

Literature Review on Electric Bike

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Abstract

The main aim of this review paper is to present the idea of harnessing the various energy and use it in today's existence of human life. For human being travelling has become vital. In order to sustain in this fast forward world he must travel from place to place. It is very important that time taking for travelling should be less, also it should be economical and easily available. With the fast depleting resources of petrol and diesel, there is need to find intermittent choice. Taking all this into account, a shift away from conventional based fuels to using a renewable sources of energy is a must. Electric bike which will be driven with the help of battery and thus provide required voltage to the motor. The focus of this report is to perform power calculations and system design of this Electric Bike. This bike can be driven with the help of electricity or also with the help of solar energy. Therefore the manufacturing of such bike is indispensable.

Keywords

Electric Bike, Harnessing, Solar energy, Economical, Electricity

Nomenclature:

P = Power

N = revolution per min

T = Torque

σ_s = Shear stress

σ_t = Tensile stress

σ_{ut} = Ultimate Tensile Stress

fos = Factor of safety

I. Introduction

The paper presents a review on Portable Electric Bike (PEB). This was first developed in 1890's in US and those were documented within various US patents. On 31st Dec, 1895 Ogden Bolton designed a battery powered cycle. He designed using 6 pole brush and commutator DC hub motor connected to the rear wheel. He was then granted a US patent. Couple of years later, Hosea W. Libbey invented electric bike which was propelled by double electric motor. This motor was so designed that it was attached with the crankset axle. Later in 1990's torque sensors and power controls were developed including some modified versions of bike with NiMH, NiCd and/or Li-ion batteries which offered lighter, density capacities batteries. But this bikes faced decrease in production when petrol and diesel resources came in existence [3][5][6][7]. Taking considerations of recent events of meager resources and facilities at their disposal, over increasing traffic, snags problem of parking and the need to make automobile a more environmental friendly, designers of vehicles are back with a view to hit upon a novel concept that completely alter the conventional design. Recent developments on Electric bike which are pedal operated are tremendously increasing all over the world market. In China 9 out of 10 Electric bikes are sold, thereby proving that they are not only energy efficient but also relative cheaper than other electric automobiles. It enables to ride in hilly areas and also in windy areas with much less human effort. The below table shows and gives the review of the world who have implemented this

electric bike system successfully and have been benefited. The table consists of the following; the type of bike, speed limit(km/hr), watt, weight limit (kg), Age requirements.

Table 1: Specifications of E-Bike in Various Countries

Country	Type of bike	Speed limit in km/hr	Watt	Weight in kgs	Age required in yrs
Australia	Pedal	25	250	None	None
Canada	Hand	32	500	None	Various
China	P/H	30	200	20	None
Norway	Pedal	25	250	None	None
Israel	Pedal	25	250	30	14
UK	Hand	27	250	40	14
Taiwan	Hand	25	200	None	None
US	Hand	25	750	None	None
China	P/H	30	500	None	None

The above table represents the information as to which country uses what type of bike and the related information. Thus this report focuses on the review of prevalent literature on the current environmental impact of vehicles, then shifting its way towards electric bike use and designing the required calculations based on standard assumptions.

A. What is Electric Bike?

The Electric bike is a bike which is driven with the help of battery which is coupled to electric motor.

Main principle: It works on the principle that the electromotive force of an A.C. motor which receives electrical energy stored in D.C. battery is converted with the help of D.C. to A.C. converter.

Working Medium: Here for the motivation of prime mover the chemical reaction takes place from which an energizing current is evolved which is responsible for the working. The working medium is sulphuric acid which is separated into columns of H ions and negative SO_4 ions when mixed with water. If the poles of the cell are connected by a load, the flow of the electrons is from negative to positive. A bivalent positive lead is produced from neutral lead when combined with bivalent negative of SO_4 group to form lead sulphate. This results due to scarcity of electrons at negative pole. Through the electron supply a bivalent positive lead is produced at positive pole from quadrivalent positive lead. A combination of SO_4 comes into existence thereby ruling the combination of O_2 which leads to formation of $PbSO_4$. The atoms of oxygen and hydrogen from electrolyte are released together to form water thereby decreasing the density of battery acid.

Operation: In this a DC waveform which is obtained is made sinusoidal due to operational transistorized D.C. to A.C. amplifying circuit by switching the electric energy in the form of electric current which flows from battery to D.C. to A.C. converter circuit. By using amplifier circuit the small A.C. current is amplified again. In order to drive the circuit through the condenser, this amplified current is fed to the stator winding of the A.C. motor. The condenser which is used acts as a storage of electric energy and delivers at

the time of requirement. The sprocket wheel installed on motor shaft is driven by the motive power of the electric energy. The rear sprocket wheel is being rotated by the chain drive mechanism on which the other two remaining sprocket wheels are installed. The wheel is driven by the rear wheel installed on the rear sprocket. Thus the electric bike is mobilized by using electric power.

