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Design calculations and selection for Power train of high utility Pedelec (Motor and Controller)

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ABSTRACT

Electricity has always played a crucial role in the welfare of mankind, it's the most reliable and efficient form of energy with tremendously lower active transportation cost, still among all these the most undeniable fact that it's the most environment friendly form of energy (when produced with the help of renewable resources of energy). Right now, we use electricity for commercial, industrial as well as domestic purposes. However, the use of electricity for transportation purpose is comparatively low; the constantly deteriorating state of our planet has left us with no option but to switch towards electric transportation. So we need to inculcate electric transport not only in vehicles of heavy consumption (traction), but also vehicles for personal use. In this paper, we have tried to make such type of a transportation alternative, which has the potential to replace IC engine, operated two wheelers. We have included the design as well as proper suitable power trains available in market.

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I. INTRODUCTION

The very first motorized bicycle that is believed to be the predecessor of the modern day e-bike was developed by two inventors who used a steam engine along with an internal combustion engine for it. This happened sometime around 1870. A few years later, during the end of 1895, Ogden Bolton Jr. was issued the first patent for an e-bike. However, his patent was regarding the improvements for the bike and did not consist of any new invention as such. Therefore, it is largely possible that it wasn't his idea originally.

The next big upgrade of the e-bike came in 1897 when Hosea W. Libbey used two motors and batteries rather than one each while designing it. It was called the 'double electric motor'. In 1898, Mathew J. Steffens patented an e-bike that had a driving belt on the wheel's outer edge. A US patent was granted to John Schnepf in 1899 for a bike that was 'roller wheel' style bike driven rear-wheel. 50 years after this, Jesse D. Tucker was issued a patent. He developed a motor that allowed one to freewheel and also used internal gearing systems. The rider now had the option to choose whether he wanted to use the pedals together with the electric motor as a combination or not.

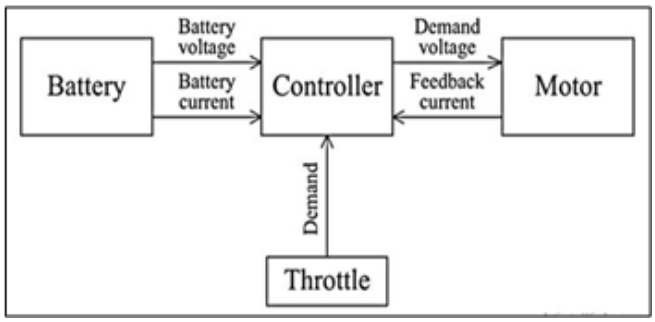
II. LITERATURE REVIEW

As mentioned earlier, Research in electric bicycles has been going on for a very long time now right from 1870. But taking our current idea of e bicycles into consideration

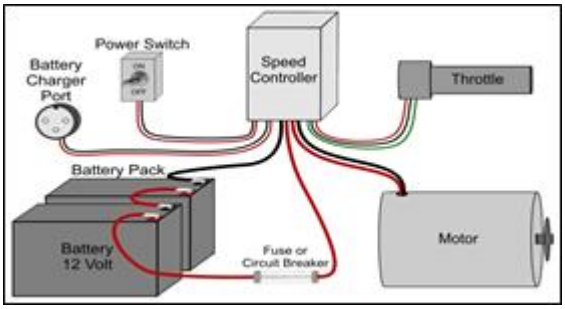
Investigation of the influence of controller, battery, and motor parameters on the different drive parameters such as motor inductance and resistance. Thereby, modifications taking our projected use in consideration and design such a combination of driving components to achieve higher efficiency with optimum power usage by selection of motor, controller and other supportive components.

Modern problems require modern solutions, one such widely recognized solution is replacing these fossil fuel consuming IC engines with electric motors. This at current state is mostly used in public transport whereas private transport has heavy dependence on fossil fuels. so, need of time is to revolutionize private transport as well and with this in mind this project tries to design an affordable and efficient two wheeler alternative by making hybrid between the traditional bicycle and motorbike.

III. BLOCK DIAGRAM



a) Block diagram



b) Schematic diagram

a) b) Fig: Power train of electric bicycle

IV. LIST OF COMPONENTS

The power train of utility mainly consist of three parts in it namely Motor, Controller and throttle.

1. Motor: Motor is the main component of power train. It is the heart of power train because it drives the utility as per requirement.
2. Controller: It is used to control the mechanism between the motor and battery as the supply provide to the motor through the controller, Also it has many features.
   It has over voltage protection, low voltage protection, over temperature protection, over current protection for battery
   and it also have brake protection.
3. Throttle: The power send to the drive is proportional to the throttle position. The controller recognizes the throttle position and according to that the power is send to the motor.
4. Peddle assist mechanism: It is the mechanism which gives us the flexible operating with human physical inputs. It senses the human inputs and according to that it will co- ordinate with controller.

V. CALCULATIONS

The breakdown of Gross Vehicular Weight of the electric Bicycle is as follows:

Sr.No	**Weight Objective**	**Quantity (in Kg)**
1	Complete cycle frame	10
2	Motor & Gear assembly	7
3	Battery	7
4	Controller	1
5	Human	80
6	Cargo	15
	Total Bicycle Weight	**120**

Other important electric bicycle considerations for calculation of motor torque & power are as follows:

Sr.No	Criteria	Num. Value	Unit
1	Target Speed	25	Km/hr
2	Inclination at target speed	o	degree
3	Operating range	35	Km

Torque Calculation:

The Torque of an electric motor is its driving force with which it can overcome the total resistive mechanical load acting against the rotational direction of motor shaft.

