

DESIGN AND FABRICATION OF CUSTOMIZED ELECTRIC VEHICLE FOR URBAN MOBILITY

Submitted in partial fulfillment of the requirements for the award of
Bachelor of Engineering degree in Automobile Engineering

By

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SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

Accredited with Grade "A" by NAAC

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the Bonafide work of **MUSTHAKEEM BASHA (39860011)**, **KOTHA SATHWIK (39860009)** who carried out the project entitled "**DESIGN AND FABRICATION OF CUSTOMIZED ELECTRIC VEHICLE FOR URBAN MOBILITY**" under my supervision from November 2022 to April 2023.

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ABSTRACT

Transportation these days has become really expensive and burden to everyone as there is rapidly increasing the price of the fossil fuels and also the increase in the vehicle price. But this problem cannot be ignored. So we have come up with a prototype of an EV which is much compatible and flexible than any other electric vehicle. The use of fuel-powered vehicles is not recommended due to their high consumption of fossil fuels and the significant risk they pose to people's safety. In addition to contributing to noise and air pollution, these vehicles are also powerful and potentially hazardous if not operated with care. As a potential solution to these problems, foldable electric bicycles have emerged as a viable option. Despite the rapid advancement of electric bikes (e-bikes), research on analyzing user experiences with them still lags behind, and it is necessary to address this gap in knowledge. The main goal of this project is to design and fabricate a foldable electric vehicle which can be adjustable according to the driver convenience. We designed a unique chassis which has length of 1600mm, it can be folded to 864mm to its length, two smaller wheels are placed at side of vehicle during folding this wheels balance the vehicle to make it compact size and can be easily transported. We design an electrical height adjustable seat it can adjust maximum length 355mm and the minimum length is 203 mm from the chassis, In this electric vehicle handle can even adjustable up to 25 degrees inclined towards driver as per driver requirement, the hinge lock mechanism is used for handle adjustment. The vehicle is made lighter by using a Lithium ion battery for easier charging and low weight materials for the body. The full charging time for the battery is up to 2hrs and can run up to 40km at a maximum speed of 30kmph.

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CHAPTER 1

INTRODUCTION

The shift towards electric vehicles (EVs) has gained significant momentum in recent years due to their potential to reduce greenhouse gas emissions and air pollution, which are key drivers of climate change and public health problems. Compared to internal combustion (IC) engine vehicles, which release particulate matter and toxins into the atmosphere, EVs emit zero tailpipe emissions, making them a cleaner and more environmentally friendly option.

Moreover, EVs offer greater flexibility in reducing trip times in densely populated areas with heavy traffic congestion, a problem that is increasingly prevalent in many urban areas worldwide. Additionally, the low power demand and reduced reliance on gasoline make EVs an affordable alternative for many consumers.

Recent studies indicate that EVs emit significantly less pollution per km than IC vehicles, especially when considering the life cycle emissions. Furthermore, the benefits of EVs extend beyond environmental and health advantages. Three-wheelers, in particular, have emerged as a practical solution for transportation in many parts of the world due to their compact size and light weight, making them suitable for congested urban areas.

Given the potential benefits of EVs, it is crucial to explore and address the challenges associated with their widespread adoption, including infrastructure, affordability, and consumer acceptance. Through further research and development, electric three-wheelers could play a vital role in promoting sustainable and accessible transportation in densely populated urban areas.

1.1 FOLDABLE ELECTRIC VEHICLES

The foldable electric two-wheeler is an innovative type of electric vehicle that has gained popularity in recent years due to its compact and portable design. The

vehicle's structure is similar to traditional bicycles or scooters, but with an electric motor and battery pack that powers the vehicle. The foldable feature is a unique advantage that allows the vehicle to be easily folded down to a smaller size, making it highly convenient for users to carry and store in limited spaces.

This vehicle has become a popular choice for urban commuters who prefer eco-friendly and cost-effective modes of transportation. It is also an excellent option for short commutes, as it can be quickly unfolded and ridden without the need for parking space. Furthermore, the foldable electric two-wheeler's zero-emission operation makes it an environmentally friendly option for urban transportation, reducing the carbon footprint associated with gas-powered vehicles.

1.1.1 Portability:

Portability is one of the primary advantages of foldable electric two-wheelers. Due to their compact design, these vehicles can be easily transported on public transportation or stored in small spaces such as closets or under desks. This feature makes them an excellent option for city dwellers who need to navigate crowded areas and have limited storage space.

1.1.2 Convenience:

Foldable electric two-wheelers are also highly convenient for short commutes. They can be quickly unfolded when needed, making them ideal for users who need to cover short distances without the hassle of parking. Furthermore, these vehicles emit zero emissions, which contributes to reducing the carbon footprint of urban transportation.

1.1.3 Environmental friendly:

Foldable electric two-wheelers can also help users save money in the long run. Compared to gas-powered vehicles, they are generally cheaper to operate, as they require less maintenance and the cost of electricity is typically lower than the cost of gasoline.

1.1.4 Cost Savings:

Foldable electric two-wheelers can also help users save money in the long run. Compared to gas-powered vehicles, they are generally cheaper to operate, as they require less maintenance and the cost of electricity is typically lower than the cost of gasoline.

1.2 BACKGROUND OF ELECTRIC VEHICLES

The 1960s and 1970s saw a requirement for electric-powered vehicles to decrease the issues of exhaust outflows from gas-powered motors and to lessen the reliance on imported unfamiliar raw petroleum. During the years from 1960 to the present, many endeavors to deliver reasonable electric vehicles happened and keep on happening.

The principal EV (Electric Vehicle) was worked between 1832 and 1839, in Scotland by Robert Anderson. The First Electric tricycle was implicit 1895 by A L Ryker and William Morrison. Electric vehicles are viewed as 97% clean, delivering no tailpipe emanations that can put the particulate matter up high. Particulate matter, cancer-causing agents delivered into the air by internal combustion vehicles can increment asthma conditions as well as other respiratory frameworks while EV makes no such issues. Three-wheeled EV empowers individuals with specific incapacities to travel freely. Likewise in very thick populated settings where EVs are generally utilized, gridlock implies this deftness is significant as far as lessening trip times. They additionally don't require gas and since they are light vehicles with a low power interest, re-energizing them is inside the limits of a spending plan of quite a large number of individuals. E-mopeds radiate significantly less contamination per km than vehicles in view of life cycle discharge examination. The Indian bike industry has embraced the new idea of electric bicycles and bikes that are exceptionally famous methods of individual vehicles in the created nations like America, Japan, and China. With the increasing expense of fuel at global furthermore, public level, expanding levels of the populace and clog in transport framework, particularly in metropolitan

regions, higher running and upkeep cost of the vehicle, the power charged mopeds have exceptionally splendid future in the area of individual transportation. The essence of the car industry, which was re-imagined with the innovation of eco-friendly four-cycle motor innovation, is all set to see the sunrise of another time in the bike industry. It's not petroleum or diesel or some other fuel, but rather its power that has started an upheaval in the bike industry.

The bike market has as of late gotten further blow after the choice of cost climb taken by the Association of Trading Nations (OPEC) alongside a rising pattern of expansion (over 10%). Both these issues have opened new roads for battery-worked bicycles that are getting notoriety, known as E-mopeds (Electric mopeds). Emopeds depend on power innovation wherein battery-powered batteries supplant the regular motor. E-mopeds can be charged effectively as a cell phone. Also, we don't need a permit to ride E-mopeds. It is very clear that this is climate amicable that gives a smooth and safe drive.

This task is one more step toward the advancement of the electric vehicle situation. This e-sulked is having highlights like collapsing component for taking care of stopping issues, three wheels for better solidness, and minimal size which makes a difference in surfing effectively in crowdie regions. As the populace is expanding there is an expansion in requests for cars. Because of expansion in vehicles, individuals will require space for driving and likewise for stopping. As we probably are aware there is restricted space accessible and because of expansion in the number of vehicles on streets they are causing gridlock and with that, they require a spot for stopping. Notwithstanding these contamination is likewise vital these days. The contamination is arriving at new cutoff points step by step. So the thought of a foldable and compact vehicle comes into the idea. The Foldable e-bicycle is a bicycle that can be collapsed effectively; thus it doesn't need a stopping place. The size of the foldable e-bicycle is multiple times less than a typical vehicle. Because of its smallness, it tends to be utilized in different shopping centers, enterprises, school grounds, and so forth foldable e-bicycle can be utilized to cover long distances many

examples. It can be utilized for numerous reasons on the streets. Rather than hanging tight in line for a taxi or transport. It can be collected in around 1 to 2 minutes and accompanies utilitarian brake lights and blinkers.

