International Journal of Interdisciplinary Innovative Research &Development (IJIIRD)
ISSN: 2456-236X
Vol. 08 Issue 02 | 2024

Design & Fabrication of Electric Recumbent Cycle

Harsh Vaidya[1], Prasad Kadam[2], Hanzala Maknojia[3], Rohan Nalawade[4]

[1,2,3&4] *B.E. Mechanical Engineering, MCT's Rajiv Gandhi Institute of Technology, Maharashtra, India.*

ABSTRACT

With fossil fuels running out, harnessing human kinetic energy will offer a quick fix for several mechanical issues and fuel shortages. Gathering energy from renewable sources could also be the key to resolving this issue. Environmentally friendly transportation methods are becoming more and more popular in both developed and developing nations due to recent worries about energy usage and the environment. The primary goal of this project is to design, construct, and test a high-performance Electric human-powered vehicle while adhering to the basic engineering principles and rules established by ASME 2024. Despite their widespread availability, bicycles have yet to reach most of the population. The aesthetics of bicycles and the effort required to drive them are the primary reasons. Safety, comfort, and efficiency drive the design of our HPV. Structural and weight analyses are performed to select the right material for the frame to build a vehicle that is lightweight but strong enough to withstand high loads exerted by the driver during a ride. The vehicle was designed with feasibility and optimal usage in mind, with a 36V 250W-watt capacity motor and a 36V 10Ah Lithium-Ion battery. The vehicle was designed to accommodate our riders' varying physiques, which was accomplished by collecting anthropometric data from all of our riders and verifying it during developmental testing with a physical wooden model of our vehicle. The seat was designed for rider comfort and dexterity by providing appropriate support at various points on the upper body. The team has included an 'Emergency Distress Signal' feature that will allow riders to contact their emergency contacts in the event of an emergency and is confident that this will pave the way for the next generation of Electric- human-powered vehicles.

Keywords: - Recumbent Cycle, Electric Vehicle, Human Powered Vehicle, Turn-By-Turn Navigation, Battery Powered, Hub Motor

1. INTRODUCTION

The semi-recumbent 2-wheel Electric human-powered cycle is designed to provide efficient, safe, and comfortable rides, outperforming its market competitor in every manner. Our intention has always been clear: make our e-cycle suitable for riding on Indian city roads while ensuring driver safety and ergonomics while keeping the Indian market in mind. In addition, we will provide our team members with knowledge and hands-on experience in all applicable engineering principles. Upright bicycles have many advantages like ease of learning, simple drive design, and cheap in construction and maintenance. Our team focused on the proper selection of electrical components for our e-cycle as the key challenge, forming a strong team and spending months researching best-suited components. The next major focus was on chassis design to ensure the driver's safety without sacrificing comfort. Furthermore, the vehicle's aerodynamics were thoroughly examined, which aids in accelerating speed by reducing drag. Learning from previous design mistakes, we made some better changes to our new vehicle. We also referred to various previous reports and designs that had previously fabricated electric cycles to choose the best design for our vehicle and to fabricate the chassis with high accuracy and precision, our team used fixtures for welding the chassis, which allowed us to get accurate angles and dimensions as per our design.

1.1 Problem Statement

Upright bicycles have many advantages like ease of learning, simple drive design, and cheap in construction and maintenance; some of their shortcomings, are listed below.
1. Back Pain - The upright position of the rider while pedaling the traditional bicycle contributes to spinal problems. A lot of back spasms are caused by frequent riders.
2. Quick Rider Exhaustion - The uncomfortable seating position of the rider can cause quick exhaustion. Thus, proving to be unsuitable on long bicycle rides.

3. Lack of Storage Space - An upright bicycle generally has limited or no storage space. Modifications made in them for storage are unconventional and contribute to the instability of bicycles.

1.2 Objectives

The semi-recumbent 2-wheel Electric human-powered cycle is designed to provide efficient, safe, and comfortable rides, outperforming its market competitor in every manner. Our intention has always been clear: make our e-cycle suitable for riding on Indian city roads while ensuring driver safety and ergonomics while keeping the Indian market in mind. In addition, we will provide our team members with knowledge and hands-on experience in all applicable engineering principles.
Design Objectives: 1. To create an e-recumbent bike that can be utilized to travel long distances with ease and offer the rider good ergonomics.
2. To create a budget-friendly, lightweight, and safe design
3. To build a vehicle that balances its speed, weight, and maneuverability to become a comfortable and economical mode of transport.
4. To study and develop new technologies to create a more sustainable future by advancing vehicles with a smaller ecological footprint and longer lifespan.

