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DESIGN AND FABRICATION OF E-BIKE

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ABSTRACT

The project revolves around improving and harnessing different forms of energy. In today's world, vehicles on the road are increasing daily. With it, the demand for fuel is also on the rise—the hazardous effects of fuel on the environment cause severe problems for all life on Earth. Combustion vehicles constitute a significant source of air pollution, contributing to more than half of the carbon dioxide, carbon monoxide, nitrogen oxides, and more than a quarter of the hydrocarbons emitted into the air. Efforts for a better future are being made with the introduction of environmentally friendly, electric vehicles on the road. Electric Bicycle is one of these products. It is not only an upgraded version of conventional cycles but can also replace petrol bikes that use combustion for their propulsion. Electric bikes can be an effective means of transportation in societies, universities, and plants and for local conveyance. Our Research focuses on the design and fabrication of the e-bike, which uses an electric motor to propel and will also have a pedal that would mechanically drive the cycle. The electric power generated can give better fuel economy than conventional vehicles, better performance, and will cause little or no environmental pollution. The E-bike would be able to switch between multiple modes easily depending on the rider's needs. The proposed E-bike has the potential to break the electric vehicle market and also has a better cost and working efficiency than the other.

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CHAPTER 1 INTRODUCTION

Motivation

The need to reduce dependency on fuel-based vehicles is growing day by day. Organizations worldwide are concerned about the environmental state of the Earth and the speed with which it is deteriorating. Moreover, to work out these issues, the exploration and expansion of electric vehicles is one of the trending topics. This has led to several advancements in Electric vehicles in recent years. For example, electric vehicles have started taking over transportation in an exceedingly short time. E.V.s are a future concept, and their use opens new possibilities. For example, most of the E.V.s used today can directly compete with their Internal combustion vehicles counterpart and even make I.C.s look outdated in comparison (Justice, 2022) (Cohen, 22).

Electric bikes are now emerging as one of the most popular daily-use vehicles. The readiness of people to switch from motorbikes to electric bikes is a good indicator that people do care about the environment and are ready to change themselves. E-bikes are popular because they have higher speeds than regular bikes, and they can make long routes more comfortable by assisting on the way and allowing the rider to rest (Johnson, 2023).

An E-Bike can serve multiple benefits; it does not cause pollution and can promote good health by allowing people to exercise. The E-bikes can help reduce the pedal load due to the use of motors that allow us to pedal easily to the destination or rely entirely on the motors to take someone to their destination. Since it is essentially a bicycle, traffic jams will not be an issue (Sodexo, n.d.).

What Is an Electric Bike?

Electric Bikes or E-Bikes can be considered motorized bicycles. With a motor integrated into its construction, E-bikes are used to assist the rider during cycling to reduce the workload for them. The motor gets its power from a rechargeable battery equipped with the bike.

Several types of E-bikes are available in the market, but broadly they can be classified into two types (REI, 2023).

- **Pedal Assist:** These bikes come with a motor that starts working when pedaling, reducing the effort needed for pedaling.
- **Throttle:** These bikes have a throttle-controlled motor that can be used whenever possible. Pedaling is unnecessary to benefit from the motor, but extended use will surlily drain the battery. However, for extended battery time, pedaling is needed in between.

A new type of E-bike is also being introduced in the market: Pedal Assist and Throttle based. One can switch between different modes depending on the conditions or the rider's preference.

Working Of an E-Bike

The working of an E-bike is the same as that of a regular bike, with just the inclusion of a motor, battery, and some electrical components to make cycling easier by taking off some of the pedaling load. Two types of motors are widely used with E-bikes to serve the purpose of pedal assist or throttle.

- Hub Drive Motors: The motor is built into the wheel hub in this type. It can be further classified into
    - Direct Drive
    - Geared Hub
- Mid Drive Motors: These motors are more efficient and can provide a long range. They provide a better cycling experience but are more expensive than the others.

Mid-drive motors allow the power to be transmitted through the chain; hence, all the external and internal gears present can be utilized efficiently in varying conditions (Cavallari, 2022).

Components Of an E-Bike

E-bikes are entirely similar in construction to any regular bicycle. The wheel, frame, brakes, chain, pedal, gears, Etc., are all the same. The critical components that make it an E-bike are stated in this section (Robu, 2021).

- **Battery Pack:** The energy source for the bike and, ultimately, one of the expensive components. Lead Acid or Nickel Cadmium batteries were used in the early days, but now Li-ion-based batteries dominate. E-bikes use rechargeable batteries, and they vary according to voltage, total charge capacity, weight, number of charging cycles before performance declines, Etc. The charging cost may be small, but the replacement cost is high. Performance is mainly dependent on the type of usage of the E-bike.
- **Motor:** It turns the electrical energy from batteries into mechanical work to rotate the wheels. The location of the motor varies for different bikes. The most important attribute for any motor is motor winding constant in rpm/V or Kv, which tells how much maximum rotational speed is available for a given battery voltage. Typical E-bike hub motors are wound around eight rpm/V, but other variations are also available.
- **Controller:** A component that connects all electric parts of the e-bike, including the motor, battery, throttle, and other sensors. The controller acts as the heart of the e-bike. It protects the motor from over and low voltage over temperatures. It also protects motor windings from over-current. The controller uses power from the battery to drive the hub motor and sends signals to the bike's motor at varied voltages.
- **Throttle:** A device that controls the amount of power delivered to the motor. The throttle propels the bike without needing to pedal. Most used throttles in e-bikes are half-twist throttles which propel the bike by twisting the throttle. Another type of throttle is a thumb throttle, which propels the bike with the simple push of a button. Throttling can come in handy when:
    - Moving up a hill
    - A quick boost is required.
    - Move around obstacles.

- **Display:** E-bikes are all equipped with a detailed display to provide a dashboard of what is happening. The display shows the battery status and provides the speed of the E-bike and the rpm from the motor. In addition, the controller serves the function of providing the data for display.

E-Bikes Are Healthier For Us!

E-bikes have shown themselves to be a healthy and environmentally friendly transport solution. These e-bikes, being cheap and having lower running costs, are the new future of transport. However, the most essential feature is that they allow for reduced fossil fuel consumption. Therefore, the margin by which one reduces their carbon footprint is applaudable (Sodexo, n.d.).