To beat previously mentioned disadvantages in the current creation, we can replace the motor with an engine and battery. Be that as it may, it will add more weight to the vehicle. Foldable E-bicycle can be gathered and camouflaged at whatever point expected too as we can convey it anyplace. In the event that necessary, we can collect it in less than ten minutes and drive it. In this foldable e-bicycle, we utilized three wheels, out of that the power is given to the back tires through the shaft, and direction of the vehicle is done by the front wheel. Power is delivered in the vehicle utilizing a DC brush electric engine. Assuming there is no utilization of the vehicle then we can just dismantle the vehicle parts and can keep it. This convenient vehicle can convey weight up to 100kg and it has a most extreme speed of 30 km/hr. The Foldable Electric bicycle will run on a battery, the power is provided by the engine, subsequently providing the ability to drive the other stuff parts. The principal reason for utilizing this E-bicycle is that it is easy to use, affordable, and moderately modest. The effectiveness of this framework is evident contrasted with customary methods of transport. Unwanted environmental change is a sign of not utilizing more non-renewable energy sources any longer. The best other option for the auto energizes to give portability and transportation to people groups is a feasible electrical bicycle. Future e-bicycle is the best-specialized application as a visionary answer for the better world and forthcoming age. The primary motivation to distinguish the need of finding and altering E-Bicycle is to conquer the issue of contamination in light of vehicles in metro towns and metropolitan zones developing uninterruptedly. Taking into account a class of society it is not sensible for all to buy (bikes, mopeds, or on the other hand bikes). Thus, consolidating issues, ecological advancement support, and the prudent reasonable option would be the best solutions.

CHAPTER 2

LITERATURE REVIEW

[1] James, O., Swiderski, J., Hicks, J., Teoman, D., Buehler, R., 2019. Pedestrians and e-scooters: An initial look at e-scooter parking and perceptions by riders and non-riders. *Sustainability* 11 (20), 5591.

The issue of miss-parked e-scooters and their impact on public spaces has been a topic of concern in recent years. They conducted a study in the United States to analyze the issue of miss-parked e-scooters, particularly in terms of their impact on sidewalks. The study found that e-scooters were often left in areas that blocked sidewalks, causing accessibility issues for pedestrians.

Moreover, the study also examined the replacement effect of e-scooters for other forms of transportation such as taxis, bicycles, public vehicles, and walking. The study found that e-scooters can provide a convenient and cost-effective mode of transportation for short distances, which can reduce the use of cars and, in turn, alleviate traffic congestion and air pollution.

[2] McKenzie, G., 2020. Urban mobility in the sharing economy: A spatiotemporal comparison of shared mobility services. *Comput. Environ. Urban Syst.* 79, 101418.

Two studies conducted by McKenzie in 2019 and 2020 explored the impact of bike-sharing systems and e-scooters on commuting trip purposes and shared mobility services' usage patterns.

According to McKenzie's 2019 study, bike-sharing systems play a substantial role in facilitating commuting trip purposes. However, the same cannot be said for e-scooters, which have not yet shown to have a significant impact in this area.

In McKenzie's 2020 study, the focus was on shared mobility services' usage patterns. The study found that micro-mobility options such as e-scooters are a quicker and more portable choice for travel during specific conditions, such as top hours and in

metropolitan settings, when compared to auto trips. This suggests that shared micro-mobility services have the potential to provide a viable alternative to traditional modes of transportation.

[3] Eccarius, T., Lu, C.-C., 2020 Multimodal Level of Service Analysis for Urban Streets. In (pp. 120p): Transportation Research Board.

The study shows the relationship between the sharing system of e-scooters, environmental values, and user intentions. The authors found that understanding the sharing system and environmental values could indirectly affect the user's intention to use e-scooters.

Another study by McKenzie in the US in 2019 analyzed the usage patterns of bike-sharing systems and e-scooters. The author concluded that while bike-sharing systems facilitate commuting trip purposes, this is not the case for e-scooters.

In a follow-up study in 2020, McKenzie examined the usage of micro-mobility, including e-scooters, in specific conditions such as peak hours and metropolitan settings. The author found that micro-mobility options are a quicker and more convenient choice than auto trips in these situations.

[4] Caspi, O., Smart, M.J., Noland, R.B., 2020. Bikes sharing in Philadelphia: Do lower-income areas generate trips? *Travel Behav. Society* 16, 143–152.

This paper offers to examine the usage pattern of e-scooters. Their findings indicated that e-scooter usage is more prevalent in areas that have cycling facilities and high rates of employment. Additionally, the study found that commuting is not the primary trip purpose of e-scooters. These results suggest that e-scooter usage is more likely to occur in areas with high levels of activity and access to alternative modes of transportation. Therefore, policymakers and transportation planners should consider providing cycling facilities and alternative transportation options to encourage the adoption of e-scooters.

[5] Nikiforiadis, A., Basbas, S., Garyfalou, M.I., 2020. A methodology for the assessment of pedestrians-cyclists shared space level of service. *J. Cleaner Prod.* 254, 120172

This paper outlines the usage pattern and attitudes of e-scooter users were analyzed. The results of the study indicate that e-scooters are mainly used as a substitute for walking and public transport trips. Additionally, the study found that e-scooters are more popular among males than females. The downtown area was also found to have a high exposure to e-scooters. Understanding user attitudes and behavior patterns can be useful for policymakers and city planners to make informed decisions regarding the implementation and regulation of e-scooters in urban areas.

[6] Uidon, S., Becker, H., Dediu, H., Axhausen, K.W., 2019. Electric bicyclesharing: a new competitor in the urban transportation market? An empirical analysis of transaction data. *Transp. Res. Rec.* 2673 (4), 15–26

Research found that compared to shared bicycles, more females are utilizing shared e-scooters. This suggests that e-scooters may be more attractive to a wider range of users than traditional bicycles. Understanding the usage patterns and user attitudes towards e-scooters is crucial for urban planners and policymakers in promoting sustainable and equitable transportation systems.

[7] Mitra, R., Hess, P.M., 2021. Who are the potential users of shared e-scooters? An examination of socio-demographic, attitudinal and environmental factors. *Travel Behav. Society* 23, 100–107.

This paper focuses on the user's demand for shared e-scooters. Their findings showed that most participants would replace walking and public transport trips with shared e-scooters. The study also revealed that the quality of walking and biking facilities, as well as street safety, played a significant role in increasing the likelihood of considering travel by e-scooters. This highlights the potential for shared e-scooters

to improve sustainable transportation options in urban areas.

[8] Lee, H., Baek, K., Chung, J.-H., Kim, J., 2021a. Factors affecting heterogeneity in willingness to use e-scooter sharing services. *Transp. Res. Part D: Transp. Environ.* 92, 102751

This focused on the willingness to use e-scooters as a mode of transportation for last-mile trips. The research found that e-scooters are a reliable solution to the last-mile problem. Furthermore, the study identified that there are variations in the choice of last-mile trip mode based on past experiences with e-scooters and income levels. This research highlights the potential of e-scooters as an effective and accessible mode of transportation for short-distance travel, especially for those facing transportation challenges in urban areas.

[9] Abduljabbar, R.L., Liyanage, S., Dia, H., 2021. The role of micro-mobility in shaping sustainable cities: A systematic literature review. *Transp. Res. Part D: Transp. Environ.* 92, 102734.

Their study examines the emerging concept of micro mobility and its potential to address mobility challenges from a sustainability standpoint. The study focuses on micro-mobility modes including cycling, e-scooters, and e-bikes. According to the authors, these modes of transport have the potential to alleviate problems such as congestion and accessibility discomfort that are often experienced in urban areas. The study emphasizes the importance of adopting sustainable transportation modes and highlights the potential benefits of micro mobility for urban transportation.

[10] O'Hern, S., Estgfaeller, N., 2020. A scientometric review of powered micromobility. *Sustainability* 12 (22), 9505.

This paper entails on powered micro-mobility, including e-bikes, e-skateboards, and e-scooters, identified an increase in the trend of micro-mobility since 2012. The review revealed that several topics such as users' behaviour, planning, policy, and health were commonly researched. Despite the positive trend in the popularity of micro-mobility, concerns over the safety of these modes of transport have been

raised. Researchers have suggested that policies, regulations, and infrastructure should be developed and implemented to enhance the safety of powered micro-mobility. The authors also noted the potential of powered micro-mobility to provide an alternative solution to urban mobility challenges, such as traffic congestion and accessibility discomfort, in the coming years.