2. LITERATURE REVIEW

L. Schwab and J. D. G. Kooijman.[1] A case study involving the development of a new front-wheel drive recumbent bicycle is used to introduce the design technique. Bicycle handling attributes are not clearly defined or evaluated; thus the design process compares the uncontrolled dynamics of novel concepts against an established design that is known to handle well. Before going into production, a prototype was constructed, and tests on the road were done to compare how it was handled. Handling quality is an essential consideration in bicycle design.
J. Nieuwendijk.[2] The lengthy chain of the recumbent cycle is the paper's main obstacle. It is challenging to transfer it from the pedals to the back wheels and line it correctly. His issue is resolved by the new Midrace idea, which places the rider's length adjustment in the back frame, between the head tube and the rear axle. The use of equal-sized wheels and a higher rider position in comparison to the low racer are two further design changes. On the other hand, the steering geometry is altered by the suggested length modification in the Midrace at the rear frame, between the head tube and the rear axle.
John Tolhurst.[3] According to the research, extending the rear frame shortens the trail and steepens the steering axis. The dynamics and stability of the bicycle are known to be significantly impacted by the tilt and trail of the steering axis. However, the wheelbase and the mass distribution of the constituent bodies have also changed. The kit was designed to provide people a way around the expensive initial cost of recumbent bikes.
Dr. M. Ashok Rajkumar & Pradyumn Shah.[4] This review paper's primary investigation focused on presenting the concept of utilizing different forms of energy to enhance modern human living. There are a lot more cars on the road these days, which increases fuel consumption and endangers the environment. We must minimize the use of gasoline and the harmful emissions it produces. Keeping this in mind, it's a tiny step in the direction of decreasing the usage of cars with higher fuel consumption and drawing attention to electric bicycles as an alternative. Thus, the goal is to create a battery-operated cycle that will require less human labor and run on a different source.
Chasland, L. C., Green, D. J., Maiorana, A. J., Nosaka, K., Haynes, A., Dembo [5] In this article, using dual-sided electric servo motors with regenerative braking capability, we have designed and constructed a semi-recumbent ECC cycle ergometer that utilizes the kinetic energy produced when a rider applies an assistive force to the pedal during the non-OPP phase to "trip" and arrest the motor-driven pedals (Figure 2). Compared to previous semi-recumbent ECC cycle ergometers that rely on a chain drive system, we propose that this one may enhance the controllability of ECC muscle contractions during semi-recumbent ECC cycling.
I Riveros, L Schiaffino, E Osella [6] Combinations of lower limb rehabilitation techniques are growing. One method combines functional electrical stimulation (FES) with riding a recumbent bicycle. In this case, activating a FES system across many muscle groups produces the power needed to move the pedals. Numerous control strategies were created for these types of platforms, with angular velocity serving as the regulated variable. To minimize the early fatigue effects associated with FES, we have developed a recumbent bicycle rehabilitation platform.

Table 2.1 Comparison of Various Bicycles with Fairings

Parameters	Development of A Fully Faired Recumbent Bike using A Three-Piece Mold	BlueStreak 9.0 DESIGN REPORT	Critical Design Review Report TEJAS 7.0	Aerodynamic Analysis and Fairing Design for a Semi-Recumbent Electric Cycle (E-Cycle)
Reference	International Journal of Engineering Research & Technology (IJERT)	BlueStreak 9.0" VEHICLE NO – 07 NIT, ROURKELA ODISHA-769008	VEHICLE NUMBER-27 National Institute of Technology Silchar	-
Model				-
Material used	Carbon Fiber using vacuum bagging and conventional hand layup techniques 35000 rs	Carbon Fibre + plexiglass 22000 rs	Carbon fibre 17000 rs	Plexiglass or Fiberglass sheets 7000
Major Focus	Material to be used fabrication technique and lower the drag force.	Only drag force lowering	Only drag force under the qualification limit	Ergonomic a low-cost, Drag force under Limit without faring so addition fairing Lower's drag force. Speed efficiency needed to be increased w.r.t distance travel

3. METHODOLOGY

The team examined the other market electric cycle reports to assess the ideas, resources, and designs. After carefully weighing all of the factors, the necessary qualities were chosen by comparing and outlining the benefits and drawbacks. The drive chain, material selection, components, chassis design, and component placement are among the qualities. After considering everything, the necessary features were chosen by contrasting and outlining the benefits and drawbacks.