This total resistive mechanical load is denoted by 'F_{total}'

Now, F_{total} for an electric bicycle specifically can be calculated by summation of individually acting forces as follows:

Rolling resistance (F_r):

$Fr = c_{rr} * m * a$

Where, c_{rr} = Coefficient of rolling resistance = 0.020

m = Mass of the Vehicle (in kg) = 120 kg

a = Acceleration due to gravity = 9.81 m/s^2

Thus, $F_r = 0.020 * 120 * 9.81$

$= 23.544$ N

Grade resistance (F_{gr}):

$Fgr = m * a * \sin\theta$

Where, m = Mass of the Vehicle (in kg) = 120 kg

a = Acceleration due to gravity = 9.81 m/s^2

θ = Slope of Gradient Angle = 0

(Considering flat surface for urban setting)

Thus, $F_{gr} = 120 * 9.81 * 0$

$= 0$ N

Aerodynamic resistance i.e., Aero Drag (F_{ad}):

$F_{ad} = 0.5 (\varrho * v^2 * c_a * A_f)$

Where, ϱ = Density of air medium (kg/m^2) = 1.23

v^2 = Velocity of vehicle (m/s) = 6.9444

[since speed is 25 km/h]

c_a = Coefficient of air resistance = 0.5

A_f = Frontal area of vehicle (m^2) = 0.4

Thus, $F_{ad} = 0.5\ (1.23 * 6.9444^2 * 0.5 * 0.4)$

= 5.9316

Therefore,

F_{total} = Fr + Fgr + Fad

= 23.5440 + 0 + 5.9316

= 29.4756 N

The motor has to overcome 29.4756 N resistance force to start propelling.

Now, the propelling power required to overcome this resistance is as follows

Power Calculation:

Power = Total resistance force (N) * Velocity of vehicle (m/s)

$= F_{total} * v$

= 29.4756 * 6.9444

Power = 204.69 W

Now, to calculate the rpm of the wheel :

Diameter of bicycle wheel is considered 26 inch = 0.6604 m,

So, radius of whee l = 0.3302 m

Wheel circumference = π*d = 2.0747 m

Thus, for 1 revolution wheel covers 2.0747 m.

Now, considering top speed of bike as 25 km/h = 416.667 m/min

Ultimately at 25km/h wheel covers a distance of 416.667 m in 1 minute

Thus max wheel rpm i.e., Distance reach per minute at top speed/Distance travel in one revolution = 416.667 / 2.0747

= 200.832

= 201 rpm

Since, we are using BLDC hub motor, Wheel rpm = Motor rpm

Thus, our selected motor should have a rated speed of 201 rpm or above.

Motor torque:

Power = 2πNT/60

204.69 = 2π*200.832*T/60

Torque = 9.7327 Nm

Maximum Torque Calculation:

By Newton's law of motion,

v = u + at

Where, v = Final velocity of bicycle (m/s) = 6.9444

u = Initial velocity of bicycle (m/s) = 0

a = Acceleration of bicycle (m/s^2)

t = Time taken to reach max speed from rest (sec) = 15

Thus, a = v/t = 6.94444/15 = 0.46296 m/s^2

Force required to move the bicycle :

f = m * a

= 120 * 0.46296

= 55.555 N

Thus, Maximum torque required to move the bicycle :

T_{max} = Force * Radius of Wheel = f * r

= 55.555 * 0.3302

T_{max} = 18.344 Nm

VI. COMPONENT SELECTION

According to the torque calculation the motor and controller selection of power is to be selected

Motor: According to the calculations motor should be capable to create the torque of 18.34 Nm. Hence keeping in that mind Bafang H300 model of motor is selected.

Here are the specifications of the motor.

Parameter	**Rating**
Power	250 W
Voltage	36/43 V
Torque	32NM
Temperature	-20 - 45° C
Weight	3 Kg

Controller: The controller selection should be basis on the motor specifications according to that controller is selected

Controller specifications

Parameter	Rating
Power	250 W
Current	15 A
Voltage	31-36 V
Phase angle	120°
Weight	213 gm
Dimensions	100*50*30 mm

VII.METHODOLOGY

1. According to the calculations the torque required by the motor is taken into consideration while choosing the motor and as per those requirements the motor is searched on the basis of efficiency and torque as well as it's suitability to the pedelec.

As per the requirement the Bafang H300 motor is selected which is a hub motor providing the torque of 32Nm and maximum speed of 25 km/hr.

2. To co-ordinate with the human inputs to the pedelec and motor torque in order to produce the required torque the torque sensing mechanism is taken into consideration.so it is very useful and optimistic solution to the pedelec.

3. Various throttle configuration has been reviewed and based on suitability and operating the half throttle mechanism was selected.

4. Controller of rated current capacity to control the motor operation and battery charging is selected.It also have the over current protection,over voltage protection during charging,under voltage protection during discharging of battery also it have some more features.

The controller is selected and It fulfills the requirement of the pedelec system properly.

VIII. EXPECTED RESULT

i. An electric Bicycle, which will actually be able to carry not only the person but also some extra working load with ease.

ii. Usability of the Electric bicycles will Increase and average cost will go down.

iii. Two-wheeler Fuel cost for a person on average ranges from 15,000 – 20,000 per annum which is projected to be brought down to less than 6,000.

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