[11] Method to Determine Level of Service for Bicycle Paths and Pedestrian Bicycle Paths. *Transportation Research Record*(1502), p. 38-44. Brown, A., Klein, N.J., Thigpen, C., Williams, N., 2020.

This paper offers that e-scooter and bike riders utilize the parking facilities when they are available, indicating the importance of adequate parking facilities for these modes of transportation. Providing additional parking facilities could contribute to the reduction of violations and safer sidewalks. The findings from this study highlight the importance of addressing parking concerns to ensure the safe and efficient use of micro-mobility modes.

[12] Kopplin, C.S., Brand, B.M., Reichenberger, Y., 2021. Consumer acceptance of shared e-scooters for urban and short-distance mobility. *Transp. Res. Part D: Transp. Environ.* 91, 102680

They investigated the usage pattern of e-scooters with a focus on owners and renters. They found that young, male, and well-educated individuals were the primary users of e-scooters. Both renters and owners of e-scooters were likely to substitute walking and public transport trips with e-scooter trips. Furthermore, the study suggested that e-scooters could potentially replace car trips as well. These findings are consistent with other studies conducted in different countries, highlighting the potential of e-scooters as a mode of transportation that can address the challenges of urban mobility.

[13] Moran, M.E., Laa, B., Emberger, G., 2020. Six scooter operators, six maps: Spatial coverage and regulation of micro-mobility in Vienna, Austria. *Case Stud. Transp. Policy* 8 (2), 658–671.

The spatial variance in scooter geofences and parking issues in Austria. The study found that there are certain areas where parking facilities for e-scooters are lacking, such as close to parks, pedestrian corridors, and cultural institutions. These findings suggest the need for improved planning and policy measures to ensure the provision of adequate parking facilities for e-scooters in high-demand areas.

[14] E-scooter Vibration Impact on Driver Comfort and Health. *J. Vib. Eng. Technol.* 9 (6), 1023–1037. Cao, Z., Zhang, X., Chua, K., Yu, H., Zhao, J., 2021.

Micro-mobility has become a popular mode of transportation in recent years, with e-scooters being one of the most widely used vehicles. They investigated the usage patterns of e-scooters, focusing on the efficiency of short-distance trips in Singapore. The study found that the use of e-scooters is more likely when there is a higher level of transport indirectness, more connections, and more access-egress walking, indicating that e-scooters are a preferred mode of transportation for short-distance trips with less direct access to public transportation. These findings highlight the potential benefits of e-scooters in providing more efficient transportation options in urban settings.

[15] Kopplin, C.S., Brand, B.M., Reichenberger, Y., 2021. Consumer acceptance of shared e-scooters for urban and short-distance mobility. *Transp. Res. Part D: Transp. Environ.* 91, 102680. Laa, B., Leth, U., 2020.

This paper investigates the consumer acceptance of e-scooters. The authors found that e-scooters are mainly considered an entertainment device, rather than a primary mode of transportation. The study also indicated that the substitution of cars for e-scooters is weakly supported and can only be recommended for short-distance trips. The results of this study provide valuable insights into the usage patterns of e-scooters, as well as their potential as a sustainable mode of transportation.

CHAPTER 3

AIM AND SCOPE OF PRESENT INVESTIGATION

3.1 AIM

The primary aim of this research project is to design and construct a foldable electric two-wheeler that is not only comfortable but also cost-effective. According to recent studies, electric vehicles are considered to be 99% cleaner than gasoline-powered vehicles, as they emit no exhaust emissions that could pollute the air with harmful particulates. Gasoline-powered vehicles, on the other hand, release pollutants into the atmosphere that can worsen asthma and respiratory conditions. Electric vehicles, which are propelled solely by electric motors, are a cleaner and more sustainable mode of transportation.

As a folding two-wheeler, this vehicle will be highly portable and easy to transport from one place to another. This feature is especially important for urban dwellers who often rely on public transportation and need a compact and flexible mode of transportation to get around crowded cities. The research will also focus on gathering data on the user's attitudes and demand for such a vehicle, as well as exploring its potential impact on reducing emissions and improving air quality in urban environments.

3.2 OBJECTIVE

The primary objective of this project is to design and fabricate a foldable electric two-wheeler that is affordable, easy to use, and suitable for urban mobility. The vehicle is designed to be compact and lightweight for convenient storage and transportation. The body construction of the two-wheeler is made of lightweight materials to reduce the overall weight and increase energy efficiency. The vehicle is powered by a Lithium-ion battery for better charging and longer battery life.

The project focuses on urban mobility to provide an alternative means of transportation for normal people who want to navigate through the city with ease. Automotive mobility is becoming increasingly necessary in modern life, especially in urban areas. However, some people may not have access to cars due to various reasons. Therefore, this foldable electric two-wheeler can provide a convenient mode of transportation for those individuals.

CHAPTER 4

MATERIALS AND MODELLING

4.1 MATERIAL SELECTION

The selection of materials is a crucial factor in designing and fabricating a vehicle that is lightweight and robust. Structural steel and aluminum alloy are two commonly used materials in the automotive industry due to their strength, durability, and lightweight characteristics. The use of structural steel in the chassis and other structural components provides high tensile strength and impact resistance, while aluminum alloy is widely used for its lightweight properties. The choice of material ultimately depends on various factors, such as strength requirements, weight, cost, and availability. The material selection process must consider the trade-offs between these factors to ensure that the final product is both structurally sound and lightweight.

4.1.1 Structural Steel

Structural steel is a carbon steel, meaning it has a carbon content of up to 2.1 percent by weight. After iron, carbon is the most important element in carbon steel. Increasing the amount of carbon in the composition of steel results in materials that have high strength and low ductility.

Structural stiffness relates to how a component bends under load while still returning to its original shape once the load is removed. Since the component dimensions are unchanged after load is removed, stiffness is associated with elastic deformation.

4.1.2 Aluminum Alloy

Structural stiffness is the basic value to consider when designing an aluminum alloy material stiffness is very little depending on alloy. Crashworthiness is beginning to be simulated recently. However, impact tests systematically check the resistance to accidental collisions such as pavements impacts and etc.

A perfect mass balance is a key parameter to avoid significant vibrations. As a result, cast and forged wheels are mostly machined. Lightness also reduces vibrations of aluminum wheels. Cast and forged wheels are painted or lacquered after chemical conversion. Strip wheels are polished and varnished or also painted. This methods prevents the wheel from corrosion

4.2 MATERIAL PROPERTIES

Table 4.1 Material properties of structural steel

Young's Modulus	2*105 MPa
Poisson's Ratio	0.3
Density	7.85e-006 kg/mm ³
Thermal Expansion	1.2e-005 1/°C
Tensile Yield Strength	250. MPa
Compressive Yield Strength	250. MPa
Tensile Ultimate Strength	460. MPa

Table 4.2 Material properties aluminum alloy

Young's Modulus	5 GPa
Poisson's Ratio	0.33
Density	2700
UTS	296.4 MPa
Strength Coefficient	562.5
Strain hardness (n)	0.5487
Yield Strength	155 MPa

4.3 DESIGN AND DEVELOPMENT

The improvement procedure of the vehicle chassis consists of different factors that are fabric choice, pass segment determination, body layout and the finite detail evaluation. The chassis should be designed in such a way that should observe various kinetic energy impacts during different conditions. By using best fabric for the

4.4 CAD MODEL OF THE ELECTRIC VEHICLE

Technical drawing of a bicycle frame showing dimensions in millimeters (mm). The frame is shown in profile, with the following dimensions labeled:

- Top tube: 660mm
- Down tube: 610mm
- Seat tube: 610mm
- Seat post: 760mm
- Chain stay: 432mm
- Wheelbase: 1600mm
- Head tube: 1016mm
- Bottom bracket height: 430mm
- Seat height: 305mm

16

Figure 4.1 shows the schematic diagram of the Electric vehicle which is made using CAD software. In this diagram detailed dimensions of the vehicle is shown. The foldable electric two-wheeler has a rectangular rear seat with storage space below it, a rear wheel hub motor, a bonnet lock for folding mechanism, an external hinge lock, and a front axle. A smaller wheel supports the vehicle during folding, and a brake lever is provided for the rider. The top view of the vehicle displays the front axle and electric motor, which can adjust the handle as per the rider's preference. The folding structure includes a rectangular rear seat that can be folded to provide additional storage space. The vehicle's front coil suspension provides better comfort during uneven road conditions, and there are two small wheels at the center of the body that help balance and carry the vehicle during folding conditions. The triangular front seat is adjustable electrically with the help of a linear actuator mechanism to provide driver comfort. A center bolt is also present, which helps to fold the vehicle. The rear wheel protects the vehicle from stone chipping.

