Design of Efficycle - Human Powered Hybrid Tricycle with inbuilt Programmable Position Control Gear Shifter using Stepper Motor

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Abstract- **This paper provides in-detail description of the design considerations, analysis and mathematical data involved in the design of a hybrid tri-cycle. The tri-cycle is powered by two humans simultaneously and also by a 373 Watt Geared PMDC. It is an eco friendly human powered vehicle with a compounded electric drive system. The focus has been laid on the simplicity of design, high performance, easy maintenance and safety at very reasonable prices .Most of the components have been chosen keeping in mind the easy availability and reliability. According to recognition of customer's need we are going to design a vehicle which is ergonomic, aerodynamic, highly engineered and easily manufactured. The tadpole type of trike has two wheels in the front and one wheel in the rear. A Tadpole trike's front-end exhibits less acceleration than the rear end when turning. This allows the trike to negotiate corners at great speed and stability. The concept used in the innovation is programmable position control of gear shifter using stepper motors. Position of motors is controlled with respect to speed by programming which in turn controls the position of gear shifter. This technology is used in robotics & position controlling of robotic arms. It has got a wide scope in automotive industry as it reduces the efforts of driver & provides more automatic control of the vehicle. Hence it makes the vehicle more efficient. Human powered hybrid vehicle present the new milestone in the realm of "Green Technology".**

Keywords— **Efficycle, pollution, hybrid, mechanical, green Technology**

I. INTRODUCTION

With conventional fossil fuel consuming rides posing a threat to the existence of life on earth, it is high time to develop alternate and greener modes of transportation for a sustainable future. The Effi-cycle was designed to be an electrically assisted, dual-human powered tricycle. Different topologies were analyzed and based on the factors such as turning radius, stability, handling and ease of manoeuvring, tadpole design was adopted with 2 wheels at the front and one at the back. The vehicle has an innovative tadpole design which is ergonomic, highly engineered and easy to manufacture. The design has been laid on the simplicity in design, high performance, easy maintenance and safety at very reasonable prices. The design was then simulated on system with the help of software namely solid works. The analysis was done on Ansys software for the tests like Front Impact, Side Impact, Rear Impact & Rollover Impact tests.

II. DESIGN METHODOLOGIES

A. Frame Configuration, Design & Material

A tadpole trike's front-end exhibits less acceleration than the rear end when turning. This allows the trike to negotiate corners at great speed and stability. Two wheels in front offer

excellent overall braking and overall excellent handling. The FEM analysis of the complete frame was carried out with help of analysis software (ANSYS 14.0). Material selection is a step in the process of designing any physical object. We have chosen steel "ST 52.3" over AISI 1018 because it is too light in weight, highly ductile and having high strength. It can be easily welded and having ability to harden in commercial applications.

Material	Yield strength	Outer diameter	Thickness	carbon percentage
ST 52.3	*450 MPa*	*1.25"*	*1.63 mm*	*0.21%*

Table I: Material Properties of ST52.3

B. Frame Configuration, Design & Material

The quality of the steering system and geometry also dictates the performance of the trike. The vehicle is provided with fulcrum link mechanism. This system gives the turning radius of 2.72m.
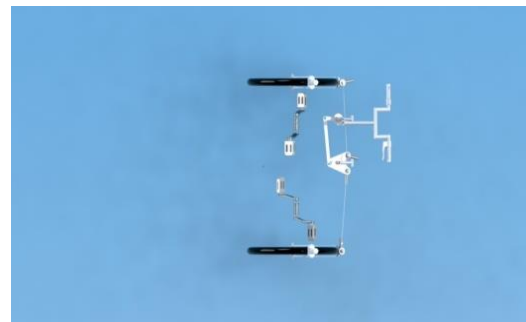

Fig1: Steering System of Trike

Steering System	
Steering mechanism	*Fulcrum Link mechanism*
Control	*T-bar*
Turning radius	*2.72m*
Fork length	*160mm*
Caster head Angle	*19°*
Steer angle	*22.44°*
Steer ratio	*1:1*

Table II: Specification of Steering Geometry

C. Drive Train

The vehicle is powered by both human and electric power. The drivers can power the vehicle using the two crank wheels in the front portion of the chassis. These two crank wheels deliver the power to the idler axle mounted in the rear part which ultimately drives the rear wheel through freewheels. The overall manual transmission has a 18 Speed Gear assembly.

