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Design Analysis of Portable Electric Two-Wheeler with Enhanced Safety Features

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Abstract:- Metropolitan cities today face twin crisis of mobility pollution and high-priced fossil fuels. Another issue that these places face is limited space of vehicle movement and upkeep in residences. The present work addresses these issues with a designed portable electric two-wheeler that can be carried as luggage trolley and can be kept in room. The designed two-wheeler is having a total weight of 28 kg with folded and unfolded horizontal length of 70cm& 140cm while height and width equals to 85 and 53 cm respectively. The vehicle is equipped with 3 phase, 48 volt, 250 W BLDC motor, 48 V controller and with two wheels of 32 cm diameter each. The system is powered with 4 batteries of 12 volt each to power the wheels. The designed electric two-wheeler is made foldable with help of scissor mechanism fitted at the centre of the system. The system is fitted with foldable mirrors and rear-view display for enhanced safety in its class. The system is tested on different gradients and variable loading for design test for enhanced market acceptability. Results indicate that the design is suited for individual travel with no noise / air pollution in congested city travelling.

Keywords: *Safety, Portable Two Wheeler, Foldable Electric bike.*

1. Introduction

The automotive industry is shifting towards electric mobility in the coming years. The demand for electric vehicles will increase, while the conventional fossil fuel vehicles will see a replacement and possibly become out of use in coming 20 years. The reserves of fossil fuels are depleting at rapid rates, and the steep rise in vehicles is putting pressure on these resources [1],[2],[3]. Also, the world is facing the menace of pollution where in vehicles running on fossil fuels is one of the main contributors in the metro cities. Hence, there is a need for developing electric vehicles in every vehicle category, from small to the large sizes. There is another factor which is ignored by the automotive industry is the need of space for vehicles with their increasing numbers. The global population has already reached 8 billion and it is further increasing with exponential rate. In a country like India as the population is increasing and number of usable vehicles on road increasing the space required for vehicle movement and storage is decreasing. Living, infrastructure, agricultural, recreational spaces, etc. are becoming sparce. Unplanned townships have also made the situation worse. Another impact of population increase is the increased congestion on roads. Traffic density has seen tremendous increase in recent years. The cause seems to be more people owning four wheelers, lesser use of public transport and missed driving sense. These factors contribute to traffic jam on roads and thus has made driving a hectic task for common man.

Because of diminishing parking spaces, there is a need to search for solutions that can make use of minimum space while being able to provide parking to a considerable number of vehicles [4],[5],[6],[7]. Either the idea can encompass modifications in parking systems, or that of vehicle design. In the present work a foldable electric-bike is designed and developed, the thin designed bike can be transported like a luggage bag when desired to move the two wheelers through rail or bus for intercity transport. Also, because it can be made to stand vertically against a support, it reduces the horizontal space or ground space required for parking. The developed design will be helpful at parking grounds, at public places like shopping malls, theatres, offices, educational institutions, etc.

Another concern in two wheelers is safety of riders. The number of casualties pertaining to two-wheelers is a lot more compared to bigger vehicles. It is a common sight that when accidents happen with two-wheeler, major casualty is faced by that two-wheeler rider. Also, it is observed that, the driver faces difficulty in getting a complete view of the traffic behind him through side mirrors. [8], [9],[10],[11],[12]. While adjusting mirrors, the driver is distracted, even for some seconds. But, a second is enough for any mishap to happen. Two-wheeler drivers are also seen having their mirrors removed, and turning their heads to look back. This increases the risk of accidents further. Hence, the present work deals with the application of rear-view display for providing constant information about the complete view behind the commuter. It helps in eliminating blind spots, and the distraction created for the driver.