II. Components of E - Bike

The Electric bike consists of following components viz, DC motor, Frame, Platform, Battery, Drive etc. [2].

1. Dc motor: The motor is having 250 watt. capacity with maximum 2100 rpm. Its specifications are as follows:

- Current Rating: 7.5amp
- Voltage Rating: 48 Volts
- Cooling: Air – cooled
- Bearing: Single row ball

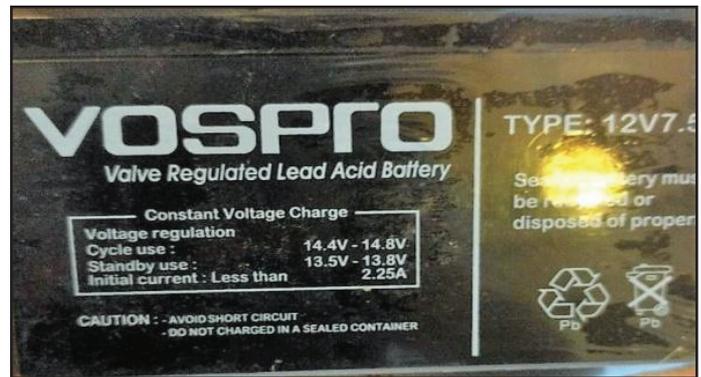


(AUTHOR)
Fig. 1: DC Motor

2. Frame: The Frame is made up of M.S. along with some additional light weight components. The frame is designed to sustain the weight of the person driving the unit, the weight of load to be conveyed and also to hold the accessories like motor. Also it should be design to bear and overcome the stresses which may arise able to due to different driving and braking torques and impact loading across the obstacles. It is drilled and tapped enough to hold the support plates.

3. Platform: The Platform is designed with robust base so that it can hold the load along with the weight of the driving person uniformly. It is fabricated from Mild Steel at a specific angle in cross section and welded with a sheet of metal of specific thickness. The platform’s alignment is kept horizontal irrespective whether it is loaded or unloaded and this is directly bolted and welded to the frame.

4. Battery: The battery also acts as a condenser in a way that it stores the electric energy produced by the generator due to electrochemical transformation and supply it on demand. Battery is also known as an accumulator of electric charge. This happens usually while starting the system.



(AUTHOR)
Fig. 2: Battery

5. Chain Drive: A Chain is an array of links held together with each other with the help of steel pins. This type of arrangement makes a chain more enduring, long lasting and better way of transmitting rotary motion from one gear to another.

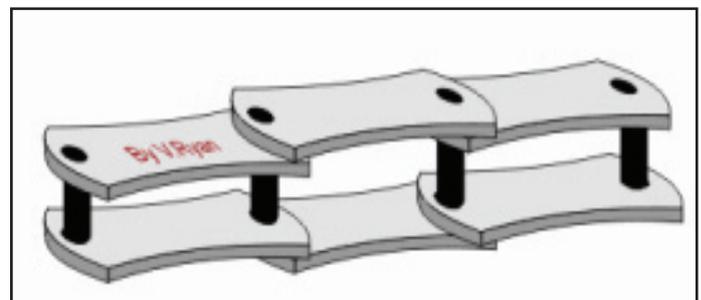


Fig. 3: Chain Links

The major advantage of chain drive over traditional gear is that, the chain drive can transmit rotary motion with the help of two gears and a chain over a distance whereas in traditional many gears must be arranged in a mesh in order to transmit motion.

6. Braking System: For the braking system it is convenient to use braking system used in band brake system which consist of spring loaded friction- shoe mechanism, which is driven with the help of hand lever.

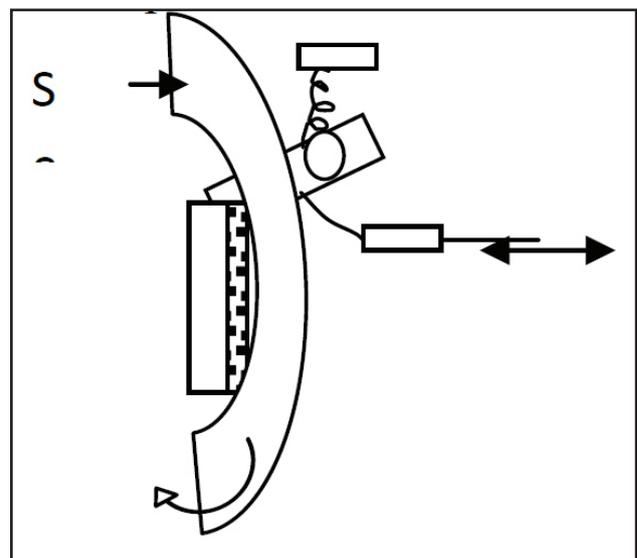


Fig. 4: Braking System

7. Sprockets: The chain with engaging with the sprocket converts rotational power in to rotary power and vice versa. The sprocket

looks like a gear but differs in three important ways:

- Sprockets have many engaging teeth but gears have only one or two.
- The teeth of a gear touch and slip against each other but there is basically no slippage in case of sprocket
- The shape of the teeth are different in gears and sprockets.

