A DYNAMIC MODEL AND ANALYSIS OF INNOVATIVE E-BIKE

Aman sharma[1], Manish K Sah[2], Abhishek kumar[3], Umesh K Yadav[4]

[1,2,3]Student Dept. of mechanical Engineering, MGM College of Engineering & Technology Noida, Uttar Pradesh, India
[4]Asst Professor Dept. of mechanical Engineering, MGM College of Engineering & Technology Noida, Uttar Pradesh, India.

---***---

ABSTRACT-*The E- Bike model has an innovative and significant number of new features that improve the user experience through an adequate position of motor. The addition of new functions such as the spring shock absorber, mosfet circuit and shimano 7 gear drives mechanism used. The design and analysis of new type of e-bike frame which is look alike of mountaineer bike frame with consideration of an aerodynamic effect. We have design a 4-bar linkage spring mechanism with attached the rear frame for absorbing the shock and vibrations. The E-bike which is able to recharge itself during travelling or riding it, so that the number of motor vehicle on the road get decreased hence the dependency of Non-renewable fuel energy resources also get decreased. The problem which have been arising like air pollution and greenhouse effect get down which will improve the health condition of people. Also provide for safe and convenient access to schools, parks, natural areas and community facilities.*

Keywords: Motor drive, MOSFET, Shimano7, Mobility, Linkage spring mechanism

1. INTRODUCTION

The e-bike can be effective to reduce the usage of cars, motor bike because people try to move toward 'clean' the global environment effects. Additionally, e-bike resolve many people give for not cycling like hills, long route, and physical strenuousness. The e-bike which is design an inexpensive and auto rechargeable electric bike. E-bike solve the problem, which is facing the cycling on long routes, hills and physical level. Electric bike is powered by a rechargeable battery which gives rider an extra boost of power and less cycling experience. E-bike as compare to normal bike it has got an electric motor to assist or replace your peddling effort and motor can be activated by pressing button with activating the accelerator. Automobile Industry in data processing and cloud connectivity technology that are fundamental in establishing to connected vehicle system. We are used to develop models using sensors like speedometer, odometer and accelerometer whose data is displayed in the database file. Typical parts of E-bike are DC Motor with sprocket drive mechanism, Throttle (Accelerator), Battery Storage, Chain Drive, sprocket drive, four bar linkage spring mechanism, development of aerodynamic Frame. According to their functions of e-bike, electric bicycle has two parts, first is power on demand and second is pedal assist. The motor is activated by a throttle with as per power-on-demand. By pedalling electric motor can be controlled with pedal-assist. The charging mechanism of this bike is done with dynamo and mosfet circuit. E-bike will be reduce traffics, air pollution, greenhouse effect and parking problem in the fast growing population.

LITERATURE REVIEW

In this research paper Chang-hua *et.al* [1] done a bi-directional converter applied in electric bike. The main structure is a cascade buck-boost converter, which transfers the energy stored in battery for driving motor, and can recycle the energy resulted from the back electromotive force to charge battery by changing the operation mode. An e-bike design Meireles *et.al* [2] The fourth-generation bike-sharing services. Bicycle sharing systems have proven their value towards urban sustainable mobility. Appropriate design of bikes for this application is fundamental for bike-sharing systems viability. Malan *et.al* [3] the design and development of a prototype super-capacitor powered electric bicycle (e-bike) is presented. The design of bicycles is concentrated Zhang *et.al* [4] on mechanism and auto appearance design, however few on matches between the bike and the rider. Since unreasonable human-bike relationship leads to both riders' worn-out joints and muscle injuries, the design of bicycles should focus on the matching. In order to find the best position of human-bike system, simulation experiments on riding comfort under different riding postures are done with the life mode software employed to facilitate the cycling process as well as to obtain the best position and the size function of it. Hatwar *et.al* [5] design electric bike using battery and super capacitor, the market of electric bikes, scooters and bicycles is growing. There are numerous brands of e-bike emerging locally. All incorporate a rear wheel bldc (brushless dc) hub motor; lead acid battery pack, a light weight chassis, and a controller. The vehicle achieves average speed of 30-50km/hr, range of 70km charge. The other drawback is the long charging time of 6-8 hrs and short lifespan of battery pack i.e. around 2 years.Abagnale *et.al* [6] model is based on the longitudinal vehicle dynamic and the electrical motor. Kunjan Shinde [7] design of electric bike and sprocket or chain mechanism for electric bike. Most number of people from the list have been those which think riding a cycle is equivalent to providing extra effort for cycling. Mei *et.al* [8] analysed e-bike usage and battery charging data from the bike field trial. By design, e-bikes were meant to be used for commuting, potentially replacing the use of cars or public transit. Zingnoli *et.al* [9] to control the strategies of electric-bikes do not take the physiological characteristics e.g. aerobic fitness status of the rider into account. By means of mathematical modelling done. Katoch *et.al* [10] developed the implementation of smart electric-bike eco-friendly with the using hub motor with self-recharging mechanism using the hybrid system and maximum current drawn from the cycle at two stages.