2. Blind spots of a two wheeler:

A two-wheeler's blind spot areas will vary depending on the two-wheeler and the type of mirrors used. Some two-wheelers may have blind spot mirrors fitted to aid in reducing the blind area. In general however, most two-wheelers will have blind spots to the sides and rear as indicated by the red shaded areas in Figure 1. [9]

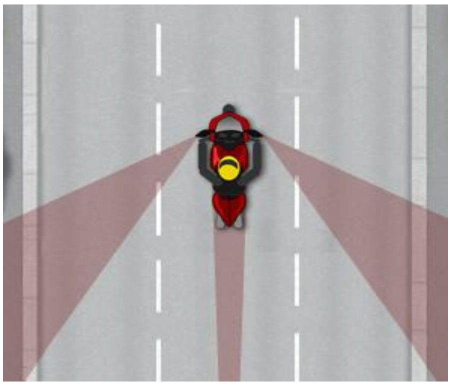

Figure 1: Blind Spots of a Two-Wheeler [9]

3. The rear – view system:

The parking camera used for the rear-view display is a night vision camera, which has 8 LEDs surrounding its lens fig. 2 , giving high quality image even at night (Lens Angle - 150º, Video Format – 420 TV, Voltage – 12V). The display panel used is a 4.3-inch-wide mirror screen is installed on the vehicle. It is a dual function display (fig. 3) and works as a rear-view mirror when driving & converts to screen while parking or reversing the vehicles. [13],[14],[15],[16].

Fig 2: Rear view camera

Fig 3: Display system

A 12V DC Motor (Fig. 4) for foldable mirror was selected. It is cylindrical in shape for fitting on the handlebar (Fig. 5). The developed design of motor on the Software Autodesk Fusion 360 is shown in the Fig 4. The second designed item is connecting rod for mirror with dimensions as shown in fig 5. The material used is steel and the

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pipes are hollow. The one end has inside grooved so that motor can be screwed in, while the other end is rounded to mount mirror with desired angle that can be adjusted by the rider as per his height during riding.

Fig 4: Image of motor used in mirror assembly

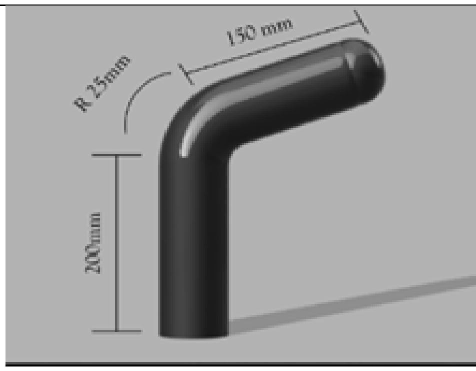

Fig 5: image of connecting rod of mirror

Mirror that's to fitted on the mount is designed keeping the aesthetics and ergonomic in account. Fig. 6 shows the images of the mirror design. Plastic is used for mirror cover.

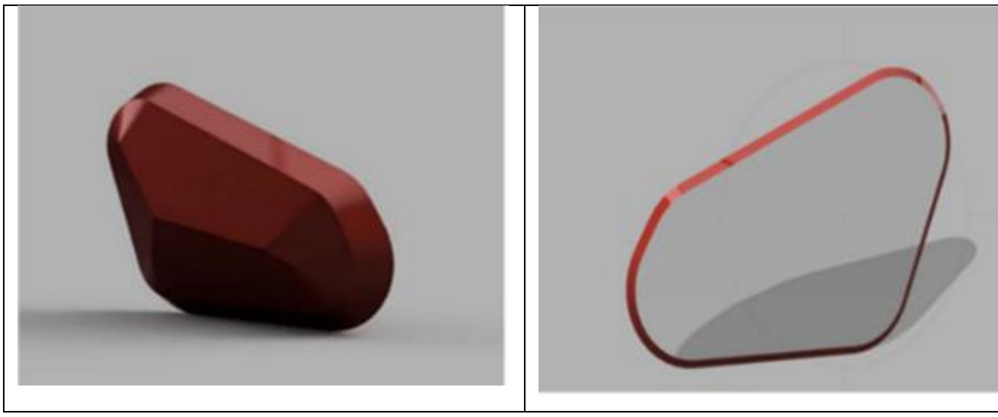

Fig 6: Image of the designed Rear-view Mirror

Table 1 provides the details of the connecting rod.