The increasing population has also caused an increase in the number of cars and motorcycles. This has led to increased traffic, ultimately resulting in increased carbon emissions. However, an e-bike transcends all this because its small and flexible body allows it to soar through the traffic and reach the destination on time. E-bikes are a sustainable product with virtually no harm to the environment.

Moreover, we have seen that the overall health of people is improving due to lack of exercise, and that is where E-bikes come in to help. E-bikes can serve as an exercise for us. Although they are pedal-assisted, it still fulfills their purpose and is suitable for our physical and mental health.

Moreover, E-bikes can reduce fuel expenses because petrol or diesel is costlier than charging a battery at home, taking almost the same mileage. One can argue about the speed, but still enjoyable time management can help in this regard (Cohen, 22).

CHAPTER 2 LITERATURE REVIEW

Bicycles have been around for more than one hundred and fifty years now, and since then, they have been one critical and one of the most used means of transportation. Thus, it is not strange to know that The Application of electric motors in Bicycles is a familiar idea. as the first patent for an electric bike was filed by Ogden Bolton Jr. in 1895, shortly after the invention of the Rover safety bicycle (Rize, n.d.). Despite the first patents referring to bicycles with electric motors integrated appearing in the 1890s, it was in the late 1990s that EAPCs started to become popular. In the past 30 years, Electric Bicycle technology has seen many improvements, and a lot of Research is being done in this field.

- **Study to Establish E-bikes as an Alternative to Conventional Transportation in Australia (2006)**

Research conducted by Alan A. Parker to study the necessity to alter Australia to survive the anticipated depletion of the world's standard oil reserves (cheap oil) between 2010 and 2020. victimization of bicycles, electrical P.A.B., sand E-bikes, rather than several 'drive alone automobile journeys,' is one of several measures needed to conserve oil in traveler transport. dynamic the Australian and state road rules to encourage inexperienced merchandise just like the electrical P.A.B.s can cut back automobile and oil dependence and gas emissions by tiny, however vital quantity. Legislation permitting the most power output of three hundred watts for the ready-bodied is needed, and to reinforce the quality of the old, the lame, and the disabled, the most power output of 600 watts is needed.

- **Development of Electric motor and other e-bike testing equipment (2006)**

The Research was conducted by Vidyadhar Gulhane, Mr. Tarambale, and YP Nerkar to develop testing equipment to evaluate electric motors and other e-bike components. There square measure some common problems associated with electric vehicle technology. These embrace the choice of batteries, choice of electrical motors for specific capability vehicles, style of controllers, style of battery chargers with specific applications to electrical vehicles, and development of a testing facility for testing of electrical motors, controllers, and battery chargers. This paper emphasizes the characteristics of varied motors and controllers used for battery-operated electrical vehicles (Vidyadhar, M. R. , & Y P , 2006).

- **Survey to study e-bike in operation speeds and other parameters in China (2008)**

Survey Conducted by Sen Lin, Min He, Yonglu Tan, and Mingwei He to find the in-operation speeds of e-bicycles and bicycles on nonmotorized lanes on eight avenues in Kunming, China. A comparison study of the in-operation speed and distribution between e-bicycles and bicycles is given. Applied mathematics analysis indicates that the mean operation speed of e-bicycles is twenty-one. 86 km/h, which is 7.05 km/h quicker, or 47.6% higher, than that of bicycles. The influence of riders' gender and age on operation speed distribution is additionally mentioned. This paper presents a subjective safety analysis from the riders' perspective by measuring 552 e-bicycle riders and 232 bicycle riders (Sen, Min, Yonglu, & Mingwei, 2008).

- **Dynamic Performance of e-bike Using Vibration Theory (2009)**

Research Conducted by Wenhua Du, Dawei Zhang, and Xing Zhao to check the feasibility of an e-bike based on multi-body dynamics theory and vibration theory, the dynamic performance of an electric bicycle is simulated. Firstly, a two-dimensional mathematical model for the motion of a driver-electric bicycle coupled system was developed. The motive force model is established, and the electrical bicycle model is made by virtual prototyping technology mistreating the computer code. Secondly, an associate degree experiment check is taken to validate the feasibility of the model. Finally, the influence of the mass and installation location of the battery to ride comfort was mentioned. The result shows that the ride comfort is healthier because the battery mass increased. Once the mass of the battery is lower, the installation location will have truly little influence on ride comfort; however, because it is greater, the influence is exceptional. Finally, through each of the values of weighted accelerations R.M.S. at the seat and hand, to the paradigm electric bicycle, the battery put in beneath the seat-tube has the higher ride comfort.

- **Accurate Calculation of Back E.M.F. and Torque (2012)**

The Research was conducted to more accurately calculate the Torque produced by the motors by Xiang Liu, Mian Li, and Chengbin Ma, Min Xu. Torque is one of the foremost necessary management factors for a vehicle's motion. Compared with burning engines, electrical motors will have a lot of correct force feedback. Direct force management of the magnet electric motor has been studied in electric vehicles. However, thanks to the non-ideal back electromotive force phenomenon, direct force management of brushless D.C. motors has yet to be widely used. During this paper, a replacement technique, victimization kriging, to calculate back electromotive force during a period of online fashion is conferred. Kriging prediction is employed to approximate the rear electromotive force of the motor-supported data from sampled points. With motor speed and rotor position as inputs, kriging predicts back electromotive force because the output that is accustomed to calculate the motor force with three section currents victimization this novel technique, motor force may be accurately calculated and implemented in small management units of vehicles, even once facing extraordinarily high/low temperature and aging conditions.

- **A dynamic model of E-bike with Brushless Motors (2012)**

Research conducted by V. Thiyagaranjan and V. Sekar to develop a dynamic model of the vehicle has been realized, and therefore the characteristics of the European are individuated. For example, a primary electrical bicycle runs on a BLDC motor powered by batteries and is controlled by an E.U. The BLDC motor for the electric bicycle is of the quality 3-section tetragon kind, usually rated at some hundred watts, and therefore, the battery voltage is typically 36V or 48V counting on the circuit current (V.Thiyagarajan & V.Sekar, 2012).