2. DESIGN OF ELECTRIC BIKE

2.1 ANALYSIS OF ELECTRIC BIKE

For Pedal calculation
Pedal power = pedal force * pedal speed in m/s
=25 kg * 9.8 m/s^2 * 1 m/s
= 245 watt
Taking the rider in travelling cycle at 15 km/h
15000m/60 min = 250 m/min
Wheel rotation/Rpm = distance in 1 min/wheel perimeter
= 250/ 2.07345
= 120.57 rpm
Wheel Rpm when pedalling at 15 km/h is 120.57 rpm.
Teeth on pedal (T_1) = 54
Teeth of sprocket at wheel (T_2) = 14
Wheel rpm (N_2) = 120.57 rpm
From equation, $N_1 T_1 = N_2 T_2$
N_1 = (120.57* 14) / 54
N_1 = 31.2588 rpm
Pedal rpm (N_1) = 31.26 rpm
Hence, torque (T) = P*60/2πN
T = (245*60) / (2*3.14*31.26)
T = 74880 N-mm.
Reduction at chain drive
= T_1/T_2 = 54/14 = 3.857
Torque at wheel shaft = T*R
= 74880* 3.857 = 288814.076 N-mm
Here we have used DC Gear motor with 250 Watt Power and 270 Rpm. The motor runs on 24 Volts and 14 Amps Power source. This motor can reach a peak current during starting equal to 15 Amps.
P = 2 x 3.14 x N x T /60
250 = 2 x 3.14 x 270 x T /60
Speed of wheel shaft = 270 /3.82 = 70.68rpm

2.2 Analysis of Shaft

Torque at wheel shaft T = 288814.076 N mm
T=3.14xσ_s x d^3/16
σ_s = 288814.076 * 16 / 3.14*24^3
σ_s = 106.40 N/mm^2

Following Stresses are taken in consideration while designing the shaft:
Material = C 45 (mild steel)
σ_{ut} = 320 N/mm2 ------------ PSG design data book.
Factor of safety = 1.4
$\sigma_t = \sigma_b = \sigma_{ut}$ / fos
= 320/1.4= 228.57 N/mm^2
σ_s = 0.5 σ_t
= 0.5 x 228.57
= 114.285 N/mm^2
σ_s is less then allowable so our shaft design is safe.