Velocity ratio: $i = n_1/n_2 = z_1/z_2$

Length of chain: $n*p$ (n=no: of links)

$n = 2(a/p) + (T_2'+T_3)/2 + [(T_3-T_2')/2\pi]^2 * (p/a)$

a= Distance of centre between axis of driving & driven shaft

T_2'- Smaller sprocket teeth's

T_3 - Larger sprocket

8.	34	26	1.307	117.63	14.633
9.	34	21	1.619	145.71	18.126
10.	34	18	1.888	169.92	21.138
11.	34	16	2.125	191.25	23.792
12.	34	14	2.428	218.52	27.185
13.	42	28	1.500	135.00	16.794
14.	42	26	1.615	145.35	18.081
15.	42	21	2.000	180.00	22.392
16.	42	18	2.333	209.97	26.121
17.	42	16	2.625	236.25	29.391
18.	42	14	3.000	270.00	33.589

Table III: Drive Train Transmission Data

Fig2: Drive Train Powered by Human Drive
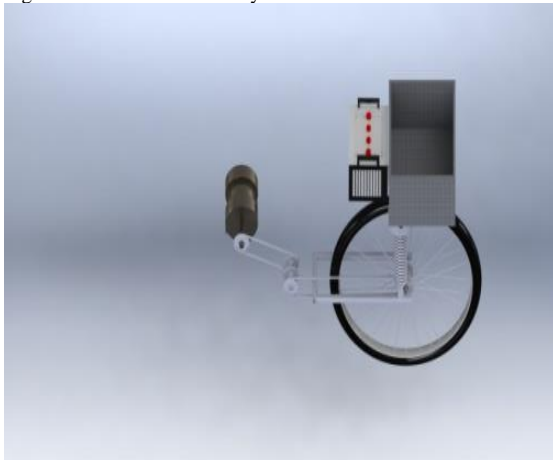
Fig3 :Drive Train Powered by Electrical Drive

MOTOR	
Motor type	Geared PMDC
Power	373 watt
Voltage	24 volts
Max current	20amp
Max Output RPM	100
Max torque	350N-m
Max Armature rpm	1500
Weight	11 kg

BATTERY	
Type	Lead acid
Output Voltage	48 volts
Discharge Rate	30 amp-hr
Battery run time	2.5 hr
Weight	15kg

Table IV: Specification of Electrically drive power train

D. Suspension Systemn

For road holding and braking "Telescopic fork suspension" is used at front and "progressively wound coil suspension" is used at rear in the vehicle .Front suspension is selected because Forks help in better handlings and due to air inside the system , front suspension is light in weight and its design is simple .   Progressively wound coil suspension is selected as Rear suspension because It has the capability to bear weight and a road holding capacity.

S.No.	T_2'	T_3	V.R=(T_2'/T_3)	N_3=V.R*N_2	SPEED (Km/hr)
1.	24	28	0.857	77.13	9.595
2.	24	26	0.923	83.07	10.334
3.	24	21	1.142	102.78	12.786
4.	24	18	1.333	119.97	14.924
5.	24	16	1.500	135.00	16.794
6.	24	14	1.714	154.26	19.190
7.	34	28	1.214	109.26	13.591

Calculations of suspension:

For rear suspension system:

Length of spring = solid length + max

Compression + clearance

= (n+3) d + δmax + 0.15 δmax

= (14+3)10 + 100 + 0.15 * 100

= 285 mm

Pitch of coil = (Lf - Ls) / n + d

Table 5: Specification of Suspension System

= (285 - 170) / 16 + 10   = 17.18

Natural frequency	3 Hz
Spring stiffness	8658 N/m
Spring index	5
Mean coil diameter	50mm

Table V: Specification of Suspension System

E. Brakes

We are using mechanical disc brakes, which are mounted on all three wheels. Disc brakes are used because of its High heat dissipation capability, high torque transmitting capacity; good efficiently in wet weather conditions (because centrifugal force tends to fling water off the brake disc and keeps it dry). It does not have Self locking capability. As alternative, Hydraulic drum brake could be used but the vehicle is not a high power vehicle also it is not good in wet weather. Non hydraulic shoe brakes are not used because the shoe gets rubbed so it is not so efficient.