Table 1: Connecting rod specifications

Criteria	Specification
Material Used	Steel
Dimension	4 mm radius x 230 mm height
Opacity	Hollow

Table 2 provides details of mirror specificatiosn

Table 2: Mirror specifications

criteria	specification
Material Used	Plastic, mirror
Dimension	5-inch mirror
Make	Universal

4. Proposed Design:

Design of foldable electric bike

The proposed electric bike has a steel frame. The e-bike has folded and unfolded horizontal lengths of 70 cm and 140 cm respectively, while the folded and unfolded heights are 145 cm and 85 cm respectively. The width of the bike at handlebars is approx. 53 cm. The weight of the vehicle is 28.388 kg (approx. 30 kg). Axle-to-axle length is 94cm, and the length of frame (when unfolded) is 76 cm. Two wheels of rim diameter 32 cm are used. The hub motor is used in rear wheel, which is a 3-phase BLDC motor, operating at a voltage of 48V, and providing a peak power of 250W. The controller used operates at 48 V. Four Sealed Maintenance Free / Valve Regulated Lead Acid (SMF – VRLA) batteries are used in series for powering the bike, each operating at 12V, and providing 7.2A current. The e-bike folds at its frame using a scissor mechanism, which reduces its unfolded height, and the front tire folds into the frame. This helps it in transforming similar to a trolley. The frame also has tricycle support wheels for working as wheels of the trolley form.

Figure 7: Proposed design of the e-bike (scissor frame)

Design Calculations

The theoretical calculations for the drive train, battery, and motor selection of the foldable electric bike is made as per the below given calculations

Aerodynamic Drag = (1/2) * ρ * CD * A* v2

v = Velocity (m/sec) = 30 km/h

Air density @ 27°C = ρ = 1.2 (kg/m3)

Vehicle Frontal Area or Projected Area = $0.85 \times 0.53 = 0.45\ m^2$

Drag coefficient = 0.6 (Assumed)

RA= $0.5 \times 1.2 \times 0.6 \times 0.45 \times (\frac{30 \times 1000}{3600})^2 = 11.205\ N$

Power required P $P_A = R_A \times v = 92.96\ W$

Rolling Resistance = $R_R = m \times g \times \mu \times cos\theta$

Permissible load = 30kg (mass of vehicle) + 60kg (Passenger weight) + 10 (Luggage) = 100 kg

Weight = mg (newton or kg.m/s²), where g = 9.80665 m/s²

μ = rolling coefficient = 0.015

θ = gradient = 4°

Rolling Resistance = $R_R = 100(\text{kg}) \times 9.81 \left(\frac{\text{m}}{s^2}\right) * 0.015 * \cos\left(4 * \frac{\pi}{180}\right) = 14.56\ \text{N}$

Power required = $P_R = 14.56 \times 8.3 = 120.91\ W$

Uphill Resistance or Climbing Force = mg sinθ

Climbing force = $R_g = \mathrm{m} \times \mathrm{g} \times \sin\theta = 100 * 9.81 * \sin\left(4 * \frac{\pi}{180}\right) = 68.43$ N

Power required = $P_R = 68.43 \times 8.3 = 567.96\ W$

Acceleration force

Reach max speed in T = 20 seconds

2-wheeler (30 kmph or 8.33 m/s):

$$F_a = m \times a = \frac{100 \times 8.33}{20} = \frac{833}{20} = 41.65$$

Average Power required = $P_a = \frac{\frac{1}{2}mv^2}{T} = \frac{0.5 \times 100 \times 8.33^2}{20} = 173.47\ W$

Peak Power required (will be at 30 kmph) = $\frac{mv^2}{T} = 346.94\ W$

The traction power creates a Force Ftrac on the vehicle to move forward

Ptrac = Ftrac × v, where v is velocity (in m/sec) of the vehicle The resulting Torque T (in Nm) on the vehicle wheel created by the force is:

T = $F_{trac} * r_{wheel}$, where rwheel is radius of the vehicle in meters

Ftrac = Acceleration Force + Aerodynamic Drag + Rolling Resistance + Climbing Force

$$F_{trac} = m \times a + \frac{1}{2} \times \rho \times C_d \times A \times v^2 + m \times g \times \mu + m \times g \times sin\theta$$

where a is the acceleration.