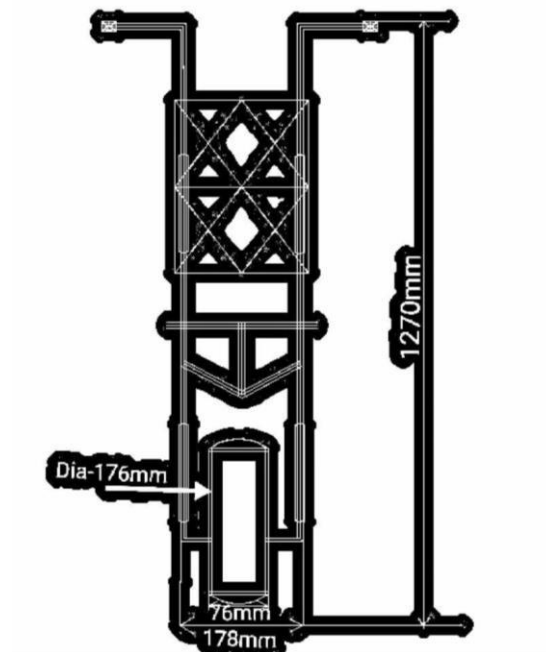


Fig 4.2 Front view of the Electric vehicle in assembly state with dimensions.

Figure 4.2 displays the front suspension of the vehicle, hinge lock mechanism, and handle bending mechanism, which can be adjusted according to the driver's preference. This mechanism is placed on the suspension mechanism, and there is

also a linear adjustment of the handle. The rear rectangular seat of the vehicle, along with the rear coil suspension placed below the body. The rectangular seat is positioned on the body of the electric vehicle, and there is a rear live axle located above the rear coil suspension. These figures help to give a more comprehensive understanding of the design and functionality of the two-wheeler electric vehicle.

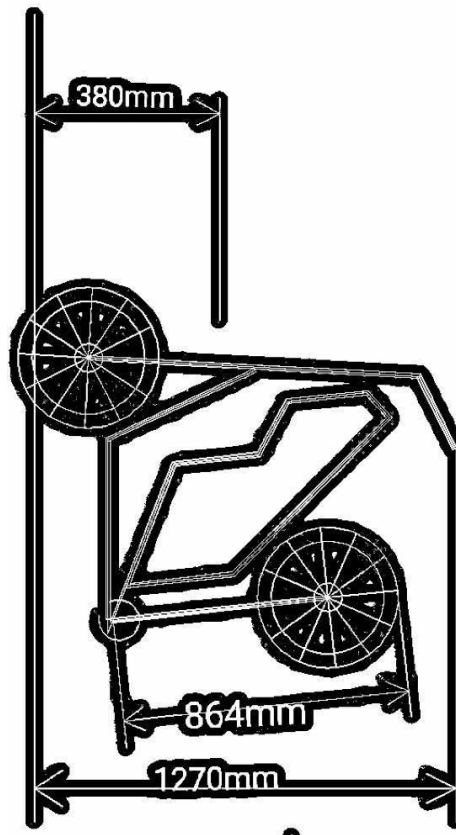


Fig 4.3 Side view of the Electric vehicle in folded state with dimensions.

The above shows the vehicle in a folded state, with the hinge lock mechanism connected to the handle and vehicle chassis to ensure smooth folding. The battery box of the two-wheeler electric vehicle is located below the driver's seat, and the folding mechanism is visible in the form of a mechanism that helps the vehicle to fold. During the folding process, two smaller wheels placed at the center balance the vehicle. In addition, the front wheel stud on the front coil suspension, as well as the light and horn switches of the two-wheeler electric vehicle, are visible. The electrical key is also visible and is used for starting and stopping the vehicle.

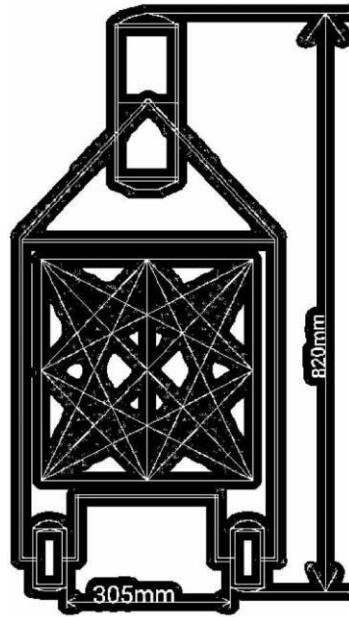


Fig 4.4 Front view of the Electric vehicle in folded state with dimensions.

The folded state displays the front wheel of the vehicle, which is positioned on top during folding. Additionally, there is a foot space that folds during the folding of the electric vehicle. There is also a bonnet lock mechanism that unlocks during folding, and these two components are designed as a single body.

CHAPTER-5

ANALYSIS AND FABRICATION

5.1 INTRODUCTION TO ANSYS DESIGN MODELER

Ansys Design Modeler is a software tool that enables three-dimensional modeling. Unlike other 3D modeling software, Ansys Design Modeler is not purely three-dimensional. Instead, it allows the user to draw in planes and then extrude solids from the planes to obtain a position in three-dimensional space. This approach offers more precision and control over the geometry of the model.

To create a model using Ansys Design Modeler, a parametric feature-based approach is used. This means that the model's shape and geometry are determined by a set of parameters, either numeric or geometric, that are linked together to capture the design intent. Numeric parameters, such as line lengths and circle diameters, can be related to each other using a relation to ensure that the design intent is preserved throughout the modeling process.

The software starts with a 2D or 3D sketch of the desired shape, which is then extruded or reduced to add or remove material from the component. Shape-based features like extrude bosses, holes, and slots can be easily added to the model to achieve the desired design.

The process for creating a robotic arm, for example, begins with geometric modeling using solid modeling software like Pro/Engineer. Ansys Design Modeler, being a Parasolid-based solid modeler, can then be used to refine the geometry of the model and create assemblies. Parameters can be used to control the dimensions and geometry of the robotic arm to ensure that the design intent is met.

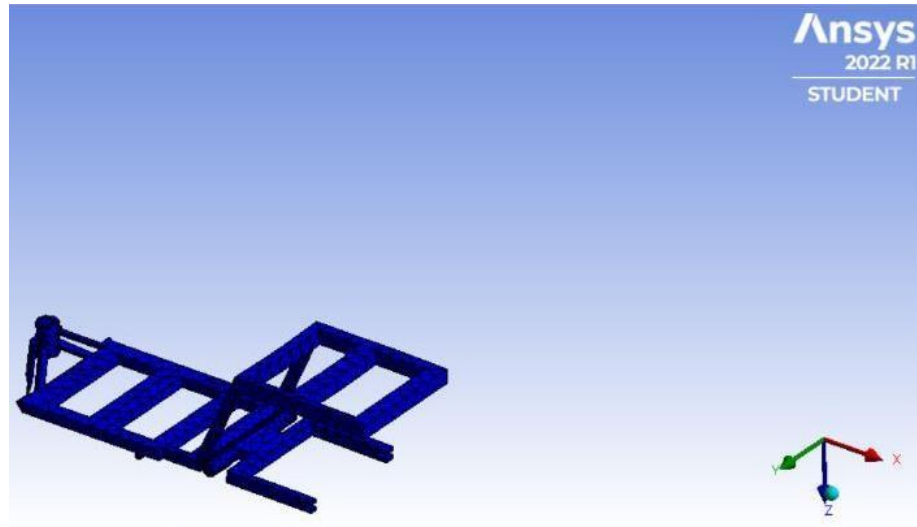


Fig 5.1 Chassis Layout

The layout of the chassis is to inclusive of a motive force effectively and safely. Principal elements of the chassis targeted on in the course of the layout and implementation Total blanketed motive force protection, suspension and drive-teach integration, structural pressure, weight, and operator ergonomics. The supposed fabrication is essential because of the constraints of the talents and competencies of the construct group in addition to layout directives. The goal is to optimize the chassis design by modifying folding mechanism.

5.2 CRASH ANALYSIS INTRODUCTION

A crash simulation is a digital Endeavour of a negative crash take a look at of a automobile the usage of a laptop simulation if you want to look at the extent of protection of the automobile and its occupants. Crash simulations are utilized by automakers in the course of Computer-Aided Engineering (CAE) evaluation for crashworthiness withinside the Computer-Aided Design (CAD) procedure of modeling new chassis design.