Fig4: Disc Brake System

Max velocity of vehicle	35 km/hr	Internal diameter of disc	120 mm
Coefficient of friction	0.4	External diameter of disc	140 mm
Braking efficiency	50%	Thickness	3 mm
Stopping distance	4.8 m	Brake torque	135N-m
Stopping time	3.36 sec	Braking force	409.99N

Table VI: Specification of Disc Braking System

F. Wheels & Tyres

Tires provide contact between the road and the vehicle. Road shocks are first absorbed by tires and then transmitted to suspension. The tyres are chosen in such a way that it must provide traction in all kind if surfaces without slipping. Wheels which is responsible for the steering responsiveness and effortless steering, targeted top speed can be achieved without any compromise in the COG of the trike. So the size of both the wheels are 26" which also fulfil the need of necessary ground clearance. 26-inch wheels offer excellent rolling resistance and made the ride significantly smoother.

G. Seating arrangement, design and feature:

In the vehicle side by side seating arrangement is provided because it is comfortable, reduces wheelbase and it provides stability to the vehicle. Fiber seats covered by foam will be clamped by nut bolts

H. Safety provisions for the safety of vehicle, its occupants

Three point harness, helmets, and elbow and knee guards, safety glasses for eye protection for rider's safety.
   a) The placement of key controls in reach of both the drivers easily.
   b) Common person, physically handicapped or old age person of the community dependent on others for their mobility can also use these vehicles.
   c) Vehicle is free from any kind of sharp edges that can harm rider or crew members.
   d) Indicators ensure safety of both riders and bystanders and pedestrians

I. Other features
   a) Digital speedometer
   b) Automatic gear shifter

J. Ergonomic Features
   a) More stable at medium and high speeds because of the low center of gravity.
   b) Two wheels in front offer excellent overall braking.
   c) Three point harness, helmets, and elbow and knee guards, safety glasses for eye protection for rider's safety.
   d) Do not pull the rider over the handle bars in severe stops

K. Programmable Position Control of gear shifter using Stepper motors

The concept used in the innovation is programmable position control of gear shifter using stepper motors. Position of motors is controlled w.r.t. speed by programming which in turn controls the position of gear shifter. This technology is used in robotics & position controlling of robotic arms. It has got a wide scope in automotive industry as it reduces the efforts of driver & provides more automatic control of the vehicle. Hence it makes the vehicle more efficient.

Gear No.	Speed	Motor 1 position(3Speed in degrees)	Motor 2 positon(6Speed) In degrees
1	9.595	0	0
2	10.334	0	10
3	12.786	0	20
4	13.591	10	0
5	14.633	10	10
6	14.924	0	30
7	16.794	0	40
8	16.794	20	0
9	18.081	20	10
10	18.126	10	20
11	19.19	0	50

12	21.13	10	30
13	23.392	20	20
14	23.792	10	40
15	26.121	20	30
16	27.185	10	50
17	29.391	20	40
18	33.589	20	50

Table VII: Specification of Programmable Position Control Gear Shifter

L. Technical specification of human powered hybrid tricycle

Vehicle make model	Values	Vehicle make model	Values
Wheel base	65"	Innovation	Automatic Gear Shifter
Wheel track	43"		
Vehicle make model	Values	Vehicle make model	Values
Overall length	94.16"	Turning radius	2.72m
Overall width	46"	Battery	Lead acid
Overall height	41.81"	Tyre size	26''
Roll cage	Tubular frame structure	Brake	Disk Brake
Roll cage weight	18 kg	Front suspension	Fork
C.G. height	25.33"	Overall weight	200kg
Max. speed	35 kmph	Ground clearance	8.054"
Material	ST 52.3 with 1.25" OD and 1.63mm thickness	Rear Suspension	Progressively wound coil spring suspension