- **Charging Device (2014)**

The Research was conducted by Dainis Berjoza and Inara Jurgena to settle on a correct charging device to load the electrical wiring network optimally and likewise opt for power and alternative parameters for energy devices to confirm the charging method. The current analysis involves five varied electrical bicycles. The analysis additionally involves battery systems with a complete voltage of 24 V, 36 V, 48 V, and 60 V. For the analysis, a knowledge assortment system and electric battery discharging system were developed.

E-Bike Controller

An electric bike (e-bike) controller is an electronic device that manages the power output from the battery to the electric motor, converting battery voltage to a controllable level of power that is then applied to the electric motor, which drives the wheel. The controller plays a significant role in an e-bike system, as it determines the speed, Torque, and overall Performance of the e-bike.

Figure I - E-bike Controller

Specification Criteria

The power specifications of an e-bike controller will depend on the type of e-bike and its intended use, but some typical specifications include the following (Aurora, 2022).

- Voltage: The controller must match the voltage of the e-bike battery, typically 36V or 48V.

- Wattage: The power output of the controller, expressed in watts. This can range from 250W to 750W or more, with higher wattage controllers typically found on more powerful e-bikes.
- Amperage: The current draw of the controller, expressed in amps. This will determine the maximum power output of the controller and will affect the overall speed and acceleration of the e-bike.
- Maximum motor speed: The maximum speed at which the electric motor can operate, typically expressed in R.P.M. (revolutions per minute), will determine the top speed of the e-bike.
- Throttle control: Some e-bike controllers have a throttle control that allows the rider to control the speed of the bike without pedaling. Others are pedal-assist only, meaning they only provide power when the rider is pedaling.

Types of Controllers

There are several types of e-bike controllers available in the market, some listed here (Cunnigham, 2023) (Glide, 2022).

- Hall Effect controllers: These use magnetic sensors to determine the position of the electric motor's rotor and control the power output to the motor. They are dependable and typically more affordable than other types of controllers.
- Torque sensor controllers: These controllers measure the amount of force being applied to the pedals and adjust the power output to the motor accordingly. This provides a more natural and intuitive riding experience, as the electric motor's assistance is directly proportional to the amount of effort being put into pedaling.
- Cadence sensor controllers: These controllers measure the speed at which the pedals are turning and adjust the power output to the motor accordingly. This type of controller is often used on entry-level e-bikes.
- Combined sensor controllers: These controllers use a combination of torque and cadence sensors to provide more advanced and responsive electric motor control.

- Programmable controllers: These controllers can be customized and programmed to match the specific needs of the e-bike and rider. They offer the most significant level of control and customization but are typically more expensive than other controllers.

Installation of Controller

The installation of an e-bike controller will vary depending on the specific controller and e-bike (Hovsco, 2022), but here is a general overview of the process:

- **i.** Prepare the tools: One will need a set of tools, including a screwdriver, pliers, wire cutters, and a multimeter.
- **ii.** Remove the old controller: Remove it from the e-bike when replacing an existing controller. This typically involves disconnecting the wires, removing mounting hardware, and unplugging the connectors.
- **iii.** Install the new controller: Mount the new controller to the e-bike frame, securing it with screws or bolts if necessary. Connect the wires from the battery, motor, and throttle (if applicable) to the corresponding terminals on the controller. Be sure to connect the wires according to the wiring diagram provided with the controller.
- **iv.** Evaluate the system: Once the controller is installed and connected, assess the system to ensure it works correctly. This can be done by turning on the e-bike's power and checking for fault indicators. Finally, one should also evaluate the throttle and pedals to ensure the motor responds correctly.
- **v.** Finalize the installation: Secure any loose wires and clean up any excess cable to ensure the e-bike looks neat.

Improper installation can damage the controller, battery, motor, or other components and pose a safety hazard to the rider.

Programming a Controller

The process for programming the e-bike controller to switch between pedal assist and fully electric modes can vary depending on the specific controller and bike model (Andrew, 2023), but here is a general idea of the steps you may need to follow:

i. Locate the programming port on the e-bike controller, which is usually a tiny port that can be accessed by removing a cover or unscrewing a panel.
ii. Connect a programming device to the programming port, such as a laptop or dedicated programming tool.
iii. Load the appropriate software for the e-bike controller onto the programming device. This software is regularly available for free on the manufacturer's website or can be purchased as a standalone tool.
iv. Use the software to access the settings and parameters of the e-bike controller. For example, look for options to change the power output, speed, and assist modes.
v. Configure the settings to switch between pedal assist and fully electric modes. The specific steps for doing this will vary depending on the controller, but it usually involves setting the power output to 0% for pedal assist mode and 100% for fully electric mode.
vi. Save the new settings to the controller and disconnect the programming device.
vii. Evaluate the new settings by riding the e-bike and switching between modes to ensure everything works as expected.

Several companies manufacture e-bike controllers, including:

- Bafang
- Shimano
- Infineon Technologies
- Panasonic

These are some of the leading companies in the e-bike controller market, but many other manufacturers exist.

E-Bike Motor

An electric bike is only complete with a motor and a battery. Various motor systems are available from various companies, all of which will allow the experience of the benefits of riding an electric bike (Norman, 2022).

Types of Motor Based on Placement

E-bike motors come in various types and designs, each offering unique characteristics and performance.

- **Hub Motors:** The most prevalent form of e-bike motor, hub motors are built into either the front or rear wheel hub.
    - **Front Hub Motor:** A front hub motor is located in the center of the front wheel hub. When accelerating, it delivers direct power to the front wheel, causing a pulling or "tugging" sensation. Front hub motors are famous for e-bike conversion kits because they are easy to build and install.
    - **Rear Hub Motor:** The rear wheel hub contains a rear hub motor. Because it powers the rear wheel directly, it provides a more balanced and natural sensation during acceleration. Because of their superior traction and handling, rear hub motors are frequently selected.

  Hub motors are well known for their ease of use, durability, and low maintenance needs. Gearless hub motors have more Torque and are more efficient but heavier, whereas geared hub motors are lighter and have a broader range of gear ratios.
- **Mid-Drive Motors:** Mid-drive motors are installed near the bottom bracket of an e-bike, where the crankset and pedals are housed. Mid-drive motors, as opposed to hub motors, send power to the drivetrain via the bike's chain. This allows the motor to use the bike's gears to provide more Torque, efficiency, and overall Performance.