During a crash simulation, the kinetic strength, strength of movement that a vehicle chassis has earlier than the effect is converted into deformation strength.

Data acquired from a crash simulation imply the functionality of the automobile

chassis shape to guard the occupants in the course of a collision (and additionally pedestrians hit with the aid of using a vehicle) in opposition to injury.

5.2.1 Front Impact Analysis

For worst situation in the front effect of vehicle chassis, it's far assumed to hit a wall at pace of 40 km/hr. Hitting a wall will deliver most viable pressure as wall is non-deformable frame and effect time will smaller Impact evaluation is used to confirm the protection of the motive force. In this evaluation situation, it's far assumed to be the vehicle chassis hits the wall at the rate of 40km/hr. The fabric kind is chosen for the evaluation is the elastoplastic. Frontal crash analysis of a designed chassis

- The wall is fixed and is taken as a rigid body
- The velocity of the vehicle chassis in negative direction is 40 km/hr

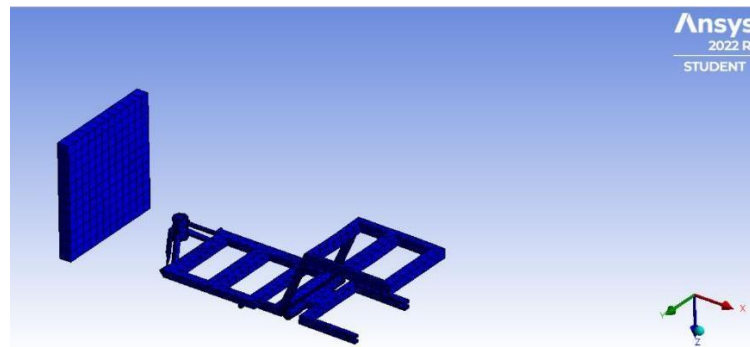


Fig 5.2 Frontal Crash analysis

The above figure represents the frontal crash test, here the wall is of fixed support as rigid support and the velocity of the car in negative direction is considered as 40km/hr

5.2.2 Total Deformation Of Structural Steel Designed Chassis

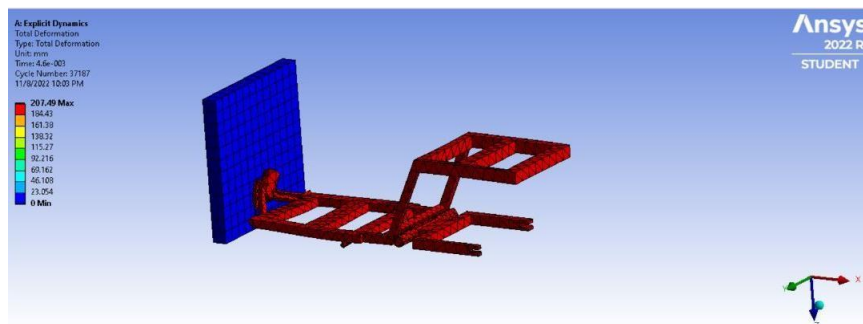


Fig 5.3 Structural Steel designed chassis Total Deformation

Figure 5.3 represents the total deformation of the structural steel in frontal crash test, the deformation is medium in front portion of the vehicle chassis.

5.2.3 Equivalent Stress Of Steel Designed Chassis

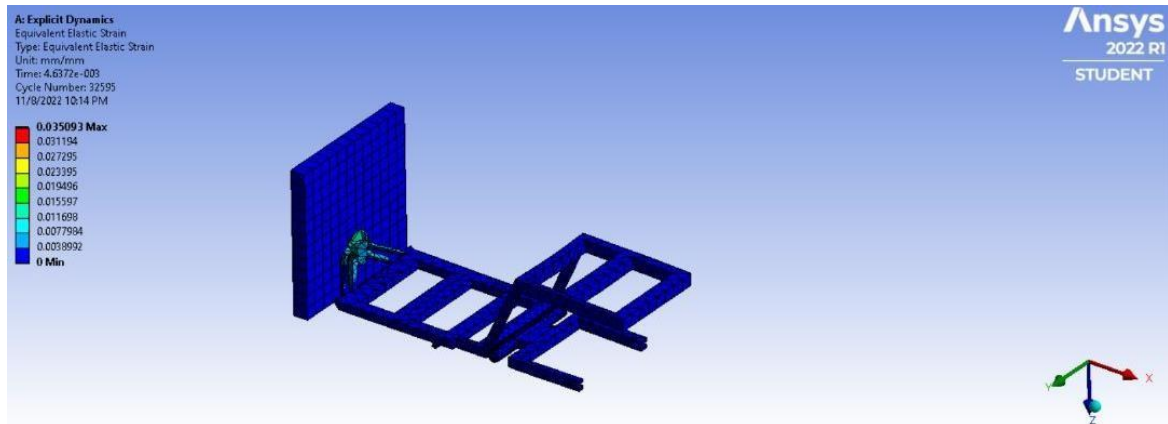


Fig 5.4 Structural Steel Equivalent Stress

The above figure represents the equivalent stress of a structural steel designed chassis, in frontal crash test we analyzed that stress is normal in the frontal portion of the vehicle chassis while comparing with other areas.

5.2.4 Total Deformation Of Aluminium Alloy Designed Chassis

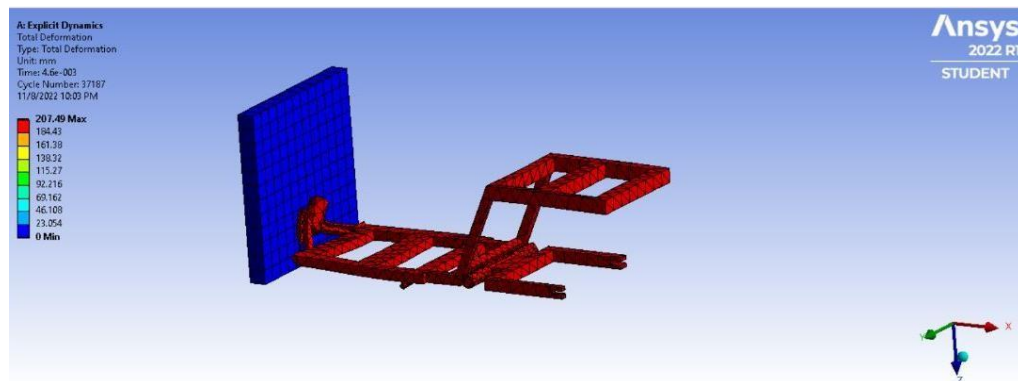


Fig 5.5 Aluminum alloy designed chassis Total Deformation

Figure 5.5 represents the total deformation of the aluminum alloy in frontal crash test, the deformation is high in front portion of the vehicle chassis.

5.2.5 Equivalent Stress Of Aluminium Alloy Designed Chassis

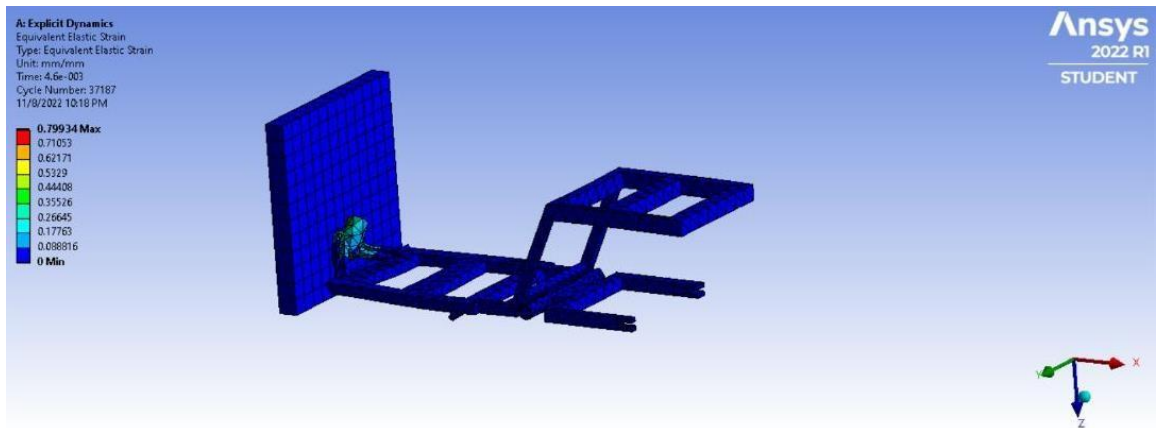


Fig 5.6 Aluminum Alloy Equivalent Stress

Figure 5.6 measures the Equivalent Stress of an aluminum alloy during the frontal crash test we found that the stress is higher at the center portion of the frame. While analyzing the other areas of the vehicle chassis.