2.3 Analysis of sprocket and chain

We have known that,
Transmission ratio = Z2 / Z1 = 54/14 = 3.82
For the above transmission ratio number of teeth on pinion and the number of teeth sprocket is in the range of 21 to 10, so we have to select number of teeth on pinion sprocket as 14 teeth.
So, Z1 = 14 teeth

2.4 Selection of pitch of sprocket

The pitch is decided on the basis of RPM of sprocket. RPM of pinion sprocket is variable in normal condition it is = 270 Rpm For this rpm value we select pitch of sprocket as 6.35mm from table. P = 6.35mm

2.5 Analysis of minimum center distance between sprocket

The transmission ratio = Z2 / Z1 = 54/14 = 3.82 (which is less than 7)
Dia. of small sprocket,
Periphery = π × dia. Of sprocket
14 × 6.25*2 = π × D_1
D_1 = **53.50 mm**
Dia. of big sprocket,
Periphery = π × dia. Of sprocket
54 × 6.25 = π × D_2
D_2 = **107.48 mm**
So from table, referred from PSG Design Data book.

The minimum center distance between the two sprocket

= C^I + (80 to 150 mm)
Where,
C^I = (Dc1 + Dc2)/2
C^I= (54 + 107.48)/2
C^I = 80.74 mm
Minimum Centre Distance = 80.74 + (30 to 150 mm)
Minimum Centre Distance = 230 mm.
Maximum Centre Distance = 2*230 = 460 mm

2.6 Maximum tension on chain.

Maximum torque on shaft = T_{max} = T = 288814.076 N-mm
Where,
T_1 = Tension in tight side
T_2 = Tension in slack side
O_1, O_2 = centre distance between two shaft
Sinα = (R_1 -R_2)/O1O2
Sinα = (115 - 54)/460
Sinα = 0.132
α = 7.62
Angle of contact between the front and rear sprocket.
θ = (180 –2α) X 3.14/180
θ = (180 –2*7.62) X 3.14/180
θ= 2.87 rad.
According to this relation,
$T1/T2 = e^{\mu\theta}$
$T1/T2 = e^{0.35 \times 2.87}$
T1 = 2.74*T2
We have,
T = (T1 – T2) X R
288814.076= (2.74* T2 – T2) X 115
T2 = 1443.34 N-mm
T1 = 3954.77 N-mm

2.7 Battery charging time.

Motor Rating
24*10.416 = 250 Watt
Battery Rating
24*14 = 336 Watt
As per value is 1 km travel will be cost up-to
1 km = 15 watt
So, full charge battery will run
Distance = 336/15 = 22.4 km.
Distance cover with full charge at any speed of 20 kmph on flat road is 22.4 km.
To charge the battery a dynamo of rotating 12 v .5 amp dynamo, if generally it will produce a 12*0.5 = 6 watt of power, at constant speed of 20 kmph running bicycle. So fully charge the battery we need to run the bicycle
Distance = 3.36/6 = 56 km.
We need to run the bicycle for 56 km at 20 kmph to fully charge the batter. But as per to the average running bicycle by a man is 7 to 10 kmph it will generate 2-3 watt, say 2.4 watt So that at the speed of 7 –10 kmph the distance that to be run by the person is:
Distance = 336/24 = 140km.

Speed

Taking 20 km/h travelling so the rotation of wheel
Wheel rotation = distance in minute/wheel perimeter
= (333.33)/ (π*0.66)
= 333.33/2.07345
= 160.76 Rpm
To travel 30 km in 1 hr so, Wheel rotation = distance in minute / wheel perimeter
= 500/2.03745 = 241.14 rpm.
But at 270 rpm the distance covered will be
270 = distance in mm/perimeter
270*2.07345 = distance in mm
Distance in mm =559.83 m/min
Distance in km hour = (559.83* 60)/1000
Distance = 33.58 km in one hour.

2.8 Motor sprocket v/s wheel sprocket

For the gear ratio
Wheel sprocket teeth =18
Motor sprocket teeth =9
Gear ratio =18/9 = 2:1
The rpm of motor at 270 only provide 270/2
= 135rpm at wheel
So, max rpm of motor the wheel rpm is 135.
Then, distance covered in 1 min = RPM * 2.07345
= 279.91 m/min. or. 279.91*60/1000 = 16.794 km/hr.
So, max speed is 16.79 km/hr on road.

