Design and Development of Foldable Electric Bicycle

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Abstract - *Transport has been one of the most important issues to be dealt with in the present day situation. Commuting from place to place within the city has become a tedious and an expensive task. To cope with time deficit, we can utilize the time spent on commuting efficiently to exercise by using bicycles, thereby also contributing to pollution control. Recently there are studies on air pollution of big cities and results proved that air pollution is increased in general. A systematic study in relationship between material properties and design for folding bicycle has been performed.*

The aim behind our project is to make a portable foldable E-bicycle which would be easy to handle by both genders and it should emit 0% emission, which will be comfortable to ride and economical.

Key Words: **Transport, Bicycle, Foldable, Electric, Pollution, etc.**

1. INTRODUCTION

All vehicles on the road pollute the environment, and the cost of gasoline is rising every day. To compensate for fluctuating fuel costs and pollution, a simple solution, namely our transportation system, is required.

Due to the ignition of hydrocarbon fuels in the vehicle, problems such as wear and tear can arise, necessitating additional attention to correct maintenance. Our vehicle is simple to operate and consumes no more fuel than other vehicles on the road.
Since the last two decades, the world's judiciary and policymakers have been deeply concerned about the urgent need to protect the environment, ecology, and humanity as a whole. There has been a steep rise in the accumulation of greenhouse gases, particularly carbon dioxide, which affect global climate change. Automobiles account for roughly 14% of total carbon dioxide emissions. Aside from pollution generated by CO, unburned hydrocarbons, particulate, and tetra ethyl oxides, lead poisoning is a health and environmental hazard caused by both petrol and diesel engine driven cars.

Vehicle manufacturers have been required to meet these standards by designing cleaner and more fuel-efficient engines, as well as providing for the treatment of exhaust gases to satisfy the specified limits, as regulations on exhaust emission from vehicle engines have become increasingly stringent in the years leading up to the year 2000 and beyond. So, in order to fulfil and overcome these two concerns, namely pollution and efficiency, a requirement for a modification in the existing alternative system that can provide higher efficiency at lower cost was considered, and an attempt to develop and build such an alternative system was created.

Due to time constraints and a hectic lifestyle, man is unable to devote specific time to his health in today's society. Exercise and bodily fitness are given the least importance. To make up for the time shortfall, we can use the time spent travelling to exercise by riding bicycles, which also helps to reduce pollution. Regular bicycles, on the other hand, take up a lot of space to park, are difficult to transport, and are prone to theft. Transportation has become one of the most significant concerns to address in the current circumstances, since commuting from one location to another within the city has become a time-consuming and costly task. It is quite difficult to locate the nearest public transportation facility, and in many circumstances, the destination will be located far from major routes, where public transportation may be unavailable or prohibitively expensive. An idea for designing and fabricating a folding bicycle is conceived to address a prevalent societal need. Many folding bicycles have been seen on the global market, but the major goal of this project is to create a foldable bicycle that is light and sleek while remaining sturdy and safe, as well as easy to manage and maintain. Unlike traditional bicycles, this one takes up very little space and is also quite easy to transport. The major goal is to design and construct a foldable bicycle that is both comfortable and affordable to ride.

1.1 Problem Statement

Development and evaluation of a low-cost, foldable electric bicycle for transportation.

1.2 Objectives

- To design and create a foldable bicycle that is powered by electricity; to analyse the foldable bicycle under various loading conditions using ANSYS software.
- To determine the technological and economic viability of an electric bicycle.

1.2 Methodology

1. Literature Review.

2. Identification of voids in literature review.
3. Objectives of work.
4. Design of model.
5. Fabrication of model.
6. Modification of model.
7. Analysis of model.
8. Performance evaluation of E-Bicycle.

2. LITERATURE REVIEW

The following is a summary of research papers on foldable electric bicycles that are currently available in the literature.

Shishir S. and Manjunath P. have created a foldable bicycle that is light and elegant while being robust and safe, as well as easy to manage and maintain. The bicycle's seat and handle locations are adjustable, allowing it to be used by both youngsters and adults. The general system of this bicycle is to save energy in batteries through pedaling, which is subsequently used to power the bicycle. In the future, using this technology for autos, trains, planes, and shuttles can be extremely effective and efficient in terms of environmental protection.