3.1 Material Selection

Material selection is the most important aspect of an Electric human-powered cycle. The material should have the best properties without compromising the strength and machineability of the frame. The material for E-Cycle was determined on factors like machinability, cost, availability, and strength-to-weight ratio. After comparing the decision matrix we determined that AISI 1018 is the best material for the body of the electric cycle based on our examination of all four materials, which revealed that they are all capable of withstanding the pressures placed on the RPS, as well as their affordability and availability.
Introduction related your research work Introduction related your research work Introduction related your research work Introduction related your research work Introduction related your research work Introduction related your research work Introduction related your research work Introduction related your research work Introduction related your research work Introduction related your research work Introduction related your research work Introduction related your research work Introduction related your research work.

Table 3.1.1 Decision Matrix for Material Selection

Material Selection				
Criteria	Weightage	Steel AISI 1018	Carbon Fiber	Aluminum 6061
Machinability	[4]	5	2	3
Weight Density	[4]	3	5	4
Cost	[3]	4	1	3
Availability	[3]	4	2	3
Strength to Weight Ratio	[4]	3	5	4
Result		68	57	62

3.2 Drivetrain Selection

Both configurations of drivetrain i.e., Forward wheel Drive and Backward wheel drive has their own advantages and disadvantages, Considering various factors like complexity, performance, and cost, our team decided to consider an AWD system for an electric cycle This could be achieved by using a motor on the front and chain drive on the back or vice versa.

Table 3.2.1 Decision Matrix for Drivetrain Selection

Drivetrain				
Criteria	Weightage	FWD	RWD	AWD
Complexity	[2]	2	3	3
Maintenance	[2]	3	3	3
Performance	[4]	2	3	4
Cost	[1]	2	3	3
CG	[3]	2	3	5
Result		26	36	46

3.3 Battery Selection

Out of the two types of batteries Li-on and LiFeSO4, our team chose the best one considering the parameters life cycle, safety, weight, etc.

Table 3.3.1 Decision Matrix for Battery Selection

Battery			
Criteria	Weightage	Li-on	$LiFeSO_4$
Energy Density	[3]	4	3
Cycle Life	[4]	3	4
Safety	[4]	2	3
Cost	[3]	3	2
Availability	[2]	2	2
Weight	[3]	4	2
Result		57	53

4. CAD MODEL & CAE ANALYSIS

The rollover protection system is one of the critical components used in the E - recumbent cycle, acting as a safety element to protect the driver during operational mishaps and crashes. Its primary function is to absorb vehicle impact stresses and minimize their transfer to other components, thereby maintaining a recumbent cycle's overall safety integrity. The same Roll over-protection system is designed by ASME standards and guidelines.

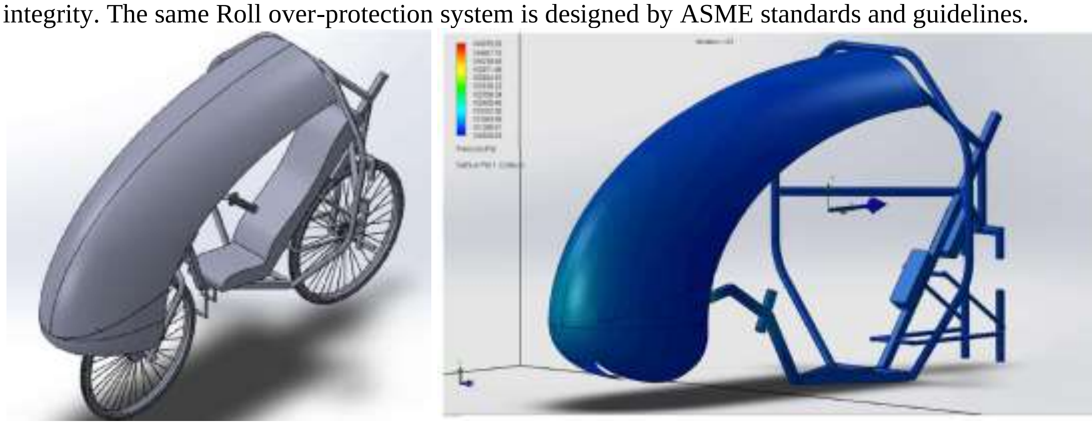

Fig 4.1 CAD Model of E-Cycle

4.1 Analysis Results

After the completion of all the above-mentioned analyses of the various components and parts of structural analysis, aerodynamic analysis, and battery thermal analysis the results obtained are within the safety criteria. The comparative conclusion of the results is as follows –