5.3 FRAME

The chassis or frame of an electric two-wheeler serves as the primary support structure to which all other components are attached. It is similar to the skeletal system of living organisms. In contrast to older car models, modern electric two-wheelers have a unibody construction design, which means that the frame and body are integrated into a single unit. The frame provides support to the mechanical components and body of the vehicle while enduring static and dynamic loads without any significant deflection or distortion. It is welded to the axles and holds the motor and body, and it must be sturdy enough to withstand the stresses of various loads such as vertical loads, cornering loads, side thrust, acceleration, and braking dip. The frame is covered in a variety of accessories and components, and its material must be cost-effective. To choose the appropriate frame for the electric two-wheeler, we considered factors such as available pipe sizes, maximum stresses on the crucial components, and the available safety factor.



(a)



(b)

Fig 5.7 Schematic view of Electric vehicle frame

5.4 FOLDABLE JUNCTION

To facilitate easier transportation, the foldable electric vehicle incorporates a bonnet lock mechanism located at the center of the vehicle. This mechanism can be operated via a cable to enable folding, which reduces the vehicle's length by up to 737mm. With this compact design, the vehicle's length is reduced by half when the handle is folded at a 90-degree angle, and the two wheels located at the center rotate 90 degrees. The three-wheel configuration during the folding process ensures that the vehicle is balanced, making it easier to transport. The compact folding structure of the electric vehicle is a significant advantage in terms of transportation, enabling cost savings while also reducing its overall dimensions.



Figure 5.8 Schematic Folding view of Electric vehicle

Table 5.1 Dimensions of the Electric vehicle

Total Length Before Folding	1600 (mm)
Total Length After Folding	864 (mm)
Height Before Folding	1270 (mm)
Height After Folding	820 (mm)
Breadth	305 (mm)

5.5 COMPONENTS OF THE ELECTRIC VEHICLE

The foldable electric two-wheeler consists of various components that are arranged and connected in a specific order, with each component having its unique specification and function. For the vehicle to operate in good working condition, it is crucial that all components are properly connected. The main parts are:

- BLDC hub motor
- Li-ion Battery
- Controller
- Charger
- DC-DC Converter
- Wiper Motor

5.5.1 BLDC Hub Motor

In a brushless motor, permanent magnets rotate around a fixed armature, eliminating the need for a brush/commutator assembly to supply electricity to a moving armature. Instead, an electronic controller shifts the phase to the windings to keep the motor spinning, using a solid-state circuit to conduct equivalent timed power distribution. Compared to brushed DC motors, brushless motors offer several advantages such as higher torque per weight, higher torque per watt, better efficiency, increased reliability, decreased noise, and a longer lifetime.

One notable advantage of brushless motors is that they are not subject to centrifugal forces because there are no windings on the rotor. Additionally, the windings are supported by the housing, which allows for cooling by conduction, eliminating the need for airflow inside the motor for cooling. This enables the internal components of the motor to be fully encased and protected from dirt and other foreign matter.

Research has shown that brushless DC motors have an efficiency of 84 percent, making them an ideal choice for various applications. Furthermore, they have a higher power-to-size ratio than brushed motors, meaning they can generate more power in a smaller space. These characteristics make brushless motors an

increasingly popular choice for a wide range of industries, including automotive, aerospace, and robotics.



Fig 5.9 36v 250w BLDC hub motor

Table 5.2 Hub motor specifications

Properties	Values
Rated power	250 W
Voltage	36 V
Speed	250 RPM
Current	7 A
Torque	60 Nm

5.5.2 LI-ION Battery

A lithium-ion battery, also known as Li-ion battery, is a type of rechargeable battery composed of cells that utilize lithium ions to transfer energy between electrodes. During discharge, the lithium ions travel from the negative electrode to the positive

electrode through an electrolyte, while during charging, the ions move in the opposite direction. The positive electrode of a Li-ion cell is typically made of an intercalated lithium compound, while the negative electrode is commonly composed of graphite.

Li-ion batteries have a high energy density and a low self-discharge rate, making them an attractive choice for various applications, such as portable electronic devices, electric vehicles, and renewable energy systems. Depending on the desired application, the electrodes of Li-ion batteries can be made of different materials. For instance, lithium cobalt oxide and graphite are commonly used in portable electronics, while lithium iron phosphate and lithium manganese oxide are popular in electric vehicles.

The electrolyte of a Li-ion battery can also vary depending on the application. Ether, which is a class of organic chemicals, is frequently used in commercial Li-ion batteries due to its low volatility and high conductivity. Additionally, Li-ion batteries can be optimized for either energy density or power density, depending on the specific needs of the application.

Li-ion batteries have numerous advantages over other types of batteries, including high energy density, long cycle life, and low maintenance. However, they also have some disadvantages, such as the risk of thermal runaway if they are overcharged or exposed to high temperatures. Ongoing research and development in Li-ion battery technology are focused on improving their performance, safety, and cost-effectiveness to enable wider adoption in various applications.

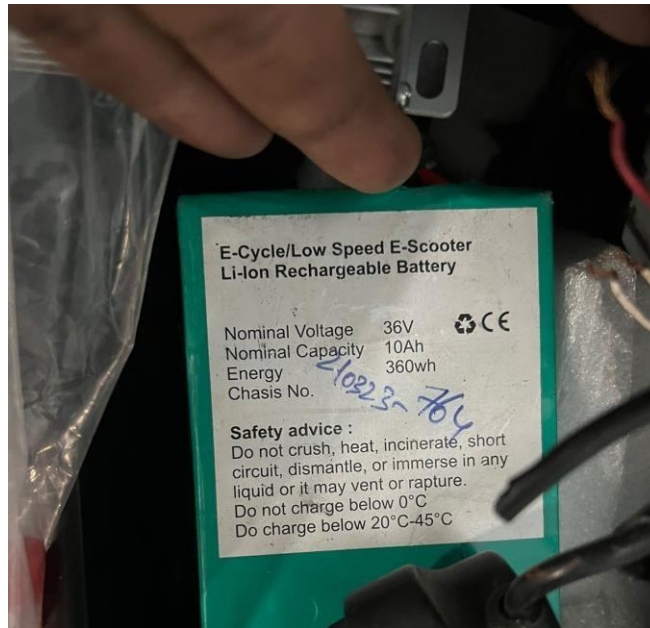


Fig 5.10 36v Li-ion battery

5.5.3 Controller

The controller serves as the crucial component of an electric vehicle, acting as the central nervous system that ensures optimal vehicle performance in terms of speed, acceleration, and range per charge. Its main function is to connect the motor to the battery, while regulating energy conversion by controlling speed and direction. The torque-to-speed ratio is typically managed by the controller, which utilizes the armature current to control torque and the armature voltage to regulate speed. To control voltage, the controller employs chopping source current, where the voltage is turned on and off, with the ratio of on-to-off determining the average voltage. The number of constant-width "on" pulses per unit time can be altered, as can the pulse width duration. Power electronics circuitry incorporates diodes, thyristors, and silicon control rectifiers (SCRs) to facilitate chopping. The controller's efficiency is usually around 90%, and its primary purpose is to manage electrical motor performance.

The DC motor controller's characteristics are influenced by the type of motor employed, whether brushed, brushless, or stepper, as well as the device's functionality. The design and working principles of an electric vehicle DC motor controller for a brushless DC (BLDC) motor differ significantly from those of an

industrial DC motor controller for a brushed motor. Research indicates that BLDC motors offer several advantages over brushed DC motors, such as higher efficiency, greater torque density, and lower maintenance requirements. They also have higher power-to-weight ratios, which make them more suitable for electric vehicle applications. Furthermore, the use of advanced algorithms, sensors, and control strategies, such as field-oriented control (FOC) and predictive torque control (PTC), has improved the performance and efficiency of BLDC motor controllers.



Fig 5.11 Controller

5.5.4 Charger

When an electric vehicle runs for 45 kilometers, the battery's energy level is depleted and requires recharging. To accomplish this, a charger is needed. However, it's important to note that batteries cannot be charged directly from an AC power supply. Instead, the AC current must be converted to DC. This conversion process is achieved using a charger that incorporates a step-down transformer, rectifier, and

filtering circuit to maintain a constant voltage output.