Table 1.1 Dimension of E-bike

S.no	Part name	Dimension
1	Top Tube	L=650mm, ∠=15
2	Seat Tube	L=420mm
3	Down Tube	L=675mm, ∠=15 & 25
4	Head Tube	L=130mm
5	Seat Stay	L=360mm
6	Chain Stay	L=490mm
7	Min Center Distance b/w Two Shaft	230mm
8	Max Center Distance b/w Two Shaft	460mm
9	Distance Covered @20Km/Hr	22.4 Km

3. MODELLING OF E-BIKE

We have use the Solid-works and Q-CAD software for the modelling of e-bike. Q-CAD is a commercial computer-aided design and drafting software application. Q-CAD software which is used for 2D designing of various object like auto mobile and many other parts. Modelling of electric bike (affordable electric bike) was done by Q-CAD software considering the design value. The E-Bike modelling of various parts as per design which is given below.

3.1 Modelling of E-Bike frame

We have used the Solid-works software for the modelling of E-bike frame as shown in fig.1.1 Solid works software is a solid modelling CAD and CAE computer program software that runs on Microsoft window while it is widely used for product design and assembly. Solid works which is used for designing of various object like auto mobile and many other parts. Modelling of electric bike (affordable electric bike) was done by solid works software considering the design value which is include the front and rear frame.

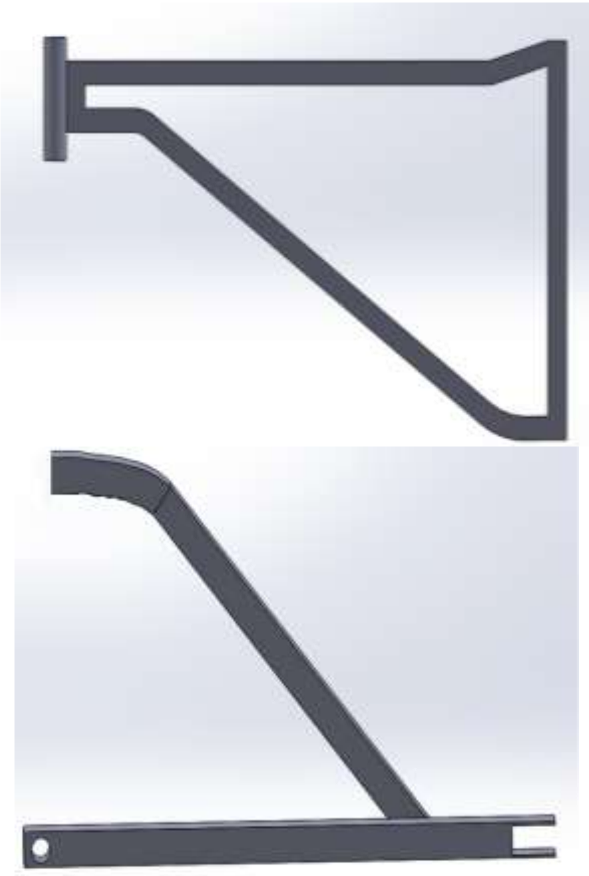


Fig.1.1 Modelling of E-Bike front and rear frame.

3.1.1 Modelling of top tube

The top tube or cross-bar connects the top of the head tube to the top of the seat tube shown in fig 1.2. Bend angle is 15 degree and length are 650 mm, the top tube is sloped downward toward the seat tube.

Fig 1.2 Top tube

3.1.2 Modelling of down tube

The down tube connects the head tube to the bottom bracket shell. Down tube is joined to the head tube and side tube and the length is 675 mm or bend angle is one side 25 degree and other side is 15 degree shown in fig 1.3.

Fig 1.3 Down tube

3.1.3 Modelling of seat tube

The seat tube contains the seat post of the bike, which connects to the saddle shown in fig 1.4. Seat tube is joined to the top tube and down tube, seat tube length is 420 mm and width is 25 mm. The saddle height is adjustable by changing how far the seat post is inserted into the seat tube.

