
1	Steel pipe	7850	25.4	21.4	2	1.15
2	Other pipe	7850	25.4	22.2	1.6	0.96

Table 1: Material dimension.

parts of the frame. Use of circular pipes and square members for making frame is a common practice, but you should optimize it such that the same weighs less, but is of same strength. Use of pipes should be based on circulation of moments and force. Generally, where the bending load occurs, higher bending strengths can be obtained by increasing either thickness or diameter or both. Moreover, you may identify the weakest member with the help of CAE and then try increasing the dia. /thickness of those members. This practice should follow until the maximum deformation at part of frame is within the acceptable limits. It is suggested that use of higher dia. or higher wall thickness pipes only at that load bearing members will increase the durability of the identified as members supporting the wheels and seats etc. Other parts may be kept relatively lighter. However, it having too much section size will also create a problem in ordering the quantity, Hence after optimization, the sections size can be normalized and max. 2-3 a section sizes should be finalized. Not only circular sections but also C- section, I- section, square /rectangular sections can also be used (Table 1).

Frome the above table you can see reading the thickness by 0.4mm can reduce the weight up to 19.13% per meter. Now, a thorough research or a suitable material in term of its mechanical properties , thickness and by analysis on CAE software and cost was done. Stainless steel AISI 304 and carbon steel AISI 1018 were shortlisted compared and analysed and finally we go for the AISI 1018 based on the market availability, cost and weld ability and machining process [4].

Structural analysis: The design of frame must do such that the protection of drivers can be offer without adding extra protection members in frame. The vertical and longitudinal members having a bent towards outside the vehicle can assume that external objects will not hit riders directly. A bending test has done using ANSYS software to check if the chassis could withstand the weight of the drivers and the components associated with the vehicle during static as well as dynamic conditions. A safety factor of 2.4 was obtained and maximum deformation was less than 1mm (Figure 6 and Table 2).

Track width and wheel base

Track width is the distance between the right and left wheel centre line while wheelbase is length from the centre of the rear wheel to the centre of the axle joining them from wheels. Track width affects the amount of lateral weight transfer and plays a key role in design of suspension [2]. Now, after several design iterations, based on the requirements of steering and suspension geometries, the track width and the wheelbase were set at 54 inches and 91 inches respectively (Figure 7 and Table 3).

Tyre and wheels

Keeping in mind the vehicle may have to deal with manoeuvrability challenges; the wheel set chosen is MTB type [5].

Brake

We use mechanical disc brakes, which has mounted on all three wheels. Disc brakes are used because of its high heat dissipation

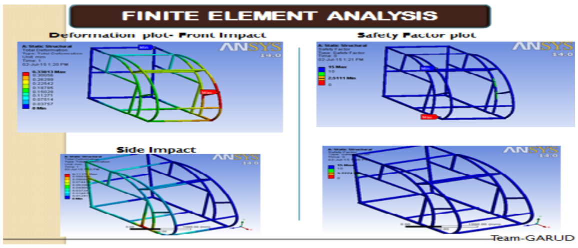

Figure 6: Structure analysis.

Properties	AISI304	AISI1018	AISI4130	AISILF6061-T6
Yield strength	290 mpa	370 mpa	435 mpa	276 mpa
Ultimate tensile strength	586 mpa	440 mpa	670 mpa	310 mpa
Modulus of elasticity	193 Gpa	205 Gpa	205 Gpa	68.90 Gpa
Alloy content	0.05% C, 18% Cr, 9% Ni	0.18% C, 0.7% Mn, 0.04% P	0.33% C, 0.8% Cr, 0.04% S, 0.6% Mn, 0.25 Pb, 0.035% P	0.35% Cr, 0.4% Cu, 0.7% Fe, 1.2% Mg, 0.15% Mn, 0.8% Si
Weld ability	Excellent	Good	Good	Good
Corrosion resistance	Good	Low	Good	Good

Table 2: Material specification.

Figure 7: Tyres and wheels.

Front wheel		Rear wheel	
Diameter	20”	Diameter	26”
Radius of rim	7.99”	Radius of rim	11”
Width of rim	13 mm	Width of rim	15 mm
No. of spokes	36 (10 number)	No. of spokes	40 (10 number)

Table 3: Tyre specification.