Sr. No	Analysis	Result	Conclusion
1	Top Load	Displacement – 6.9 mm Stress – 6.062 MPa	Result less than prescribed guidelines. No permanent deformation.
2	Side Load	Displacement – 9.54mm Stress – 4 MPa.	Result less than prescribed guidelines. No observation of the occurrence of fracture on RPS.
3	Rear End Bump	Displacement 7.76mm. Stress – 8 MPa.	No occurrence of fracture on RPS. Hence design under safe limits.
4	Driver and Battery Weight	Displacement – 0.04mm Stress – 0.8 MPa.	Design structural integrity is maintained. Hence design under safe limits.
5	Aerodynamic	Drag Coefficient – 0.57 Lift Coefficient – 0.2	Aerodynamic forces under safe limits.
6	Battery Thermal	Max Cell Temperature – 27.81 degrees.	Battery pack under safe limits.

4.2 Fabrication Techniques

Electric - Human Powered Cycle. After conducting the CAE analysis and ensuring all technical parameters meet the specification requirement as discussed in the previous chapter, the next steps towards project implementation is to manufacture the product by fabrication of the main cycle chassis followed by assembly of required components along with its testing. Before the initial manufacturing of the product to ensure the structural integrity of welding fabrication which is required to be carried out on the chassis additional components known as welding fixtures were designed using SolidWorks by considering the initial chassis dimension and manufactured with the help of CNC Router. The fixtures were made up of MDF wood as it is less costly, light in weight, and easy to machine. The fixtures were cut using a CNC Router Cut machine. To save the material proper nesting of all the panels was done using Fusion 360.

5. RESULTS

After the Initial fabrication of the product, the task was To determine the turning radius of the vehicle by using the methodology which is as follows, Formulating trigonometric equations with vehicle design parameters by simulating the vehicle's position along a curved path and hence, determining the turning radius

Wheel Base, $W = 45$ inches $= 1.143$m

Maximum Possible Steering Angle, $\alpha = 30°$

Then, $\sin\alpha = W/R$ i.e., $R = W/\sin\alpha$

$R = 1.143/\sin 30$

$R = 2.52$ m

The turning radius is 2.52m which satisfies the ASME standards.

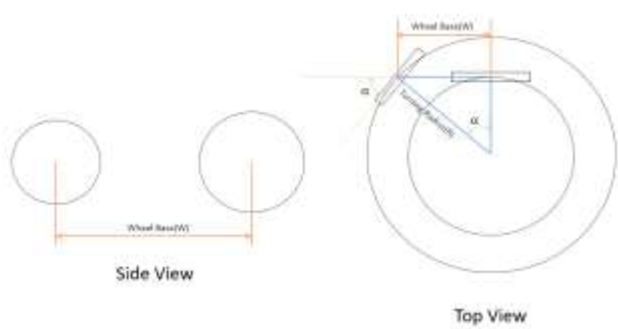

Fig 5.1 Turning Radius Diagram

The main objective of this testing is To determine the capacity of the battery for finalizing the specifications and later testing it under real-world conditions. Firstly, battery rating capacity is found using the analytical method of calculation which is as follows.
To find the amp-hr. rating of the battery:
The capacity of the motor per hour- 250W × 1 hr. = 250Whr
Considering the safety factor of +20 of the 100% capacity,
∴ 250Whr × 1.20 = 300Whr Capacity in terms of Ah, 300Whr ÷ 36V = 8.3 Ah ≈ 10 Ah
Therefore, the minimum requirement of the battery should be 10 Ah.
Therefore, the final battery capacity is 36V 10Ah. Maximum weight carrying capacity of the motor:
250W ÷ 2= 125kg.

6. CONCLUSION

The project aimed to be designed with all Product Design Specification (PDS) requirements and ASME Standards limitations in mind, resulting in the best results. After making the necessary design changes, The project passed all inspections and tests, including those for strength, environmental impact, cost, and other factors. This also fulfils our desire to improve on the initial design's dependability, stability, manufacturability, comfort, and cost-effectiveness. The aim of the project is achieved by creating a vehicle that combines all of the cutting-edge concepts and ideas found in human-powered vehicles. The overall conclusion is represented as follows.