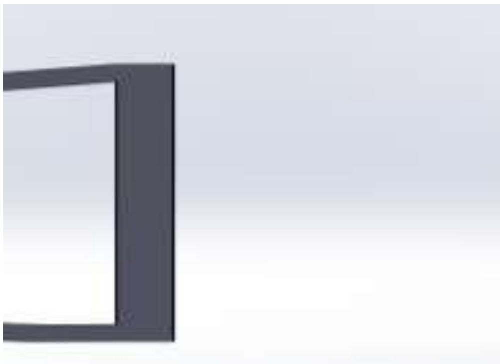


Fig 1.4 side tube

3.1.4 Head tube length

The head tube contains the headset, the bearings for the fork via its steered tube shown in fig 1.5. In an integrated headset, cartridge bearings interface directly with the surface on the inside of the head tube, on non-integrated headsets the bearings in a cartridge or not interface with "cups" pressed into the head tube.

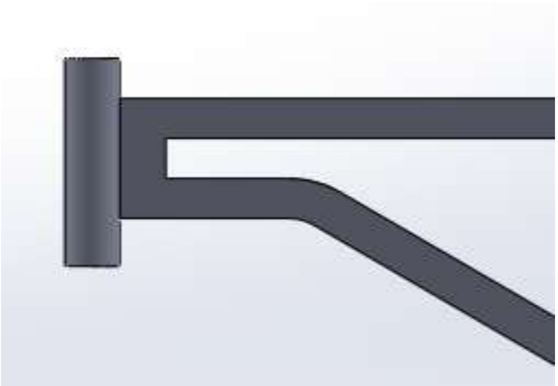


Fig 1.5 Head tube

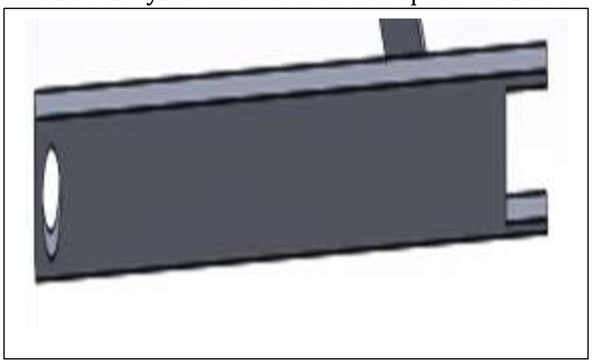
3.1.5 Chain Stays

The chain stays run parallel to the chain and connected the bottom bracket shell to the rear fork ends. We made shorter chain stay so that the bike will accelerate faster and be easier to ride uphill. According to the calculation the length of chain stay is 490 mm shown in fig 1.6.

Fig 1.6 Head tube

3.1.6 Seat Stays

The seat stays connected to the top of the seat tube or near the same point as the top tube and to the rear fork ends. It is also used for attaching the rear brake calliper. The distance between the chain stay to the seat tube is 340 mm.



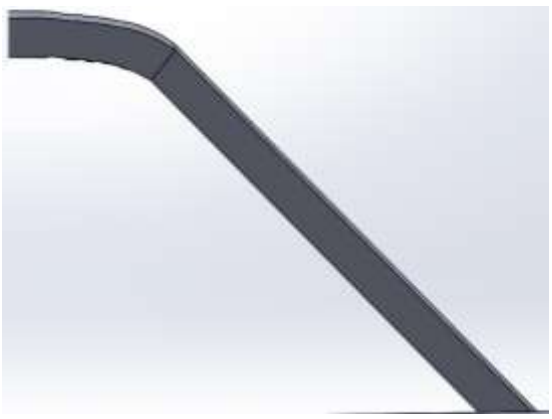


Fig 1.7 Seat stay

3.3 SPRING MECHANISM

It is a single pivot joint suspension design attached to the seat tube. It is typically of four bar linkages on to which the rear axle is attached. When there is a sudden shock or jerk load is transferred to the down tube of the front frame so that the Load is distribute as to wear the sudden load. This makes the rear frame free to move in up-down motion. The shocker spring length 185 mm and the distance between the hinge point is 90 mm. The max deflection/compression of the spring is 6.45 mm. By fixing that position as shown in the fig 1.8. The jerk load very effectively transfers by the hinge link to the shock absorber spring.