  Mid-drive motors are popular because of their excellent weight distribution and handling. Positioning the motor near the bike's center gives a more balanced feel, superior weight distribution, and enhanced stability.

  Mid-drive motors are more complicated and may have specialized frame designs to suit their integration. They are also more costly as compared to hub motors.

When buying an e-bike, things like motor type, power output (measured in watts), Torque, and efficiency should be considered. These parameters will impact the e-bike's performance, climbing ability, range, and overall riding experience.

E-Bike Battery

E-bike motors are driven by the e-bike's battery and controlled by a controller, which regulates the power supply based on rider input and selectable assist modes. E-bike batteries are an essential component that defines an electric bicycle's range, performance, and general functioning. These batteries store and supply electrical energy to the e-bike's motor, allowing users to experience assisted pedaling or complete electric propulsion.

Figure II - Li-Ion Battery Pack

Types of Battery

The Lithium-Ion (Li-ion) battery is the most often used battery type in e-bikes. Li-ion batteries have a high energy density and a favorable weight-to-capacity ratio and are lightweight, small, and capable of providing consistent power for extended periods. Other battery types, such as Nickel-Metal Hydride (NiMH) and Lead-Acid, are less common because of their poorer energy density, heavier weight, and shorter lifespan.

Capacity and Voltage Rating

The capacity of e-bike batteries is commonly measured in ampere-hours (Ah). The battery's capacity dictates the amount of energy it can store and, as a result, the potential range of the e-bike. A larger-capacity battery will often provide a more fantastic range. However, it is crucial to note that topography, rider weight, assistance amount, and riding style can all impact range.

Typically, e-bike batteries function at specific voltage levels, such as 36V, 48V, or 52V. The voltage directly impacts the e-bike system's power output, with higher-voltage batteries usually generating greater power. More power can lead to faster acceleration, better climbing abilities, and faster max speeds. Therefore, it is critical to check that the battery voltage is compatible with the motor and controller of the e-bike.

To refill their energy levels, e-bike batteries must be charged regularly. The battery's capacity determines the charging time, the charger parameters, and the technique.

For selecting an e-bike battery, due consideration needs to be given to these factors to achieve an optimized design meeting the required standards.

E-Bike Throttle and Mode Selection

Many e-bikes include a throttle that allows users to operate the engine without having to pedal. The throttle is usually positioned on the handlebars and is controlled by the rider's thumb or twist grip. Riders may experience fast engine assistance using the throttle, which is especially handy for speedy acceleration or traversing steep inclines. Throttles come in various shapes and sizes, including thumb throttles, half-twist throttles, and full-twist throttles.

Figure III - Throttle

Throttles are a practical way to manage motor power, allowing riders to pick when and how much help they require at any particular time. It is convenient to start from a stop or sustain a pace on flat ground when pedaling may be difficult or inconvenient.

E-bikes often have multiple help modes, allowing users to choose the degree of motor aid based on their riding conditions. These modes are accessible via a mode selection switch built into the handlebar controls.

- **Full Power/Electric Mode:** The motor gives full power without pedaling in this mode. Riders may rely entirely on the e-bike's engine to propel it.
- **Pedal-Assist Mode:** Pedal-assist modes vary the amount of help provided dependent on the rider's pedaling input. The sensor on the e-bike detects pedaling action and triggers the motor to deliver extra power. Many degrees of pedal assist are available, allowing users to select the level of assistance they require.

These throttle and mode selection capabilities increase e-bike flexibility and user-friendliness. In addition, they provide riders discretion over motor assistance, letting them tailor their riding experience to diverse terrain, fitness levels, or special requirements.

CHAPTER 3 CALCULATIONS

Numerical calculations are a crucial step in designing and selecting e-bike motors and batteries. These calculations help to determine the amount of power required for the motor to reach the desired speed and the size and capacity of the battery. For example, a motor with too little power will result in slow speeds, while a battery that is too small will not provide enough range. The results of these calculations help to ensure that the e-bike delivers the best possible performance, safety, and range for the rider (Ranjan, Munna, Pradhyumn, Mustaim, & Kumar, 2018) (Mishra, 2019). The following calculations are performed for this project.

```
% Given parameters
Cr = 0.004;
m = 150;
g = 9.81;
v = 30 * 1000 / 3600; % Convert km/hr to m/s
Ca = 0.88;
Af = 0.56;
rho = 1.23;
acceleration = 0.55;
radius = 0.33;


% Calculate rolling resistance force
Frolling = Cr * m * g;


% Calculate aerodynamic force
Faero = 0.5 * rho * v^2 * Ca * Af;


% Calculate inertia force
Finertia = m * acceleration;


% Calculate total force
F = Faero + Frolling;
```

```
% Calculate torque required
torque = (F + Finertia) * radius;


% Calculate power required
power = F * v;


% Display the result
fprintf('Power required: %.4f W\n', power);
Power required: 224.4389 W
```

Our power requirement is 224W, and the next available design in the market is 250W, so we chose a 250W, 36V motor for our E-Bike and calculated the battery required to power the motor for one hour.

```
E = 250; % Energy in watts
V = 36;  % Voltage in volts


Q = E / V; % Calculate charge


fprintf('Q = %.3f Ah\n', Q)
Q = 6.944 Ah
```

CHAPTER 4 COMPONENT REVIEW AND SELECTION

Motor Specifications

Since a new hub motor was costly, a scooter tire was used. The scooter tire had a hub motor in it with the following specifications.

- Type: Hub Motor
- Power: 250W
- Voltage: 36V
- Torque: 30 Nm
- Gear Ratio: 5:1

The selected hub motor from the scooter had several key specifications that made it a viable choice for the project. It is a hub motor, which is compact in design and provides efficient power transfer to the e-bike's wheels. With a power output of 250W, it offers good speed and acceleration, while the 36 V voltage rating balances power and efficiency.