Jayesh S. Renge has created a folding three-wheel vehicle powered by an electric motor. The main goal of this project is to create a portable vehicle that is easy to operate for both men and women and emits zero emissions. They employed a DC brush motor for power supply, which does not require fuel to run and hence does not cause pollution. The project is more affordable for middle-class individuals because the batteries can be charged. It can be used to reduce walking distance on college campuses and in industrial regions.

In India, foldable bicycles are manufactured of hefty materials that make them difficult to transport. Many of them are not foldable in a geometrically customizable order, making transit extremely challenging. By analyzing previous designs, the limitations of the designs were discovered, paving the path for the development of new foldable bicycle designs.

3. DEVELOPMENT OF FOLDABLE BICYCLE

3.1 Components Required

The major components that are used in the design and manufacture of the folding electric bicycle are listed below.

Standard Components

- Battery
- Motor
- Dynamo
- Throttle
- Controller
- Chain and sprocket
- Shock absorber
- Tyres
- Steering

Fabricated Components

- Frame
- Pedal
- Hinges
- Locking nut

3.2 Working Principle

Manufacturing procedures are the phases that raw materials go through to get a finished product. The creation of the materials from which the design is formed is the first step in the production process. These materials are subsequently transformed into the desired part through manufacturing methods. In an electric bicycle, there are two modes of operation:

3.2.1 Pedal Assist Mode

Pedal assist, often known as pedelec, is a mode in which the rider receives power solely when pedaling. When compared to the throttle mode, the pedal assist option feels more natural if you're used to riding a regular bike. The pedal assist mode is especially convenient since it allows you to concentrate just on pedaling and eliminates the need to hold the throttle in a specific position. Because you must pedal, the pedal assist mode will typically provide more range than the throttle option. Pedal assist bikes come in a variety of levels of assistance, such as low, medium, and high.

Low pedal assist - you're in good shape riding the bike. Low assist delivers a small amount of electric assistance as you pedal harder and get a better exercise. You enjoy a pleasant tailwind wherever you go with medium pedal assist. A nice balance of your pedal strength and the motor power can be found with medium pedal assist. You'll feel like Superman with the high pedal assist! When you want to go somewhere quickly and with little effort, use high pedal assist. If you want to get to work without breaking a sweat, this could be handy. You could use the low pedal assist on the way home to work off the stress of the day.

3.2.2 Throttle Mode

The throttle mode works similarly to a motorcycle. The motor provides power and moves you and the bike ahead when the throttle is depressed. You can pedal without using the throttle, use the throttle while pedaling, or just use the throttle without pedaling if your bike has one. With a simple twist of the wrist, you may change the throttle to different top speeds depending on your comfort level. We already have dynamo-powered bicycle lights and an electric bicycle! Consider this: you rotate the wheels by pumping your legs up and down on the pedals. In the dark, a small dynamo (generator) located on the back wheel generates a modest stream of power that keeps your back safety lamp lit. Consider what would happen if you reversed the process. What if the lamp was removed and replaced with a large battery? The battery would produce a constant electric current, which would drive the dynamo in reverse, making it spin like an electric motor. The dynamo/motor would rotate the tyre and propel the bike forward without the assistance of your pedaling. And there you have it: an electric bike! Although it may appear far-fetched, this is essentially how electric bikes functions.

3.3 Folding Mechanism

In order to address the issues of economic infeasibility and pollution, research is being conducted in the fields of energy that is directly delivered by living beings and to living beings when it comes to vehicles powered by manual energy. The most common vehicles are bullock carts, horse carts, and other similar vehicles. Cycles is one of the most well-known names among them. In my opinion, the bicycle is the most efficient and practical mode of transportation. The only disadvantage of the cycle is that it takes up a lot of room, hence foldable cycles were invented to solve this problem.