Table VIII: Technical Specification of human powered hybrid tricycle

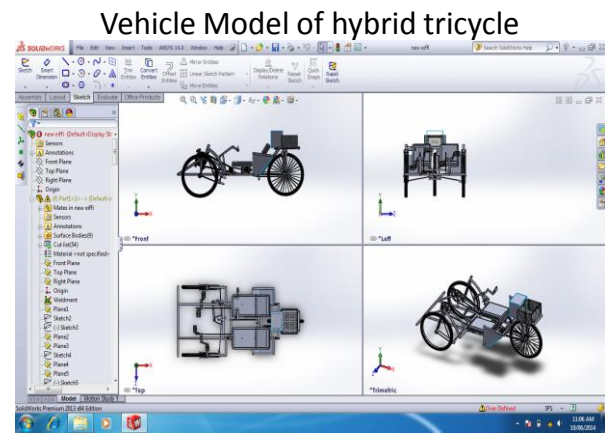## Vehicle Model of hybrid tricycle

Fig 5: Modelling of Hybrid Tricycle

## III. RESULTS & DISCUSSION OF STRUCTURE ANALYSIS

An impact test was done using ANSYS12.0 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. The weights were applied at respective seating positions. Similarly, load was applied at specific locations allotted for battery case, electrical components etc. Results obtained proved the chassis to be strong enough for the purpose. A safety factor of 1.4 was obtained, maximum deformation was obtained on roll over 13.56 mm & Maximum equivalent Stress was obtained on rollover 433.33 MPa

Technical Parameter	Front	Rear	Side
Velocity (Km/h)	35	35	30
Velocity (m/s)	9.7222	9.7222	8.3333
Time(s)	3	3	3
Force (N)	6481.481	6481.481	5555.55

Impact Mode	Max. Equivalent Stress (MPa)	Deformation (mm)	F.O.S.
Front	321.22	1.79	1.4009
Side	427.8	5.23	1.0518
Rear	384.49	12.08	1.17
Roll over	433.33	13.56	1.0384

Table IX: Impact Assessment Data by using Ansys Software12

FINITE ELEMENT ANALYSIS (R AND S)
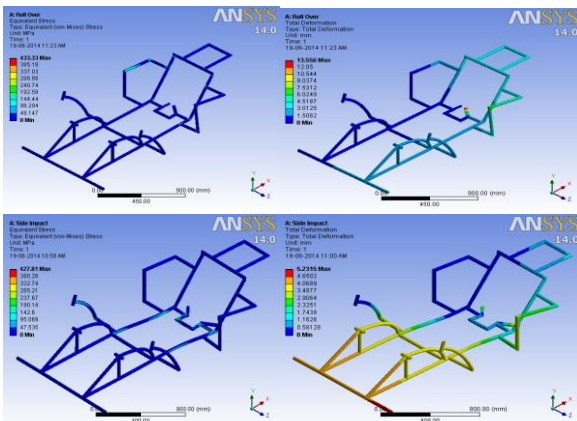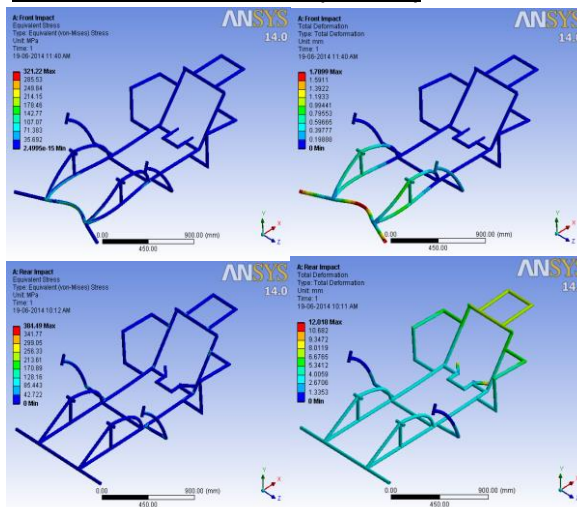

FINITE ELEMENT ANALYSIS (F AND R)

Fig 6: Finite Element Analysis of Chassis

IV. CONCLUSION

The Efficycle was designed for the benefit of the humanity. It is an eco friendly human powered vehicle with a compounded electric drive system. The focus has been laid on the simplicity of design, high performance, easy maintenance and safety at very reasonable prices . The concept used in the innovation is programmable position control of gear shifter using stepper motors. Position of motors is controlled with respect to speed by programming which in turn controls the position of gear shifter. This technology is used in robotics & position controlling of robotic arms. It has got a wide scope in automotive industry as it reduces the efforts of driver & provides more automatic control of the vehicle. Hence it makes the vehicle more efficient. Human powered hybrid vehicle present the new milestone in the realm of "Green Technology".

V. REFERENCES

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