Battery Specifications

The choice of battery is crucial in any electric vehicle. An e-bike's battery serves as its lifeblood, providing the necessary electrical energy to propel it forward with ease and efficiency. However, with increasing advancement, the price of batteries also increases, and the newer batteries become more expensive. Lead Acid batteries are cheap but too heavy and bulky to be used with E-bikes, which is where Li-ion batteries come in. Li-ion batteries are lightweight, have a better energy density, and have a long lifespan. A battery with the following specifications has been chosen.

- Nominal Voltage: 36 V
- Category: Li-ion Battery
- Voltage: Peak - 42V, working - 36V
- Capacity: 4.4 Ah

Although the requirement for our E-bike was a battery of 7 Ah capacity, we are using a 4.4 Ah because of budget limitations. This 4.4 Ah battery still does the job in the best way possible but now for less time than 7Ah.

Bike Specifications

The project aimed to convert an ordinary bicycle into an E-bike with the 3 ride modes, and for that, a standard-size bicycle was used.

Figure IV - Bicycle for converting E-Bike

Controller and Throttle Specifications

The controller specification plays a significant role in smooth power relay from the battery to the motor depending on the need specified by the user through the throttle. The controller used for this project has the following specifications.

- Voltage Rating: 36 V
- Power: 250 / 350 W

The throttle needs to be of the same power rating as the controller to be compatible and properly function with it.

- Voltage Rating: 36 V

Switch

An ON-OFF-ON toggle switch has been installed with the E-bike to navigate between the different modes. The switch can be positioned to have a fully electric bike mode, the pedal assist mode of the bike, or completely turn off the electric circuit to make it work just like a regular bicycle.

Figure V - Toggle Switch

Arduino

Although some controllers come with a pedal assist mode, they are made under conditions that significantly differ from real life. So to make sure that a proper pedal assist is obtained depending on the condition, an Arduino has been used. For example, the Arduino reads the signal from the hall sensor attached to the pedals to get the required motor assistance level and sends appropriate control signals to the controller, which then relays the required power to the motor.

Hall Effect Sensor

A Hall effect sensor is a device that uses the Hall effect to detect the presence and strength of a magnetic field. The Hall effect is the phenomenon of an electric potential being generated perpendicular to both an electric current and a magnetic field.

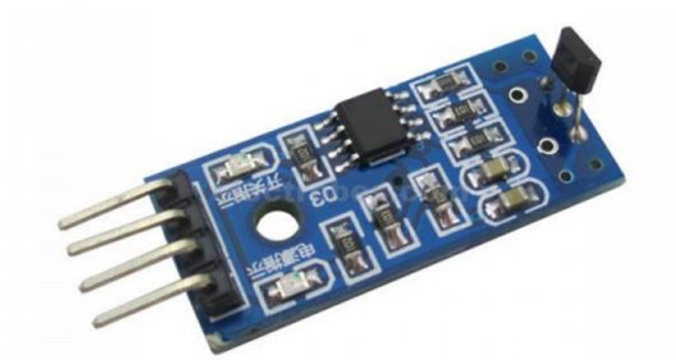

Figure VI - Hall Effect Sensor

It is frequently used to determine the rotation of the bike's pedals. By placing a magnet near the pedal arm and placing the Hall effect sensor nearby, the magnetic field changes as the pedals revolve, allowing the electric motor to provide an appropriate degree of assist dependent on the assist mode selected and the rider's input. The pedal-assist function improves the entire riding experience by combining the Hall effect sensor into the e-bike's control system.

CHAPTER 5 ANALYSIS AND SIMULATIONS

Using computer-aided design (CAD) models and simulations are essential in developing an efficient and reliable electric bike. CAD models allow engineers to design bike frames and components that are lightweight, sturdy, and resistant to wear and tear.

Simulations provide insights into how a design will perform in various conditions and how the frame and components will react to different forces. This helps engineers optimize the bike design for optimal performance and stability.

CAD models and simulations are beneficial for identifying weak points in the design. In addition, CAD models and simulations can help identify any design problems before the bike reaches the market, saving time and money.

A 3-D bike model was designed in industrial software, SolidWorks so that simulations could be performed later.