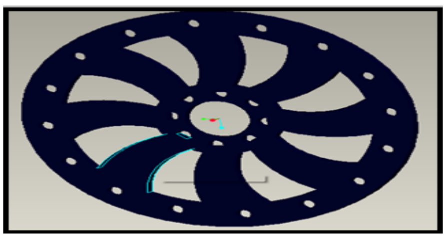

Figure 8: Disc brake.

30 Km / hrs.	50 Km/hrs.	η%
3.5m	9.8 m	100%
4.4m	12.2 m	80%
6.0m	16.3 m	60%
12m	32.6 m	30%

Table 4: Brake calculation.

5 m	50 m
Braking zone	Speed zone

Table 5: Brake test condition.

capability, high torque transmitting capacity, good efficient in wet weather conditions (because centrifugal force tends to fling water off the brakes disc and keeps it dry) (Figure 8).

Brake specifications: Independent disc brake with lever actuation (Table 4).

Efficiency of brake: 80%

Force on front/ rear wheel: 681.67/659.14 N

Torque on front/rear wheel: 145.5/140.7 Nm

Braking distance: 3.5 m

Material of disc: Cast iron

Thickness/ID/OD of the disc: 2.1/58/160 mm

Braking calculation: Stopping distance=(S)=$V^2 \div 2\mu g$ m

Where, V=Velocity (m/s)

μ=Coefficient of friction between the tyre and the road

g=Acceleration due to gravity (m/s^2)

Case 1: Under top speed condition (V=40 Km/hrs.),

normal condition of μ=0.8

$40 \times 1000 \div 3600 = 11.11$ m/sec

$S = V^2 \div 2\mu g$

$S = (11.11)^2 \div (2 \times 0.8 \times 9.81) = 7.86$ m

Extreme condition, μ=0.3

$S = V^2 \div 2\mu g$

$S = (11.11)^2 \div (2 \times 0.3 \times 9.81) = 20.9$ m

The brake efficiency in general use varies from 50% to 80%, which enable the vehicle to stop within reasonable distance. In previous table given approximate stopping distance at different vehicle velocity for the various braking conditions. We also shown above the stopping distance with velocity of 40 km/hrs. with different coefficient of friction. However, the minimum allowable limit of brake efficiency for for any vehicle is 50% for foot brakes and 30% for hand brakes. The distances given in table and calculated are approximate only and they vary, within the type of road surface and condition of type trends etc (Table 5).

Case 2: Brake test condition

Team will allow covering a distance of 50 m in 15 sec. time and then to apply brakes. Vehicle must stop within the distance of 5 m after applying brakes.

$V^2 - U^2 = 2as$ m/s

Considering the 5m available for bringing the vehicle to a complete halt, V=0 m/s

S=5 m

U=distance ÷ time

U=50 (m) ÷ 15 (sec.)

U=3.33 m/s

$V^2-U^2 = 2as$

$0^2-(3.33)^2 = 2 \times a \times s$

a= -11.0889 ÷ 10

a= -1.10 m/s^2

Acceleration (d) during the braking of the vehicle that is 1.10 m/s^2

However, acceleration in G unit (d)=│1.10 │ × g ÷ (9.81)

a=0.112 g

Braking force required (B_f)=

$B_{f=}$(Mass of vehicle including driver) × (Deceleration)

$B_{f=}$240 × 1.10

$B_{f=}$264 N

Braking torque=T=B_f × (R ÷ r_p) Nm

Where, R is the static laden radius of the tire and r_p is the ratio of the radius of the brake disc to the static laden radius of the wheel.

r_p=Radius of the brake disc ÷ static laden radius of the wheel.

$r_{p=}$0.29÷0.5842=0.496 m

T=264 × (0.29÷0.496)

T=154.35 Nm

Frictional force (F)=μ × mass of the vehicle (including driver)=1.78 × 240

Frictional force (F)=427.2 N

Suspension

For road holding and braking, suspension is required. Now, from different research and topology we found that the suspension is required only on the rear wheels so the coil over type suspension was used on rear wheels [6].