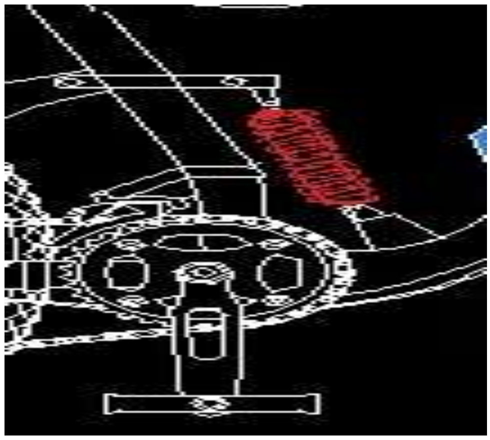


Fig.1.8 Linkage spring mechanism

3.4 SPROCKET MECHANISM

We have used the two-side sprocket mechanism in rear wheel. One side is gear drive system and second side are normal sprocket system which is connected to the motor sprocket because motor sprocket mechanism is chain transfers that rotation to the rear sprocket, which turns the rear wheel, and the bicycle moves forward. When you turn the pedals, the front sprocket turns. The chain transfers that rotation to the rear sprocket, which turns the rear wheel, and the bicycle moves forward.

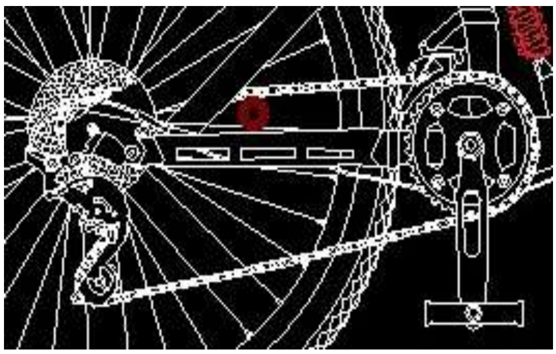


Fig. 1.9 Sprocket with shimano 7 gear drive mechanism

Fig. 1.10 Modelling of E-Bike

3.5 ACCESSORIES PART OF E-BIKE

The Electric bike consists of following components viz., DC motor, Frame, Platform, Battery, Drive etc. The detail parts with specification and quantity are given in table 1.2.

Table 1.2 parts of E-bike

S. No	Part	Quantity	Specification
1	D.C motor	1	Power 250 W RPM 270, Air Cooled, 14Amp 24v
2	Brakes	4	2 Sets power pads
3	Battery	2	12v 7amp Lithium ion
4	Alloys wheels	2	Wheel dia. 26inch Width 1.95 inch
5	Gears	1	7 Speed gear shimano for easy shifting
6	Frame	1	Made with mild steel, light weight and good durability.
7	Speedometer	1	Magnetic attached reader for accurate speed reading.
8	Charger	1	1.8amp 24v Portable.
9	Ignition switch	1	To activate the main electrical system for the vehicles.
10	Charging port	1	To recharge the battery easily. 3 pin Eu-plug.
11	Head lamp	1	Attached to the front portion of the vehicle to illuminate the road. IPX6 rated water proof.
12	Hand accelerator	1	Control unit of a vehicle that used to increase and decrease speed. 3 Wire Throttle For 12V-48V.
13	Controller	1	Converts input power of battery into the desired power for the different accessories.
14	Horn	1	Low sound horn 6v.
15	Suspension	2	Absorbing the shocks from the uneven road. Primary suspension dual type (oil) Secondary suspension (spring).
16	Mud guard	1 set	To stop mud, water and gravel.