Table 6.1 Conclusion Summary

Sr.no	Design Specification	Target	Obtained	Validation
1	Cost	<Rs. 50,000/-	Rs. 49,530/-	Cost Analysis
2	Weight	<40kg	37 kg	--
3	Field of Vision	Minimum of 180° peripheral vision	180° peripheral vision	--
4	Frame	Safe	Obtained	Structural Analysis
5	Drag Coefficient	<0.8	0.57	Aerodynamic Analysis
6	Min. turning Radius	<6m	2.54m	Turning Radius Analysis
7	Braking	<5m	4m	
8	Speed	>30Km/hr.	35Km/hr.	Motor & Battery Testing

Fig 6.1 Final Product (e-Cycle)

6.1 Future Scope

Many different types of electric mobility are available today in the market. However, the project meets all the current requirements of the drivers, but due to scalability of the model there are limitation which are required to be addressed by further modification. Certain few suggestions for improvements to electric cycle are as follows.
1. Enhancing ergonomics by employing an adjustable seating arrangement system.
2. Improve structural and aerodynamic integrity by adding a full body fairing mechanism.
3. Addition of regenerative braking System.
4. Employment of GPS for ease of travel without worrying about getting lost in a journey.
5. Addition of more safety features such as air bag systems to enhance driver safety.

7. ACKNOWLEDGEMENT

With all reverence, we take the opportunity to express our deep sense of gratitude and wholehearted indebtedness to our respected guide, Dr. Atul G. Londhekar, Department of Mechanical Engineering, Rajiv Gandhi Institute of Technology, Mumbai. From the day of conception of this project his active involvement and motivating guidance on day-to-day basis has made it possible for us to complete this challenging work in time. We would like to express a deep sense of gratitude to our respected Head of the Department, Dr. Rajesh V. Kale who went all the way out to help us in all genuine cases during the course of doing this project. We wish to express our sincere thanks to Dr. Sanjay U. Bokade, Principal, Rajiv Gandhi Institute of Technology, Mumbai and would to like to acknowledge specifically for giving guidance, encouragement and inspiration throughout the academics. Also, I would like to thank our sponsors Mr. Devashish Samanta, CEO at Space & Tech Engineering and Mr. Rupesh Kambli, proprietor of Wohlstand Enterprises for their assistance and financial help in making this project. We would like to thank all the staff of Mechanical Engineering Department who continuously supported and motivated during our work. Also, we would like to thank our colleagues for their continuous support and motivation during the project work. Finally, we would like to express our gratitude to our family for their eternal belief in us. We would not be where we are today without their support and encouragement.

8. REFERENCES

[1] Nieuwendijk, J. (2010) Engineering of Recumbent E-Bikes Proceeding for ASME HPVC 2010 ASME Digital Journal.
[2] John Tolhurst (2002) Race car Vehicle Dynamic for Internation Journal for Recumbent Technology. Volume 4 Issue 2.
[3] William Milliken (2002) Race car Vehicle Dynamic for Internation Journal for Recumbent Technology. Volume 4 Issue 2.
[4] Dr M. Ashok Rajkumar International Journal of engineering and technology, volume 6 issue 4 2018 ISSN 2278-0181.
[5] Jesin James, Jesse Wilson, Jovna Jetto, Alna Thomas, Dhahabiya V K, 2016, “Intelligent IoT in Electric cycle.”, International Conference on Mechatronics and Automation, pp. 332-337.
[6] Sushil Vijaykumar Deshpande, Nitin Santoshrao Chokhat, Satish Akharam Andil, Kunal Suresh Kadam, Jayesh Ashok. Dhake, 2018,”, IJARSE, Vol.7, Issue.3, pp. 1283-1286.
[7] Nehal D. Jadhao and M.S. Tufail, 2017, Review Paper on “Automatic Railway Track Cleaning Machine”, Journal of Basic and Applied Engineering Research, Volume 4, Issue 1, pp.24-27.
[8] R.S. Khurmi, Gupta J.K., 1979, A textbook of machine design, S. Chand Publication, first edition.
[9] Ballany P. L., 2005, Theory of machines & mechanisms, Khanna publishers, Twenty fourth edition.
[10] Bhandari V. B., 2003, Design of machine elements, Mcgraw hill companies, eighteenth edition.
[11] PSG college of Technology, 2003, Coimbatore design data, Kalaikaikathir