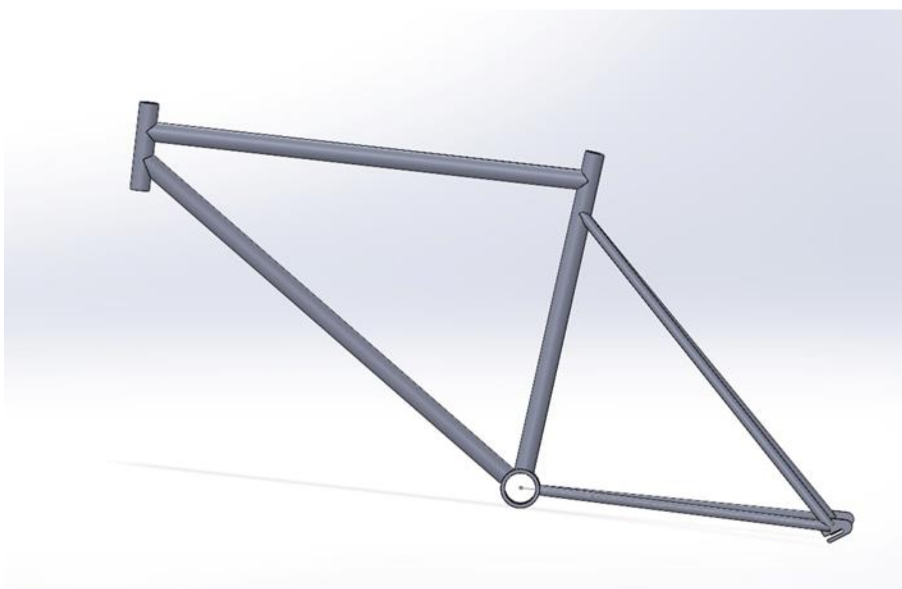

Figure VII - Side View of Frame

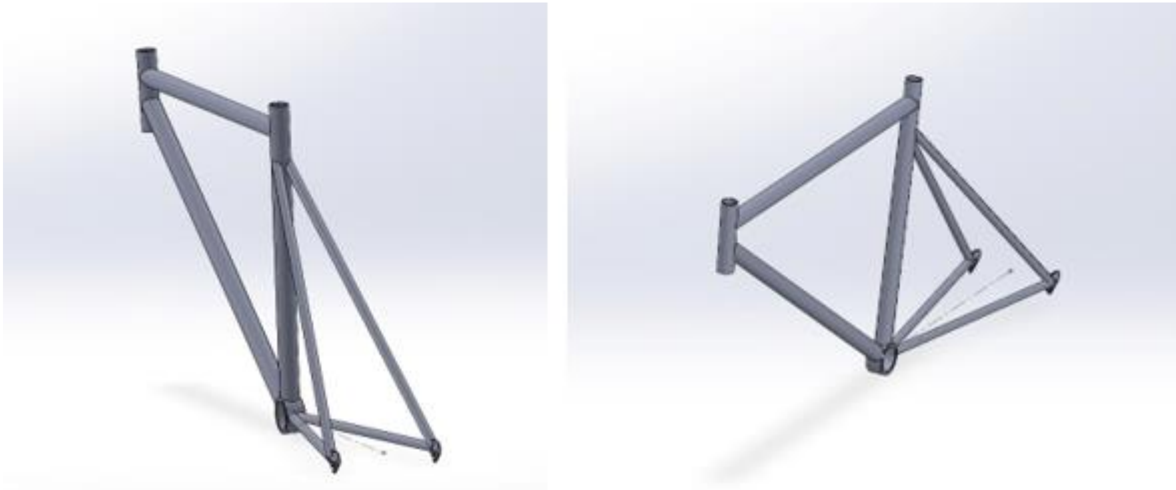

Figure VIII - Isometric View of Frame

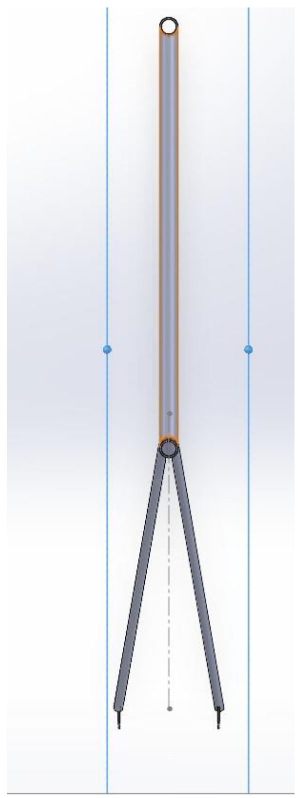

Figure IX - Top View of Frame

Then the model was imported to analysis software, ANSYS, and simulations were performed. Finally, the load was applied to the bike frame to determine the maximum load capacity of the bike and points of maximum stress.