4. RESULTS & DISCUSSION

1 Design of Frame

The structure of E bike is made of hollow square rectangular pipe. E bike is differ from the other bike because its design is like a aerodynamic which provide more speed with reducing the air resistance while driving. The rear part of E bike is connected with hinge point so that the jerk is transferred through seat stay to shocker.

2 Shock Absorbing spring

Our electric bike can be divided into two part because we had given a hinge connectivity. A four bar linkage suspension on the rear axle is attached when there is sudden load or Shock is transferred to the spring shocker very effectively shown in fig 1.10.

3. Battery charging mechanism

For self-charging the batteries we have used the dynamo with mosfet circuit for the charging while pedalling. The Operating cost per/ km is very less with the help of recharging system. The charging system has fewer components thus require less maintenance. The distance cover with full charge battery at speed of 20 kmph on flat road is 22.4 km.

Conclusion

We have design and analysis of new type of e-bike frame which look alike of mountaineer bike with consideration of an aerodynamic effect. E-bike is a modification of the current using bicycle. E-bike is powered with electric energy. E-bike can be used by any age of people for shorter distance and it is cheap and affordable bike as a new way of transportation with the uses of more Non-renewable fuel, it is required to use an alternate way of saving the non-renewable fuel by introducing bike does not require any non-renewable source of energy and most important function of this e-bike. It is eco-friendly, noiseless, pollution free, and provide comfortable in ride. Based on detailed study the following conclusions have been drawn:

1-The objective of a comfortable, compact, high speed and efficient bicycle can be achieved by this dynamic model.
2-Dynamic model of e bike with detail analysis of different parts done.
3. It will reduce traffic and parking problems in this fast growing population.

REFERENCES

1. Chang-Hua, Lin Hom-WeiLiu, Chien-Ming wang "A design and implementation of a bi-directional converter applied in electric bike with charging feature" Proceedings of the 5th conference IEEE (2010) ISSN 2156-2318.
2. Ricardo Meireles, Jose Silva, Alexandre Teixeira, Bernardo Ribeiro "An E-bike design for the fourth-generation bike sharing service" World Electric Vehicle Journal (2013)Vol. 6 - ISSN 2032-6653.
3. Keagan Malan , Michael Coutlakis , James Braid "Design and development of a prototype super-capacitor powered electric bicycle" IEEE International Energy Conference (2014) ISBN 978-1-4799-2449-3.
4. Long Zhang, Zhongxia Xiang, Huan Luo, Guan Tian "Test verification and design of the bicycle frame parameters" Journal of Mechanical Engineering CJME(2015) Corpus ID 56228079.
5.Nikhil Hatwar, Anurag Bisen, Haren Dodke, Akshay Junghare, Milind Khanapurkar "The design approach for electric bikes using battery and super capacitor, for performance improvement" IEEE Conference (ITSC 2013) ISSN 2153-0017.
6. C. Abagnalea, M. Cardoneb, P. Iodicea, R. Marialtoc, S. Stranoa, M. Terzoa, G. Vorraro "Design and development of an innovative e-bike" Energy Procedia (2016) 101 774 – 781.
7. Kunjan shinde "Literature Review on electric bike" IJRMET (2017) vol.7 ISSN 2249-5762.
8. Huan Mei, Yang xiaobao, jia bin "Crossing realibility of electric bike riders at Urban intersections" Green transportation system and safety, (2013)ISSN 1024-123X .
9. Andrea Zignoli, Lorenzo Beatrici , Francesco Biral "Analysis of assistive strategies for electric bikes that include riders physiological characteristics" ASME-85288, (2018) V003T01A012.
10. Sunikshita Katoch, Rahul, Ranjit Kumar Bindal"Design and implementation of smart electric bike eco-friendly, IJITEE (2019) Vol.8 ISSN 2278-3075.