Charger technology has come a long way in recent years, with numerous advancements contributing to more efficient and faster charging times. For example, newer chargers can provide higher power outputs, which enables faster charging of electric vehicle batteries. Additionally, smart charging technologies, such as bidirectional chargers, allow for two-way energy flow, allowing EV owners to not only charge their vehicles but also sell energy back to the grid during times of high demand.

Another significant development in charging technology is the use of renewable energy sources to charge electric vehicles. Solar panels, for instance, can be installed on homes or at charging stations to generate clean energy for EVs. Furthermore, wireless charging, also known as inductive charging, is becoming more prevalent, with companies working to develop high-powered wireless chargers that can charge EVs while they're in motion. Overall, charging technology continues to evolve, providing more efficient and sustainable ways to power electric vehicles.



Fig 5.12 Charger

5.5.5 DC-DC Converter

A DC-DC converter is a critical component in foldable electric vehicles (EVs) that enables efficient power management by regulating the voltage level of the vehicle's electrical system. In foldable EVs, space is a crucial consideration, and therefore, DC-DC converters are designed to be compact and lightweight.

A DC-DC converter takes the high-voltage DC output from the battery and converts it to the appropriate voltage level for different vehicle components, such as the motor, lighting system, and infotainment system. It accomplishes this by using switching devices, such as transistors, to control the voltage and current flow. The output voltage can be either higher or lower than the input voltage, depending on the requirements of the system.

Foldable electric vehicles require a DC-DC converter that is not only compact but also efficient. Recent advances in DC-DC converter technology have led to the development of more efficient and lightweight models that are suitable for foldable EVs. For example, new gallium nitride (GaN) and silicon carbide (SiC) power semiconductors offer higher efficiency and faster switching times than traditional silicon-based semiconductors. This results in smaller and lighter DC-DC converters that provide higher power density and reduce energy loss during conversion.

Moreover, research into new topologies and control strategies for DC-DC converters, such as interleaved and multilevel converters, has also led to improved performance and efficiency. These advanced topologies distribute the load across multiple converters, reducing current ripple and improving efficiency.



Fig 5.13 DC-DC Converter

5.5.6 Wiper Motor

A wiper motor is an electric motor that is responsible for powering the windshield wipers on vehicles. It is mounted on the vehicle's firewall or wiper assembly, and it must provide enough torque to operate the wipers efficiently, even when under heavy loads, such as wiping snow or debris from the windshield. The wiper motor is usually controlled by a dashboard switch that sends a signal to the motor to turn on and off at a desired speed.

Most modern wiper motors are made using permanent magnet technology, which offers several advantages over other motor types. These benefits include smaller size, lighter weight, and higher efficiency, which result in less strain on the vehicle's electrical system.

Wiper motors are also used in other industries, such as the marine industry for controlling boat windshield wipers. In these applications, the wiper motor must be durable and able to withstand harsh environments, such as saltwater and extreme temperatures.

The wiper motor is a crucial safety feature in automobiles, as it ensures driver visibility during inclement weather conditions. Regular maintenance, including checking the wiper blades and ensuring proper lubrication, is essential to ensure optimal performance and longevity of the motor. It's important to note that wiper motor failure can sometimes be caused by a blown fuse or faulty switch, so it's important to address these issues before replacing the motor itself.



Fig 5.14 Wiper Motor

5.4 FABRICATION PROCESS

The fabrication process of a foldable electric two-wheeler involves several stages to ensure the production of a robust and reliable structure. The frame material selection is crucial as it must provide adequate strength and rigidity while being lightweight. For this purpose, lightweight materials like aluminum alloys are preferred over mild steel.

The frame fabrication process involves the cutting and welding of the material to form the frame structure. The frame design must take into consideration the foldable mechanism while maintaining structural integrity. The folding mechanism must also be designed to ensure that it can withstand repeated folding and unfolding without failure.

In addition to the frame, the assembly of various components is necessary for the successful operation of the foldable electric two-wheeler. These components include

the motor, battery, controller, wheels, brakes, and suspension system. The assembly process must be carried out in a specific order and with the correct torque settings to ensure that the components are installed correctly and function efficiently.

To improve the overall design and performance of foldable electric two-wheelers, manufacturers are exploring the use of lightweight and advanced materials like carbon fiber composites. Carbon fiber composites offer high strength-to-weight ratio and stiffness, making them an ideal choice for foldable electric two-wheelers.



Fig 5.15 Initial stage of fabrication

Figure 5.15 depicts the preliminary stage of fabrication for a foldable electric two-wheeler, where the frame assembly process is underway. The frame material has been cut and welded to form the frame structure, and the hinge mechanism is being welded to connect the main frame and the main body. The hinge mechanism is crucial in enabling the folding mechanism of the two-wheeler while maintaining structural integrity. In addition to the hinge mechanism, other foldable mechanisms such as quick-release clamps, locking pins, and folding pedals are also incorporated in the design of foldable electric two-wheelers. These mechanisms must be designed to withstand repeated folding and unfolding without failure, and to ensure a smooth and reliable folding process.

The use of foldable mechanisms allows for easy storage and transportation of the electric two-wheeler, making it a practical solution for urban commuting. As such, the design and fabrication of foldable electric two-wheelers are continually evolving to meet the growing demand for eco-friendly and efficient transportation options.

Ongoing research in this area focuses on developing more advanced folding mechanisms, exploring the use of lightweight and sustainable materials, and improving the overall design and performance of foldable electric two-wheelers. These advancements are expected to increase the adoption of foldable electric vehicles in urban environments and contribute to a more sustainable future.

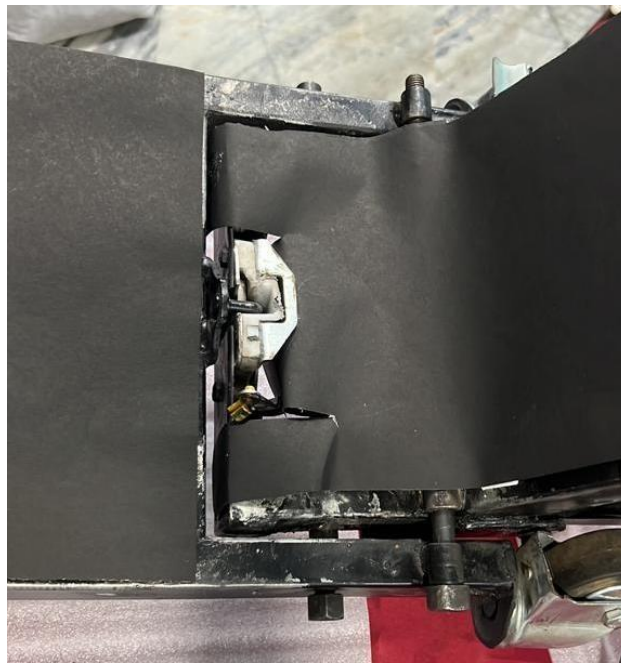


Fig 5.16 Hinge at the mid section of electric two wheeler

In the fabrication process of a foldable electric two-wheeler, a hinge mechanism is essential to enable the folding of the vehicle. Figure 31 shows that the hinge at the mid-section of the two-wheeler is secured using a bonnet lock mechanism, which prevents free swiveling movement and ensures the safety and stability of the vehicle while in use.

Along with the hinge mechanism, various components such as the battery, controller,

hub motor, wheels, and charger are assembled and fitted in separate locations based on the specific application and design requirements. The placement and arrangement of these components must be carefully considered to optimize the overall performance and functionality of the vehicle.

Moreover, the use of a bonnet lock mechanism in the hinge system of foldable electric two-wheelers is becoming increasingly popular due to its ease of use and improved safety features. This mechanism typically involves the use of a latch and lock system, which securely fastens the two parts of the hinge together and prevents accidental opening or separation during operation.



Fig 5.17 Wiring setup of the electric two wheeler

Our research involved conducting a comprehensive literature review to gather relevant technical information that could guide the project. We used a defined design methodology to create the most efficient and reliable configuration for the foldable electric two wheeler. In the process, we carefully considered mechanical, electrical, and rider compatibility issues, along with factors such as component selection,

aesthetics, and ergonomics.

The foldable electric two wheeler we designed is suitable for normal people who desire an affordable, environmentally-friendly, and convenient mode of transportation for urban mobility. It is powered by an electric motor, making it easy to use and maintain. Its compact size and light weight make it suitable for transportation via car trunks, public transit, and elevators. The manufacturing costs are moderate, making it an affordable option for people of different economic backgrounds.