3.3.1 Folding of Bicycle

1. The frame's folding in this phase, the frame clamp of the folding bicycle is opened, and the primary frame or folding body of the folding bicycle is folded in such a way that the front wheel's horizontal axis and the back wheel's horizontal axis are aligned.
2. Seat Height Adjustment In this step of the folding bicycle, open the seat clamp and allow the folding bicycle seat to be adjusted as shown in the diagram. Undo the lever, push the saddle all the way down, and then re-clamp the lever. Because of this, the rear frame remains folded during this operation, keeping the front wheel folded.
3. Handle Refolding Open the handle clamp and fold the handle of the folding bicycle as shown in the figure in this phase of the folding bicycle. Handlebar Remove the handlebar stem hinge clamp. Simply lower the handlebars to lie alongside the front wheel and press home so that the nipple contacts in the clip.

3.3.2 Unfolding of Bicycle

1. Unfolding the handle: Open the handle clamp and enable the handle to return to its original position during this step of the unfolding the handle of the bicycle. The folding bicycle handle is seen in its unfolded state in the diagram.
2. Unfolding the Frame: The unfolding of the folding bicycle's primary frame or folding body begins. To begin, remove the front and back wheel holder attachments by detaching the Velcro and opening the frame clamp of the folded bicycle, then unfold the main frame or folding body of the folding bicycle.
3. Seat Adjustment: In this step of the unfolding bicycle, open the seat clamp and allow the seat to be adjusted as needed.

Fig -1: Folding mechanism of front rod

Fig -2: Unfolding mechanism of front rod

Fig -3: Folding mechanism of middle rod

Fig -4: Unfolding mechanism of middle rod

3.4 Material Selection

The bicycle's material should be sturdy enough to handle the weight and shocks. On the other hand, it should be light in weight, with the cost of the material being a crucial consideration. The materials listed below can meet the application's requirements.

Table -1: Materials and Properties

Material	Fatigue Strength (Mpa)	Yield Strength (Mpa)	Density (kg/m^3)
Titanium	612	1085	4430
Mild Steel	120	240	7850
Carbon Fibre	402	700	1800
Aluminium	98	280	2710

As demonstrated in Table 1, titanium has the highest strength, but it also has the highest density and cost, making the product heavier to use. Carbon fibre and aluminium have a lower density, but they are more expensive. As a result, mild steel is the greatest choice for us because of its low cost and light weight, as well as its sufficient strength to bear the stresses. As a result, we began our investigation and analysis with mild steel. Mild steel is inexpensive and readily available in the desired diameter and length. One of the key advantages of mild steel is that it is simple to manufacture with since it is welded using an arc welding procedure, which is less expensive than other welding methods. Other materials, such as aluminium alloys, were not chosen because of their limited availability and high fabrication costs. Mild steel tubes in sizes of 1", 1.5", and 0.5" are widely available on the market and are commonly used in traditional bicycle construction. The market hinges are similarly composed of mild steel, making the operation of connecting the frame to the hinges easier.

The chemical composition and mechanical properties of mild steel are listed below.

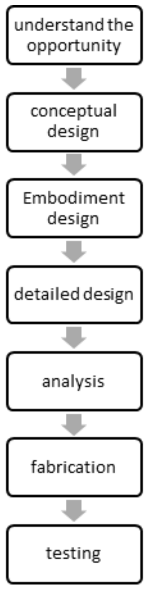
Table -2: Chemical composition of Mild Steel

Chemical Composition	
Carbon	0.16-0.18%
Silicon	0.40% max
Manganese	0.70-0.90%
Sulphur	0.040% Max
Phosphorous	0.040% Max

Table -3: Mechanical properties of Mild Steel

Mechanical Properties	
Maximum Stress	400-560 N/mm^2
Yield Stress	300-440 N/mm^2 Min
0.2 % Proof Stress	280-420 N/mm^2 Min
Elongation	10-14% Min
Young's Modulus	210 GPa

3.5 Stages of Design



The stages of a typical product development process are depicted in this flow chart. The task of concept design is to create a vision for a new product. It examines what is already there and then generates possibilities for developing a new design. The detailed design stage is concerned with the detailed drawings and specifications of the product's components. Welding folding joints to the bike frame at numerous locations is part of the fabrication of the actual electric bicycle.