Ftrac = 11.205 + 14.56 + 68.43 + 41.65 = 135.845 N

Ptrac (Watts) = Ftrac × v (Nm/sec) = 135.845 × 8.33 = 1131.58 W (Peak power requirement)

Motor selection:

Power for gradient and acceleration are not required together. Gradient movement is never done at high speed so for climbing 4° slope at 15 kmph will require about 373 W. Acceleration (pick-up) power is small at 15 kmph; and only 174 W even at 30 kmph. Rolling resistance on decent roads is small and higher than others only at very low speed. Drag power is only 93 W even at 30 kmph but can become very high at higher speed. Force related to Torque: Only gradient or acceleration torque matters at all speeds T req = 17.61 Nm (r-wheel = 0.16m) at 30 kmph. Speed Below 25 kmph: 250 Watts motor will be enough. Since the weight of the designed vehicle is less and the movement required is only on plain surfaces the 250-Watt motor is selected.

Battery Selection:

As per the Indian Standard Drive Cycle, a low-end two-wheeler with max speed of 30 Km/h consumes only 15.38 Wh per km (without considering any regeneration). So, for a battery with 48V-28Ah specifications, total range of the vehicle will be given by:

Range = 1344 Wh / 15.38 = 87.38 Km

So, the battery selected is good enough to provide the desired range performance.[17]

5. Working and experimental setup:

Working of the bike:

For the working of controller and the BLDC hub motor in the rear wheel, there is a requirement of a constant voltage of 48V. Hence, the 4 VRLA batteries (12V, 7.2Ah) are connected in series for getting the required voltage, with a constant current of 7.2A. When the ignition switch is turned on, the circuit is closed and the components which get power from the batteries initially are the controller, the camera, and the display. After the throttle is twisted, the controller sends electric current to the motor, based on the signal from throttle body, and the vehicle moves ahead. As the throttle is increased, the current flow from the batteries is increased. This increases the power output of the motor, and hence, the vehicle speed. The hall sensor gives the information of motor speed and position to the controller.

Experimental Setup:

For experimentation, the battery of electric bike was fully charged. This was done by charging the batteries after removing from the bike and connecting them to an external charger. After this, they were reinstalled in the bike. A person of 70kg weight sat on the bike, to test for the strength of the frame. The bike was then run until the batteries were dry, to test for the range. The throttle was varied during the run to get the data on maximum cruising speed and the maximum comfortable riding speed. The rear-view display was tested for the field of view that the camera provides of the situation behind the vehicle.

6. Testing and validation:

The designed and developed vehicle was tested on gradients up to 40 with speed of 10 km/hr with single person of 70 kg seating. The vehicle has performed the test successfully. Also, it was tested for 25km/hr on plain surface where in the test results were comparable with the theoretical calculations.

The designed foldable mirrors were tested for its operations and were found to be suitable for applications. In the similar line rear view camera display was fitted and analyzed during the running mode of vehicle it was observed that full view was available with out any blind spots.

7. Results and Discussion

The results obtained were comparable with the theoretical values as per the design. Some comparative charts of the designed vehicles were prepared with vehicles already in market. The proposed design has the following parametric features as given in the table: 3

Table 3: Designed two-wheeler specifications

Aerodynamic Drag (N)	Rolling Resistance (N)	Climbing Force (N)	Acceleration Force (N)	Average Power (W)	Peak Power (W)	Traction Force (N)
11.02	14.56	68.43	41.65	173.47	346.94	135.84

Comparative Charts

The proposed design was compared with similar make and brands having BLDC, Hub motor i.e Ujaas ezy, Avon E Plus and Velev Motors VEV 01 in terms of battery capacity (Fig 8), Range (Fig. 9) and Price (Fig. 10) the same is shown in figure below based on comparative design table 4

Table 4: Design parameter

Make	Max Torque Nm	Max Power Watt	Top Speed (Km/hr)	Battery Type	Battery Capacity	Range (Km / charge)	Price in Thousand
Ujaas eZy	75	250	25	Lead Acid	1.25 Kwh	60	34.88
Avon E Plus	48V 12 Ah battery	220	24	Lead Acid	0.58 Kwh	50	25
Velev Motors VEV 01	24Ah	250	25	Lead Acid	1.15 Kwh	80	32.5