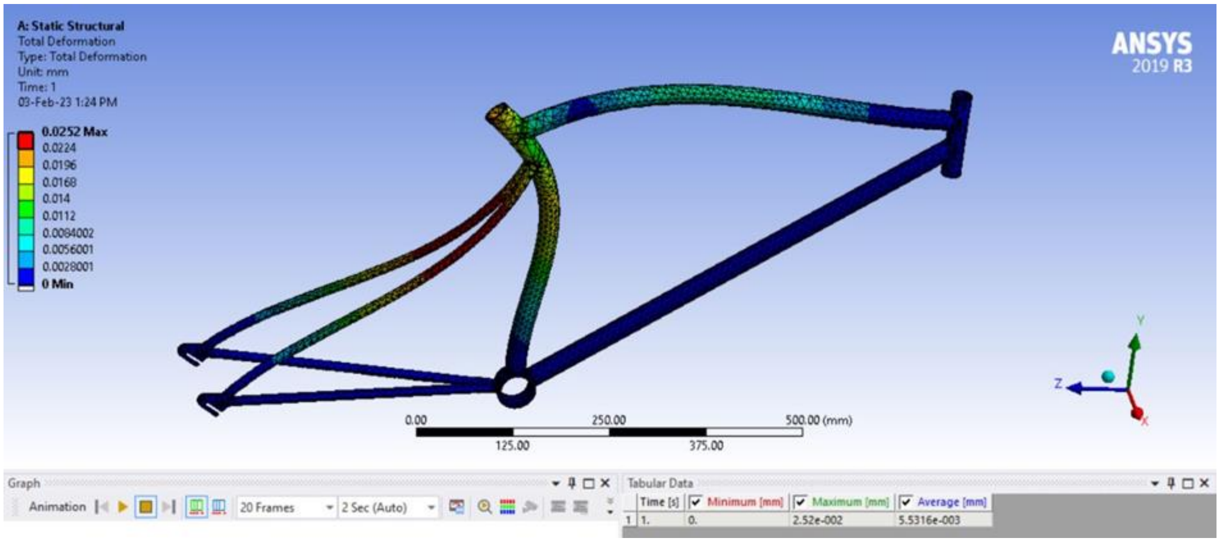

Figure X - Deformation Results

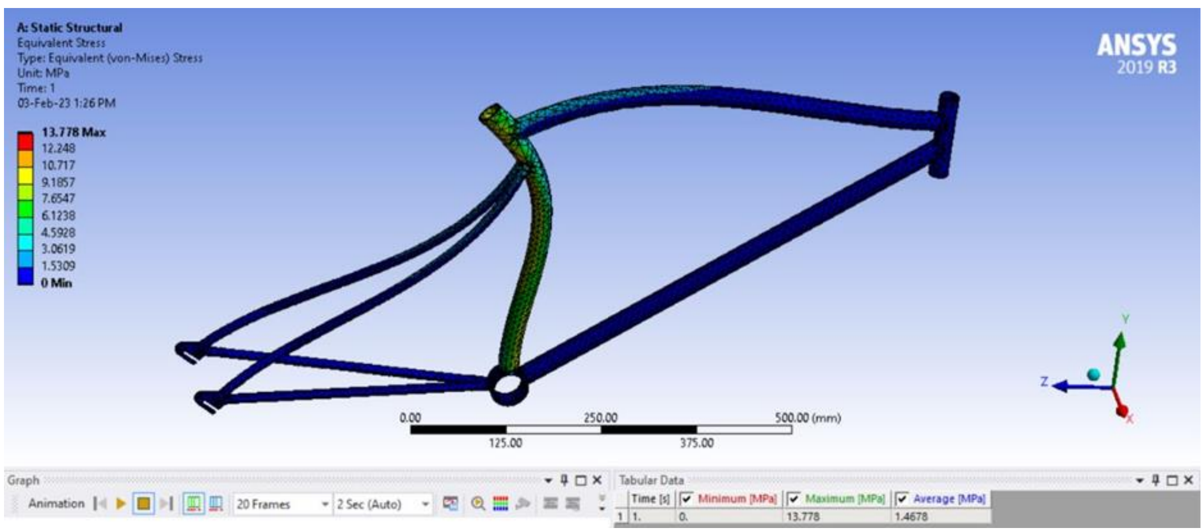

Figure XI - Stress Results

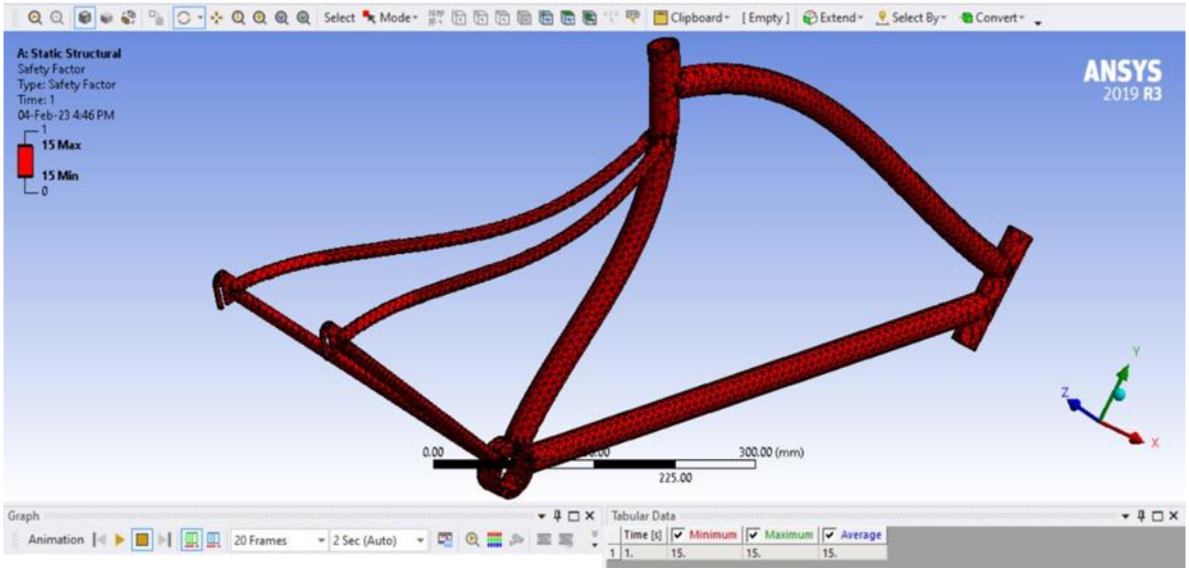

Figure XII - Factor of Safety Results

CHAPTER 6 DESIGN AND FABRICATION STRATEGY

The design of the e-bike project began with the purchase of a regular bicycle that could be turned into an e-bike. Designing a fully new frame from scratch would have been a challenging task, so reusing an old bicycle frame was an appropriate choice. After purchasing the bicycle, the next step was to evaluate the frame shape and the project requirements to decide the best conversion method.

Following careful study, it was determined that a rear wheel hub motor design would be best for the e-bike conversion. A back wheel hub motor gives the bike a clean and streamlined appearance, preserving the original aesthetics while giving the required power support. This design also provides more traction and stability than other motor position possibilities.

For a successful conversion, the power rating of all electrical components including the motor, battery, controller, switch, and throttle, had to be calculated. These calculations took into consideration different factors such as the required speed, range, and ride conditions. The power rating calculations helped in determining the optimum capacity and requirements for each component.

The required components were purchased after the power rating calculations were completed. This included a suitable battery pack with enough capacity and voltage, a controller capable of handling the power needs, and a switch and throttle system for controlling the motor assistance.

For the motor, a new rear wheel hub motor was too costly, so to improvise a hub motor from an electric scooter was taken with the same power rating as required.

After the procurement of components, the next phase of the e-bike project involved the fabrication and installation process. The rear wheel hub motor, which was originally from an e-scooter could not fit straight into the bicycle frame. Because the motor could not be replaced and its use was constant, the idea came to alter the frame to provide more room for the hub motor.

The first step was to remove the rear mudguard. The rear wheel's side parts were then cut and welded again, but this time they were placed wider apart than before. This adjustment created enough room between the frame sections for the hub motor to fit properly.

Figure XIII - Hub Motor Placement

An issue arose during the hub motor placement with the tire rim that there was no room for spokes to attach to the hub motor. Since it had no attachment points for spokes, two circular steel plates were designed to bridge this gap.

Two steel plates with a diameter exceeding that of the hub motor were cut using a laser cutting machine and 18 holes were drilled around each of them. 36 Holes were made because it corresponds to the number of spokes on the bicycle wheel.

Once the steel plates were ready, they were firmly fastened on both sides of the hub motor. The plates served as points of contact for the hub motor, giving a surface on which the spokes could be attached. The holes in the steel plates lined up with the flange of the hub motor, allowing the spokes to be threaded through them.

After securing the plates, the spokes were inserted through the holes in the steel plates and secured to the rim as normal. This method made sure that the hub motor remained firmly attached to the tire rim via the spokes.

All this modification made sure that the structural integrity of the tire frame is not compromised and that there are no compatibility issues anywhere between the hub motor, rim, and frame.

A gear normally seen on rear wheels was used to add a pedal-only mode in the e-bike. This gear was connected to the motor through a small shaft, allowing the e-bike to function as an ordinary bicycle even when the motor power was turned off.

Figure XIV - Gear and Chain Placement

A typical chain drive system was used to connect the gear attached to the hub motor and the center crank pedal gear of the bicycle. The gear on the engine and the center crank pedal gear were linked together with a chain, similar to how bicycles are built.

Following the successful installation of the motor, the next stage was to install the auxiliary components, beginning with the controller. The controller was correctly connected to the motor by following the directions in the controller's manual. The controller was mounted on the frame of the e-bike as normal.