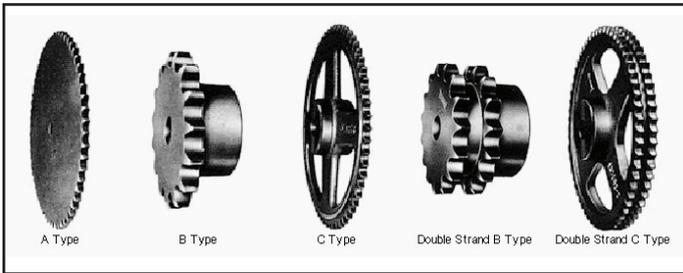


Fig. 5: Various Types of Sprocket [3]

III. Design of Electric Bike

Here we have used permanent magnet self generating motor with 250 watt power and 2100rpm. The motor runs on 48volts and 7.5amps power source. This motor can reach a peak current during starting equal to 15 amps [2-3].

$$P = 2 \times 3.14 \times N \times T / 60$$

$$250 = 2 \times 3.14 \times 2100 \times T / 60$$

$$T = 1.13 \text{ N m} = 1136 \text{ N-mm}$$

Reduction in chain drive

$$R_{\text{chain}} = 66/11 = 6:1$$

$$\text{Torque at wheel shaft} = T \times R_{\text{chain}} = 1136 \times 6 = 6820 \text{ N mm}$$

$$\text{Speed of wheel shaft} = 2100 / 6 = 350 \text{ rpm}$$

A. Designing of Shaft

Bending: The force which develops across a specific cross section of the shaft, it generates stress at that point of cross section that are subjected to maximum loading. This internal or resisting moment gives rise to the stress called as bending stresses.

Torsion: When the shaft which is twisted by the couple such that the axis of that shaft and the axis of the couple harmonize, that shaft is subjected to pure torsion and the stresses generated at the point of cross section is torsion or shear stresses.

Combined Bending and Torsion: In actual practice the shaft is subjected to combination of the above two types of stresses i.e. bending and torsion. The bending stresses may occur due any one of the following reasons:

1. Weight of belt
2. Pull of belts
3. Eccentric Mounting of shafts/gears
4. Misalignment of shafts/gears

On contrary, the torsional movement occurs due to direct or indirect twisting of the shaft. Hence at any given point on cross-section of the shaft, the shaft is subjected to both bending and torsional stresses simultaneously. Following stresses are taken in consideration while designing the shaft:

1. Shaft Design

$$T = 36000 \text{ N mm}$$

$$T = 3.14 / 16 \times \sigma_s \times d^3$$

$$F_s \text{ allowable} = 80 \text{ N/mm}^2$$

$$6820 = 3.14 \times \sigma_s \times d^3 / 16$$

$$\sigma_s = 34.73 \text{ N/mm}^2$$

Material = C 45 (mild steel)

$$\sigma_{ut} = 320 \text{ N/mm}^2 \text{ ----- PSG design data book.}$$

Factor of safety = 2

$$\sigma_t = \sigma_b = \sigma_{ut} / f_{os} = 320 / 2$$

$$= 160 \text{ N/mm}^2$$

$$\sigma_s = 0.5 \sigma_t$$

$$= 0.5 \times 160$$

$$= 80 \text{ N/mm}^2$$

σ_s is less then allowable so our shaft design is safe.

2. Design of Sprocket and Chain for Electric Bike

We know,

$$\text{Transmission ratio} = Z_2 / Z_1 = 66/11 = 6$$

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 11 teeth.