Calculation for suspension=For rear suspension system=Length of spring=solid length + $\delta_{max.}$

Compression + clearance=(n+3) d + δ_{max} + 0.15 δ_{max}=(14+3)10 + 100+0.15 × 100=285 mm

Pith of coil=(L_f + L_δ) ÷ (n + d)

=(285+170) ÷ (16+10)

=17.18

Technical specification suspension-Natural frequency=3 H_z

Spring stiffness=8658 N/m

Spring index=5

Mean coil diameter=50 mm

Drive train

Both the passengers were provided with individual power train to power the vehicle in both single passenger and dual passenger mode. The front driver and the rear wheels by the co-driver powered the front wheels. The aim of the drive train model is to deliver the power produced by the drivers to the driving wheel most efficiently. Now, here the objective is to reduce the weight of drive train also.

Conventionally, the mode of power transmission in effi-cycle is through chain drives (where in the power from prime mover is transmitted to wheels by a system of sprockets (on prime mover and the wheel hub) connected through a metallic chain, in its simplest form).

However, an equally efficient transmission medium the belt drive, is increasingly becoming popular in bike applications. In fact, the use of belt drives in motor driven bikes dates back to the early 1900's, the Harley Davidson FXB Sturgis of 1980's being a classic example. Successfully implemented in number of cruiser style motorcycles, the belt drive has conveniently adopted in the present format of effi-cyle vehicle also, in an attempt, to reduce weight while maintaining transmission efficiency at par with chain driven effi-cycle.

Options available

Use of hollow shafts/stepped shafts/half shafts: Transmitting shafts can be made hollow as they can sustain more torsional loaded generated by torsional bending moments. Many a times stepped shaft can also be used instead of hollow or solid shaft, the idea used in this is to add more material (increase thickness) where the load is acting directly and to remove the material (reduce thickness) where the load is not acting. Half shafts are also reliable and can be used in efficycle , powered rickshaws or all modern LMV'S (Figure 9).

Use of thin sprockets/smaller pitch chains/reducing chain length: Many times we forces a problems of chain slacking and chain loosing problem while the dynamic events or endurance race is going on. This is because excessive long transmission line (distance between the two sprockets) (Figure 10).

The length between the two sprockets should be optimised, which helps in reducing chain length as well as it helps in increasing transmission efficiency.

In the same way use of thermoplastic material sprocket/alloy, steel sprocket can save weight.

Even if the composites are not available, you can drill some material out from sprocket by making them thin (reducing the module) and reducing the weight (Figure 11).

In addition, many times we try out drilling holes on the face of the sprockets; this is actually a good idea. However, the holes should be drilled considering the balancing of the sprockets. Remember this is a rotating member and needs perfect dynamic balancing.

Use of belt drives: Conventionally it is of two types- the flat belt drive and the V- belt drive. V- belts can be effectively used for afore mentioned purpose as it has superior transmission efficiency, negligible slip and can operate in any position with same efficiency (even if the belt is vertical) (Table 6 and Figure 12).

Comparison: Here, we can see for per meter length we save almost 0.4 kg. Advantages of belt-drives over chain drives are Weight saving- Belts are much lighter then metallic chains. One can save around 50% to 60% in the drive train department just by replacing chains by belts. And if the sprockets used are custom made by some

Citation: Tiwari A, Jaswal I, Das S, Singh A (2017) Design of Efficycle-Human Powered Light Weight Hybrid Tricycle with Inbuilt Rear Wheel Steering and Use of Universal Joint in Front Axle. Adv Automob Eng 6: 167. doi: 10.4172/2167-7670.1000167

light weight material such as aluminium, weight saving might go up to 65% to 75%. Noise and vibration levels- Given the smooth functioning of belts drives, it ensures quieter operation and drastically reduces the vibrations produced in the transmission components, ensuring longer life. Transmission efficiency- Transmission efficiency is in the range of 90% to 96%, which is at par with their chain drive counter parts. No-grease=less maintenance and its cleaner- Engineers should be lazy, that is how we innovate. If you are one of those lazy ones then this is good news and it saves your money or buying grease and cuts

Figure 9: Hollow shaft.

Figure 10: Hollow stepped shaft and solid stepped shaft.

Figure 11: Half shaft.

S. No.	Torsion load (Nm)	Strength (mpa)	Calculated dia. (mm)	Available size (mm)	Actual Fos	Weight (kg/m)
1	100	350	11.85	15	1.23	
2	100	350	OD-18	OD-22	1.56	1.38
			ID-16	ID-18		

Table 6: Torsion load on the shaft as 100 nm and shaft material strength as 350 mpa. Now calculate the shaft diameter.