Proposed Design	48V, 7.2Ah	250	30	Valve regulated (VR) lead acid battery	1.38 Kwh	87	35

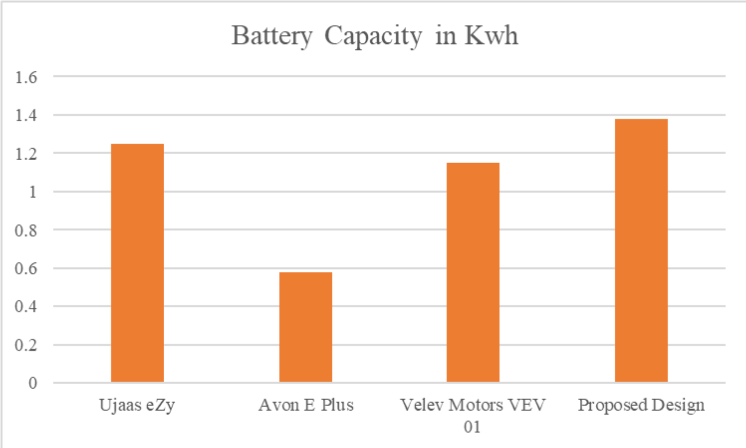

Figure 8: Comparative table in terms of battery Capacity

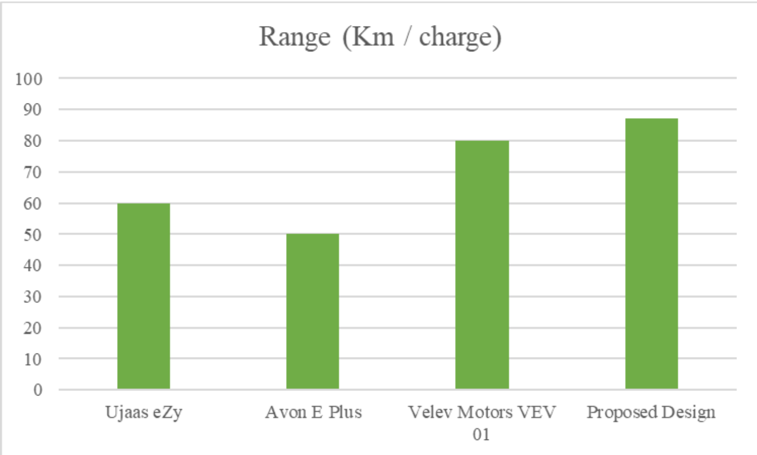

Figure 9: Comparative table in terms of range

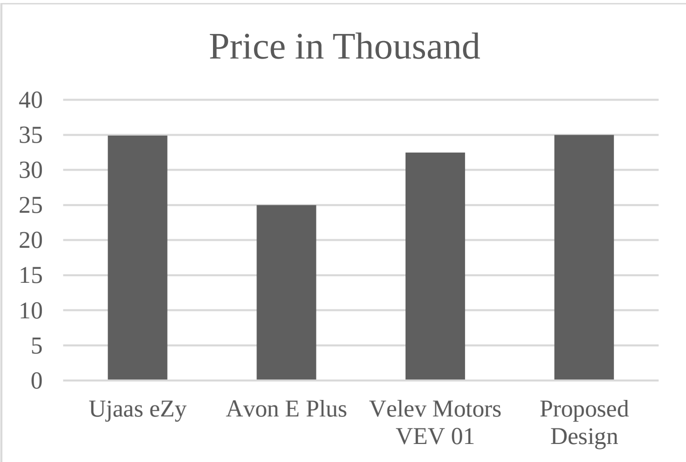

Figure 10: Comparative table in terms of price

8. Conclusion:

The electric two-wheeler is designed and developed with customers satisfaction given highest priority. The vehicle occupies less space when idle and can be easily transported like a luggage. The safety feature in form of foldable mirror and rear-view camera that are fitted on the vehicle were tested for its use on two wheelers and were found to be in good agreement as per the planned design.

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