3.6 Comparison of Concept Designs

Because there were two front rods, the initial design used a single fold in the centre of the bicycle. Because there were two front rods, the complexity of the folds could be increased. The bicycle folded to a volume of 39" X 36" X 22" as a result of its design, which felt a little cumbersome. The hinge's axis was set perpendicular to the ground, and the frame's cross-section was round. The second option, on the other hand, has two folds, one at the front and one at the handle. Approximating the proportions of this design, it takes up a volume of 24" X 30" X 19" after folding, which is a significant improvement over the first option. This design, like the previous one, uses hinges with axes perpendicular to the ground. However, this design is based on a circular cross-section frame.

When the volume occupied, ease of construction, and cost of fabrication were compared, it was discovered that the second option was superior to the first because it took up less room and the fabrication did not appear to be difficult. As a result, the second option was chosen after numerous brainstorming sessions.

Table -4: Parameters of folds

	Before Fold	After Fold
Frame 1	66" X 60" X 22"	39" X 36" X 22"
Frame 2	40" X 50" X 19"	24" X 30" X 8"

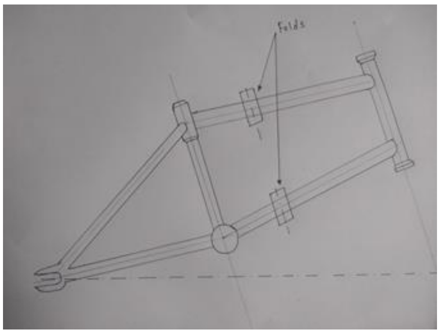


Fig -5: Frame 1

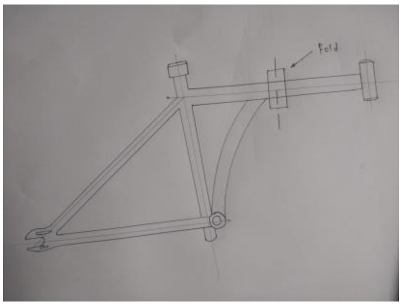


Fig -6: Frame 2

3.6 Selection of Electric Motor

1) Rolling Resistance

Taking,
Coefficient of Friction in Rolling $= 0.015$ (Tyres on Asphalt or Concrete roads)
Design Weight =70 Kg

$$R_r = \mu \times W$$
$$= 0.015 \times 70 \times 9.81$$
$$= 10.300\ N$$

2) Air Resistance

Assume,
Coefficient of Drag $= 0.5$
Air Density $= 1.27\ Kg/m^3$
Air Velocity = Vehicle Velocity = 25 mph = 6.94 m/sec

$$Frontal\ Area = Height \times Width$$
$$= 1.25 \times 0.575$$
$$= 0.7178\ m^2$$
$$R_{air} = C_d \times \rho \times A \times V^2$$
$$= 0.5 \times 1.27 \times 0.7178 \times 6.94^2$$
$$= 21.98N$$

3) Total Resistance

$$Total\ Resistance = R_r + R_{air}$$
$$= 10.300 + 21.98$$
$$= 32.28\ N$$

Considering,
The radius of wheel = inch
Torque required to rotate the wheel $= R_t \times radius\ of\ wheel = 32.28 \times 0.475 = 7.65\ Nm$
Now,
N = Wheel rpm

$$N = \frac{V \times 60}{\pi \times D_w}$$
$$= \frac{6.94 \times 60}{\pi \times 0.475} = 279\ rpm$$

4) Power required to drive the vehicle

$$P = \frac{2 \times \pi \times N \times T}{60}$$
$$= \frac{2 \times \pi \times 279 \times 7.65}{60}$$
= 223.5 Watt

Selected Standard Motor Power = 250 Watt
Specifications of motor are as,

1. Input Voltage, E = 24 V
2. Rated Current, I = 14 A
3. Rated Speed, N =2700 rpm

Selection of Battery
Power Output required $= 250\ Watt$
Required range in one charge $= 10\ Km$
Average speed required $= 25\ Kmph$
Time $= 1\ Hr$

Using, a V Lead Acid Battery,

$$Energy = Power \times Time$$
$$= 250 \times 1$$
$$= 250\ Watt.hr$$

$$Capacity = \frac{Energy}{Volt}$$
$$= \frac{250}{12}$$
$$= 20.8333 \sim 21\ A.hr$$

Table -5: Parameters of Battery

Battery Energy (Watt-hr)	Load (Watt)	Run Time (hrs)
250 Wh	250 W	2 hr
250 Wh	500 W	1 hr
250 Wh	1000 W	30 min

3.7 3D Modelling

3D model of components and assembly of foldable electric bicycle is prepared in Catia software.