CHAPTER 6

SUMMARY AND CONCLUSIONS

A foldable electric two wheeler with a range of 40km on a single charge was successfully designed and developed. The compact size of the vehicle, which can be reduced up to 864mm after folding, makes it easier to transport and reduces transportation costs based on dimensions and weight. The vehicle's working mechanism is simple and mainly operated using the throttle on the handle, making it suitable for normal people. The electric vehicle has been designed with excellent pulling capacity, modified mechanical components, comfortable travel, simple maintenance, and a small number of components. The vehicle's performance was evaluated under various operating conditions, including battery backup and time durations. The vehicle's intended speed is set to 35 kilometers per hour.

- The foldable electric vehicle is a two-wheeler design that features a brushless direct current hub motor with 36V and 250W, powering a rear driving wheel.
- A set of lithium-ion batteries with a voltage of 36V are connected in parallel and positioned beneath the seat to act as the primary power source for the 36V hub motor. The rotational motion generated by the motor provides the linear motion necessary for the movement of the vehicle, with a phase angle of 120 degrees.
- The BLDC hub motor rotates the wheel at 250 rpm, generating the necessary linear motion for the vehicle, when it receives power from the lithium-ion batteries
- To charge the 36V lithium-ion battery, a 42V lithium-ion charger with a 10Ah capacity is utilized, taking approximately two hours to complete a full charge. With a single charge, the vehicle can travel a distance of 35-40kms. Compared to typical lead-acid batteries, the lithium-ion battery makes the electric vehicle lighter, with a GVW of 40kg.
- A bonnet lock mechanism located at the center of the vehicle can be

operated via cable to facilitate a foldable operation, reducing the length of the vehicle up to 737mm. This compact design allows for greater ease in transportation.

- Positioned at the center, the hinge lock serves as external support for the bonnet lock mechanism in the event of failure.
- To enhance the attachment to the frame, mild carbon steel coated with 5mm thick zinc sheets is incorporated to cover both the main body structures and electrical components.
- In order to provide important information about the status of the battery, the handlebar of the vehicle has a battery level indicator that is connected to the power supply via the controller. The combination switch, which can be turned on or off with a key, is also present.
- An automatic power cut-off system is incorporated in the electric vehicle to enhance safety. This system establishes an electrical connection between the controller and the front and rear brakes. In the event of an emergency, the system is activated, cutting off the power supply to the hub motor and enabling the vehicle to come to a halt swiftly.
- The foldable electric vehicle features four wheels, and when it is being folded, the handle is folded at a 90-degree angle, and the two wheels at the center of the vehicle rotate 90 degrees, causing the vehicle's length to be reduced by half. During the folding process, the vehicle is balanced on three wheels, making it easy to transport.
- The driver's seat is equipped with an electric jack mechanism that includes a 12V, 4.2A electric motor, allowing for easy and precise adjustment of the seat to the driver's preference.
- The height of the driver's seat can be adjusted to a maximum of 355 mm, while the minimum distance of the seat from the chassis is 203 mm.
- The foldable design of the electric vehicle offers a significant advantage in terms of transportation, as it can be folded into a compact structure, resulting in reduced dimensions and providing cost savings.

REFERENCES

- [1] A comparative analysis of e-scooter and e-bike usage patterns: Findings from the City of Austin, TX. *Int. J. Sustain. Transp.* 15 (7), 571–579. <https://doi.org/10.1080/15568318.2020.1833117>.
- [2] Abduljabbar, R.L., Dia, H., Liyanage, S., 2021. The role of micro-mobility in shaping sustainable cities: A systematic literature review. *Transp. Res. Part D: Transp. Environ.* 92, 102734.
- [3] Baek, K., Chung, J.-H., Kim, J., Lee, H., 2021a. Factors affecting heterogeneity in willingness to use e-scooter sharing services. *Transp. Res. Part D: Transp. Environ.* 92, 102751.
- [4] Basbas, S., Garyfalou, M.I., Nikiforiadis, A., 2020. A methodology for the assessment of pedestrians-cyclists shared space level of service. *J. Cleaner Prod.* 254, 120172
- [5] Brown, A., Klein, N.J., Thigpen, C., Williams, N., 2020. Method to Determine Level of Service for Bicycle Paths and Pedestrian Bicycle Paths. *Transportation Research Record*(1502), p. 38-44.
- [6] Brand, B.M., Kopplin, C.S., Laa, B., Leth, U., Reichenberger, Y., 2021. Consumer acceptance of shared e-scooters for urban and short-distance mobility. *Transp. Res. Part D: Transp. Environ.* 91, 102680. Laa, B., Leth, U.,
- [7]Burghard, U., Dütschke, E., 2019. Who wants shared mobility? Lessons from early adopters and mainstream drivers on electric carsharing in Germany. *Transp. Res.* .
- [8] Cao, Z., Chua, K., Zhang, X., Yu, H., Zhao, J., 2021.E-scooter Vibration Impact on Driver Comfort and Health. *J. Vib. Eng. Technol.* 9 (6), 1023–1037.
- [9]Cavill, N., Kahlmeier, S., Racioppi, H., Rutter, P., Spatial associations of dockless shared e-scooter usage. *Transp. Res. Part D: Transp. Environ.* 86, 102396 d. 2008.
- [10]Crowe, B.S., Elkbuli, A., 2021. Electric scooters and traumatic injuries: A review of the literature. *Am. J. Emerg. Med.* 42, 162–166.
- [11] Christoforou, Z., de Bortoli, A., Gioldasis, C., Seidowsky, R., 2021. Who is using e-scooters and how? Evidence from Paris. *Transp. Res. Part D: Transp. Environ.* 92, 102708.

- [12] . Cherry, C., Fishman, E., 2016. Understanding cyclists' perceptions, keys to a successful bicycle promotion. *Transp. Res. Part A: Policy Pract.* 63, 1–11
- [13] Caspi, O., Smart, M.J., Noland, 2020 R.B. Bikesharing in Philadelphia: Do lower-income areas generate trips? *Travel Behav. Society* 16, 143–152.
- [14] . De Ceunynck, T., Wijnhuizen, G.J., Fyhri, A., Gerike, R., Kohler, " D., Ciccone, A., Dijkstra, A., Dupont, E., Cools, M., 2021. Electric scooter-related injuries: the desperate need for regulation. *Am. J. Emerg. Med.* 47, 303–304
- [15] D. Teoman, J. R. Hicks, J. Swiderski, James O. Buehler, and J. Teoman authored the 2019 article "Pedestrians and e-scooters: An initial look at e-scooter parking and perceptions by riders and non-riders" in *Sustainability*, volume 11 (20), pages 5591.
- [16] Dowling, R.G., Reinke, D.B., Flannery, A., Ryus, P., Vandehey, M., Petritsch, T.A., et al., 2008. Assessing the Willingness to Use Personal e-Transporters (PeTs): Results from a Cross-National Survey in Nine European Cities. *Sustainability* 13 (7), 3844.
- [17] Estgfaeller, N., O'Hern, S., 2020. A scientometric review of powered micromobility. *Sustainability* 12 (22), 9505.
- [18] Emberger, G., Laa, B., Moran, M.E., 2020. Six scooter operators, six maps: Spatial coverage and regulation of micro-mobility in Vienna, Austria. *Case Stud. Transp. Policy* 8 (2), 658–671.
- [19] E-bikes in the Mainstream: Reviewing a Decade of Research. *Transp. Rev.* 36 (1), 72–91. <https://doi.org/10.1080/01441647.2015.1069907>.
- [20] Eccarius, T., Lu, C.-C., 2020. Multimodal Level of Service Analysis for Urban Streets. In (pp. 120p): Transportation Research Board.
- [21] Eccarius, 2020 Multimodal Level of Service Analysis for Urban Streets. In (pp. 120p): Transportation Research Board., T., Lu, C.-C.
- [22] . Fernandez-Heredia, Jara-Díaz, S., Monzon, ´ A., 2014. Adoption intentions for micro-mobility – Insights from electric scooter sharing in Taiwan. *Transp. Res. Part D: Transp. Environ.* 84, 102327

- [23] Fitch, D.T., Handy, S.L., Sharpnack, J., 2020. The psychological stress of bicycling with traffic: examining heart rate variability of bicyclists in natural urban environments. *Transp. Res. Part*
- [24] Hess, P.M., Mitra, R., 2021. Who are the potential users of shared escooters? An examination of socio-demographic, attitudinal and environmental factors. *Travel Behav. Society* 23, 100–107.
- [25] McKenzie, G., 2020. Urban mobility in the sharing economy: A spatiotemporal comparison of shared mobility services. *Comput. Environ. Urban Syst.* 79, 101418