So, $Z_1 = 11$ teeth

B. 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 = 2100 rpm

For this rpm value we select pitch of sprocket as 6.35mm from table.

$$P = 6.35 \text{ mm}$$

Calculation of minimum center distance between sprockets

THE TRANSMISSION RATIO = $Z_2 / Z_1 = 66/11 = 6$ which is less than 7

Dia. of small sprocket,

$$\text{Periphery} = \pi \times \text{dia. Of sprocket}$$

$$11 \times 6.25 = \pi \times D$$

$$D = 11 \times 6.25 / \pi$$

$$D = 21.8 \text{ mm}$$

Dia. of sprocket,

$$\text{Periphery} = \pi \times \text{dia. Of sprocket}$$

$$66 \times 6.25 = \pi \times D$$

$$D = 66 \times 6.25 / \pi$$

$$D = 131.3 \text{ mm}$$

So from table, referred from PSG Design Data book

The minimum centre distance between the two sprocket = C' + (80 to 150 mm)

$$\text{Where } C' = \frac{Dc1 + Dc2}{2}$$

$$C' = \frac{131.3 + 21.8}{2}$$

$$C' = 76.5 \text{ mm}$$

$$\text{MINIMUM CENTER DISTANCE} = 76.5 + (30 \text{ to } 150 \text{ mm})$$

$$\text{MINIMUM CENTER DISTANCE} = 170 \text{ mm}$$

C. Calculation of Values of Constants K1 K2 K3 K4 K5 K6 – (with help of PSG Design Data)

Load factor $K_1 = 1.25$ (Load with mild shock)

Distance regulation factor $K_2 = 1.25$ (Fixed center distance)

Center distance of sprocket factor $K_3 = 0.8$
 Factor for position of sprocket $K_4 = 1$
 Lubrication factor $K_5 = 1.5$ (periodic)
 Rating factor $K_6 = 1.0$ (single shift)

D. Calculation of Value of Factor of Safety

For pitch = 6.35 & speed of rotation of small sprocket = 2100 rpm

Factor of Safety for this drive = 8.55

Calculation of Allowable Bearing Stress:

For pitch = 6.35 & speed of rotation of small sprocket = 2100 rpm

Allowable Bearing stress in the system = 2.87 kg/cm^2
 $= 2.87 * 981/100 = 28 \text{ N/mm}^2$

1. Calculating Maximum Tension on Chain

Maximum torque on shaft = $T_{\max} = T_2 = 6820 \text{ N-mm}$

Where,

T_1 = Tension in tight side

T_2 = Tension in slack side

O_1, O_2 = center distance between two shaft

$$\sin \alpha = \frac{R_1 - R_2}{O_1 O_2}$$

$$\sin \alpha = \frac{65.65 - 10.9}{170}$$

$$\sin \alpha = 0.33$$

$$\alpha = 18.78$$

TO FIND θ

$$\theta = (180 - 2\alpha) \times 3.14/180$$

$$\theta = (180 - 2 * 18.78) \times 3.14/180$$

$$\theta = 2.48 \text{ rad}$$

According to this relation,

$$T_1/T_2 = e^{\mu\theta}$$

$$T_1/T_2 = e^{0.35 \times 2.48}$$

$$T_1 = 2.38 T_2$$

We have,

$$T = (T_1 - T_2) \times R$$

$$6820 = (2.38 T_2 - T_2) \times 65.65$$

$$T_2 = 75.27 \text{ N}$$

$$T_1 = 2.38 \times 75.27$$

$$T_1 = 179.16 \text{ N}$$

So tension in tight side = 179.16 N

We know,

$$\text{Stress} = \text{force} / \text{area} \times 2$$

$$\text{Stress induced} = 179.16 / (3.14 * 3^2 / 4) \times 2$$

$$\text{Stress induced} = 12.67 \text{ N/mm}^2$$

As induced stress is less than allowable stress = 28 N/mm^2 design of sprocket is safe.

IV. Advantages

- Easy to commute with low fatigue.
- Less maintenance cost.
- Normal Drag/Pedal is possible when power is not in use.
- Deployable batteries – can be taken inside house.
- Cost of the unit is very low.
- Easy to carry since it is portable.
- Less energy consumed.

- High efficiency can be obtained if inverter is used.
- If using solar panel, free utilization of energy can be done [9].

V. Disadvantages

1. High intensity of wind load
2. High centre of gravity.
3. Cannot tolerate drastic changes in environment.
4. Needs Periodic Monitoring [9].

VI. Conclusion

With the increasing consumption of natural resources of petrol, diesel it is necessary to shift our way towards alternate resources like the Electric bike and others because it is necessary to identify new way of transport. Electric bike is a modification of the existing cycle by using electric energy and also solar energy if solar panels are provided, that would sum up to increase in energy production. Since it is energy efficient, electric bike is cheaper and affordable to anyone. It can be used for shorter distances by people of any age. It can be contrived throughout the year. The most vital feature of the electric bike is that it does not consume fossil fuels thereby saving crores of foreign currencies. The second most important feature is it is pollution free, eco – friendly and noiseless in operation. For offsetting environmental pollution using of on – board Electric Bike is the most viable solution. It can be charged with the help of AC adapter if there is an emergency. The Operating cost per/km is very less and with the help of solar panel it can lessen up more. Since it has fewer components it can be easily dismantled to small components, thus requiring less maintenance.

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