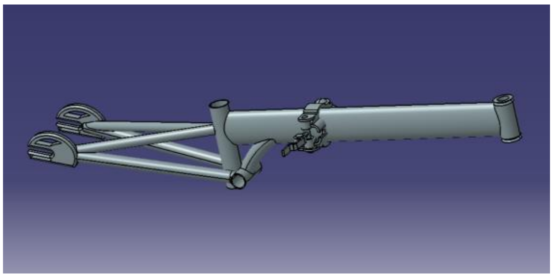


Fig -7: Frame with Joint

Fig -8: Fork with Joint

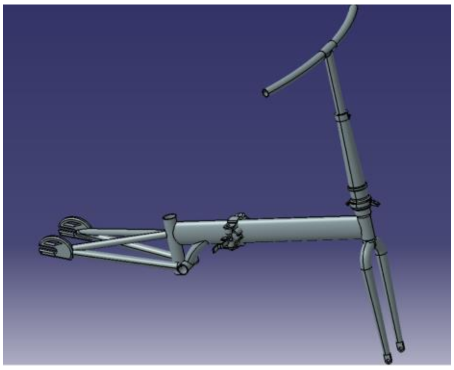


Fig -8: Assembly of Bicycle

3.8 Fabrication

1. We bought the bicycle from a scrap yard and all of the standard components from H. K. Motors in Mumbai, including the battery, engine, brakes, and throttle.
2. Replace the junk bicycle's front handle with another folding handle with a foldable joint.
3. The centre rod is cut and the folding joint is welded to the middle rod.
4. Modification of the hub to include a system for distributing power from the hub to the motor via a chain and sprocket system.
5. Attaching the hub to the back wheel of the bicycle.
6. Mild steel bars for holding the batteries are being fabricated.

Fig -8: Layout of Foldable Electric Bicycle

4. COST ESTIMATION

4.1 Standard Components

Table -6: Cost estimation of standard components

Sr. no.	Name of the component	Quantity	Cost(Rs.)
1.	Motor	1	3500
2.	Battery	2	1400
3.	Controller	1	700
4.	Brakes	1	800
5.	Chain and sprocket	1	400
6.	Alternator	1	300
7.	Standard cycle	1	5000
8.	Joints	2	1500
9.	Throttle	1	650
10.	Solar Plate	1	600
Total			14850

4.2 Machining Cost

Table -7: Machining cost

Sr. no.	Machining process	Cost(Rs.)
1.	Welding	500

2.	Grinding	100
3.	Cutting	100
4.	Painting	200
Total		900

Total cost = 14850+900 = **15750 (Rs.)**

5. CONCLUSIONS

The foldable portable electric bicycle was created using industry-standard data. The fabrication was done with materials that were readily available in the area. The project's goal was to design and develop a portable foldable bicycle that would take up less space in parking and could be taken around. It can be used to reduce walking distance on college campuses and in industrial regions. The vehicle is small, lightweight, and has a simple design, making it portable. Manufacturing costs are moderate. In comparison to other foldable electric bicycles on the market, ours is more technologically advanced, cost-effective, and takes up less room.

The bicycle's seat and handle locations are adjustable, allowing it to be used by both youngsters and adults. Though the bicycle is foldable, sleek, and has small wheels, complete justice is given to the rider's ergonomics, making it comfortable. The idea of providing a foldable bicycle that is light and sleek yet rigid and safe, easy to handle, and easy to maintain was inspired by the idea of providing a foldable bicycle that is light and sleek yet rigid and safe, easy to handle, and easy to maintain. The notion of changing the bicycle to make it compact and easy to carry by offering folding joints, as well as to make it simple by using electric power, has been realized.

5.1 Future Scope

- A cycle's design should be aerodynamic in order to reduce air drag and increase speed.
- Depending on the situation, a higher-voltage battery can be used.
- The amount of battery left can be determined using an electronic display device.
- Utilization of lighter materials for material optimization.
- The use of Ceramic Speed Driven instead of Chain and Sprocket reduces chain sliding.
- Cost-effectiveness is achieved by mass production.

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