Figure 12: Thin sprocket and pocket drilled sprocket.

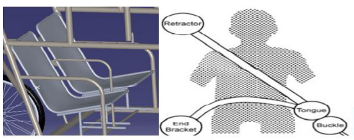

Figure 13: Design of seat.

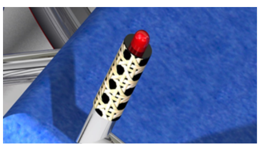

Figure 14: Kill switch.

the maintenance costs too! Less wear and tear=greater durability-Component wear specially that of chain and sprockets is a predominant factor in chain drives. In belt drive systems, however, it is negligible over longer periods of time that increases the durability of the drive train components. Overall operating costs-Belts drives cost lesser in longer run as compared to chain drives, given negligible maintenance costs involved. However, the installation costs can be more than that of chain drive. Unsprang mass reduction=stability - Roller chain suspended between the countershaft and rear sprockets has more wrap at the rear wheels and thus places more of its weight there thus increasing the unsprang mass. Belts however are lighter than chains and hence help reducing the unsprang mass.

Calculations:

Velocity ratio=$I=n_{1\div}n_2=Z_{1\div}Z_2$

Lengths of chain=n × p (no. of links=n).

$n=2(a \div p) + (T_2 + T_3) \div 2 + [(T_3 - T_2) \div 2\pi]^2 \times (p \div a)$

a=Distance of centre between axis of driving and driven shaft.

$T_{2=}$Smaller sprocket teeth's.

$T_{3=}$Larger sprocket.

Electrical specification of vehicle

The efficycle basically comprises of the following parts:

Energy storage - Battery bank of 48 V and 35Ah

Driving motor - PMDC of 370 watts, 1500 rpm, 48 V. Kill switch=the battery will be disconnected from the motor as soon as kill switch is passed and rendering the completely electric system dead.

Design of seat

From safety point of view design of seat is also very important part the vehicle. In effi-cycle side by side seating arrangements were provided. The seats have been properly designed in order to provide best possible comfort to the drivers. Seat belts have also been employed to provide safety to the drivers. In designing of seat there should be proper headrest, H- point should be 19", proper torso support, seat angle should be not less than 25^0, knee angle should be 67.328° and the most important part is that the legs of both the drivers can reach the pedals very comfortably and secondly the clearness of minimum 3" is maintained (Figure 13).

Safety features

There should be protection from the impacts due to the presence of shocks. Complete thigh and torso support to both the drivers. There should be kill switch on easy reach to both drivers. Provision of light accessories during fog in winters. Roll cage should be used for protection and to provide aerodynamic feature to our design. Safety of all the moving parts is provided regarding the protection of drivers and to the ones standing by Figure 14.

Ergonomics

Stability will be medium and high speed because of the low centre of gravity. Overall braking will be excellent due to two wheels in front. Do not pull the rider over the handlebars in severe is stops.

Conclusion

Human powered hybrid vehicle present the new milestone in the realm of '' Green technology". The effi-cycle has designed for the benefits of the humanity. It is an eco-friendly human powered vehicle with a electric drive system. Such a lightweight tricycles can be modified and can be used for transporting good and can even be used for disaster management. India being a load of multi lingual and multicultural festivals, such tricks becomes a useful element for carrying out cleaning and sanitations activities in public places during such festival.

References

1. SAE-NIS (2016) Effi-cycle. Rulebook.
2. Gaffney EF, Salinas AR (1997) Introduction to formula SAE® suspension and frame design. SAE Technical Paper.
3. Sithananum C, Leelaphongrasut C, Baitiang C, Rnugpipaphol N, Noomwongs N, et al. (2011) SAE student Formula Space Frame Design and Fabrication. The second TSME International Conference on Mechanical Engineering, Krabi. Thailand.
4. AK Steel Holding (2016) Product data sheet 304/304L Stainless steel, AK steel Holdings, Ohio, USA.
5. Depenyou F, Doubla A, Laminsi S, Moussa D, Brisset JL, et al. (2008) Corrosion resistance of AISI 1018 carbon steel in NaCl solution by plasma-chemical formation of a barrier layer. Corros Sci 50: 1422-32.
6. Jazar RN (2008) Vehicle dynamics-Theory and application. Chapter 7: Steering dynamics. Springer, Berlin.