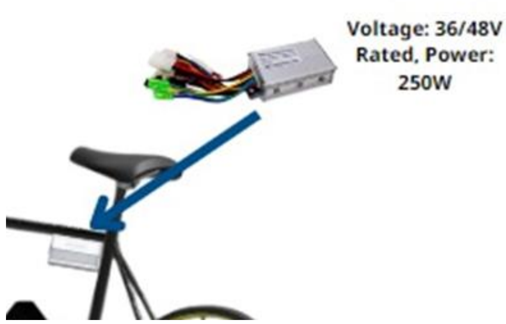

Figure XV - Controller Placement

After installing the controller, the throttle was attached to it according to the directions in the manual. The throttle was placed on the handlebar, easily accessible to the rider. The throttle made it easier to adjust the motor's power output and to activate and disengage the motor.

The battery was the last component to be installed. The battery connections were properly attached to the controller, with careful attention paid to polarity and insulation, to ensure a reliable and secure electrical connection.

Figure XVI - Battery Placement

After installing all of the components, a test drive was performed to evaluate the bike's performance, which included acceleration, speed, braking, and overall handling. Initially, the speed was limited because of the pre-set controller settings. However, the controller's settings were modified by installing an Arduino in between the throttle and controller to ensure that the controller produced the optimum amount of power, providing for a smoother and more customized riding experience.

The Arduino acted as an amplifier for the controller's throttle input. By processing and amplifying the throttle signals through the appropriate code, the Arduino ensured accurate and responsive control over the motor's power output.

In addition, the Arduino was used to integrate the pedal assist mode into the e-bike. This was accomplished by attaching an Arduino to a Hall effect sensor and uploading the required code to it (Appendix II). The hall effect sensor sensed the rotation of the pedals and gave the appropriate input to the Arduino to enable the pedal assist feature. This mode enabled the motor to aid the rider during pedaling, resulting in a more smooth and effortless riding experience.

An ON-OFF-ON toggle switch was set up to allow for quick switching between modes. This switch featured two ON settings, one for each mode—fully electric and pedal assistance. When the switch was switched off, the e-bike functioned like a traditional bicycle, relying completely on the rider's pedaling power and providing no electric help. The circuit for the designed project is attached in Appendix III.

Finally, the e-bike fabrication process was finished successfully with careful attention to detail. Following thorough testing to assure its performance and safety, additional touches were made to enhance its visual appeal and protection. A new layer of paint was applied for both aesthetic and durability reasons. To protect the controller, Arduino, and battery from moisture and dust, covers were added.

CHAPTER 7 DELIVERABLES AND END GOALS

Considering the work, the following deliverables have been considered for the project.

- 3D design of the main body
- Structural Analysis
- Light Weight Frame
- Prototype
- Product Manual
- Quality check report

The primary goal of this project is to design and fabricate a fully functional Electric bicycle with sufficient power and distinguished design. The secondary goal is to make it economical with no compromise on quality.

END GOALS

The end goals that have been defined for the project are,

- A fully functional E-bike.
- The maximum speed of the bike on the throttle of about 20 – 30 km/h.
- Average charging time.
- Increased efficiency than models already available in the market.

CHAPTER 8 SUSTAINABLE DEVELOPMENT GOALS

Sustainable Development Goal 7 (SDG 7)

Sustainable Development Goal 7 or SDG 7 is one of the 17 SDGs established by the United Nations General Assembly (UNGA) in 2015. The goal is as follows, 'Ensure access to affordable, reliable, and sustainable modern energy for all.' Our project, "Design and Manufacturing of E-Bike," relates to all the targets of the SDG, and our Research and investment are focused on the fulfillment of this goal.

Following are the targets of SDG-7 and how our work relates to them:

Target 7.2: Increase the Global Percentage of Renewable Energy

The driving force behind our work is to increase the global percentage of renewable energy somehow and reduce the world's carbon footprint. Our project fulfills this task splendidly, as no fuel is required to work the bike. Also, we are using mechanical work to charge our battery.

Target 7.3: Double the Improvement in Energy Efficiency

The primary purpose of our project is to develop a product with a better cost-performance ratio than products already available in the market. A central part of the Research and work is focused on improving the energy efficiency of the bike.

Other Identifiable Sustainable Development Goals (SDGs)

Apart from SDG-7, our project also identifies some targets of other SDGs, which are as follows: -

- The e-bike runs on sustainable energy and has a minimum carbon footprint. Therefore, it relates to the Target 3.9 of SDG-3, 'Good Health and Well-Being.'
- The transport industry in developing countries is generally dependent on fuel consumption. Our project promotes ways to make this industry more sustainable in a much easier and more efficient way. Therefore, our project relates to target 9.4 of SDG-9, 'Industry, Innovation and Infrastructure.'

- Target 11.2 of SDG-11 states, 'Affordable and Sustainable Transport Systems.' Our work also identifies with this SDG by improving the cost-performance ratio and ensuring the efficient working of our e-bike on sustainable energy.

CHAPTER 9 CONCLUSION

Finally, the e-bike concept, which incorporates pedal assist, completely electric, and traditional riding modes, provides a versatile and eco-friendly transportation solution with several advantages. First, e-bikes encourage physical activity and a better lifestyle by offering aid when pedaling and making the commute more accessible than ever. Furthermore, converting to conventional riding mode allows one to experience traditional cycling without motor help.

E-bikes are a more environmentally friendly alternative to regular motorbikes, generating fewer pollutants and contributing to lower carbon emissions. As a result, they are a useful asset in the fight against air pollution and climate change. In countries like Pakistan, where air pollution and traffic congestion are significant concerns, e-bikes can play a vital role in improving air quality and relieving road congestion.

Further improvements can be made in E-bikes by including a battery charging mechanism to enhance the sustainability of e-bikes. Regenerative braking or energy from pedaling can also be introduced into the bike.

E-bikes have the potential to revolutionize transportation networks, enhance public health, and contribute to a cleaner, more sustainable future as technology advances and their popularity grows.

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APPENDIX I – ROLLING RESISTANCE COEFFICIENT

The chart for the variation of rolling resistance coefficient value on different surfaces is shown here.

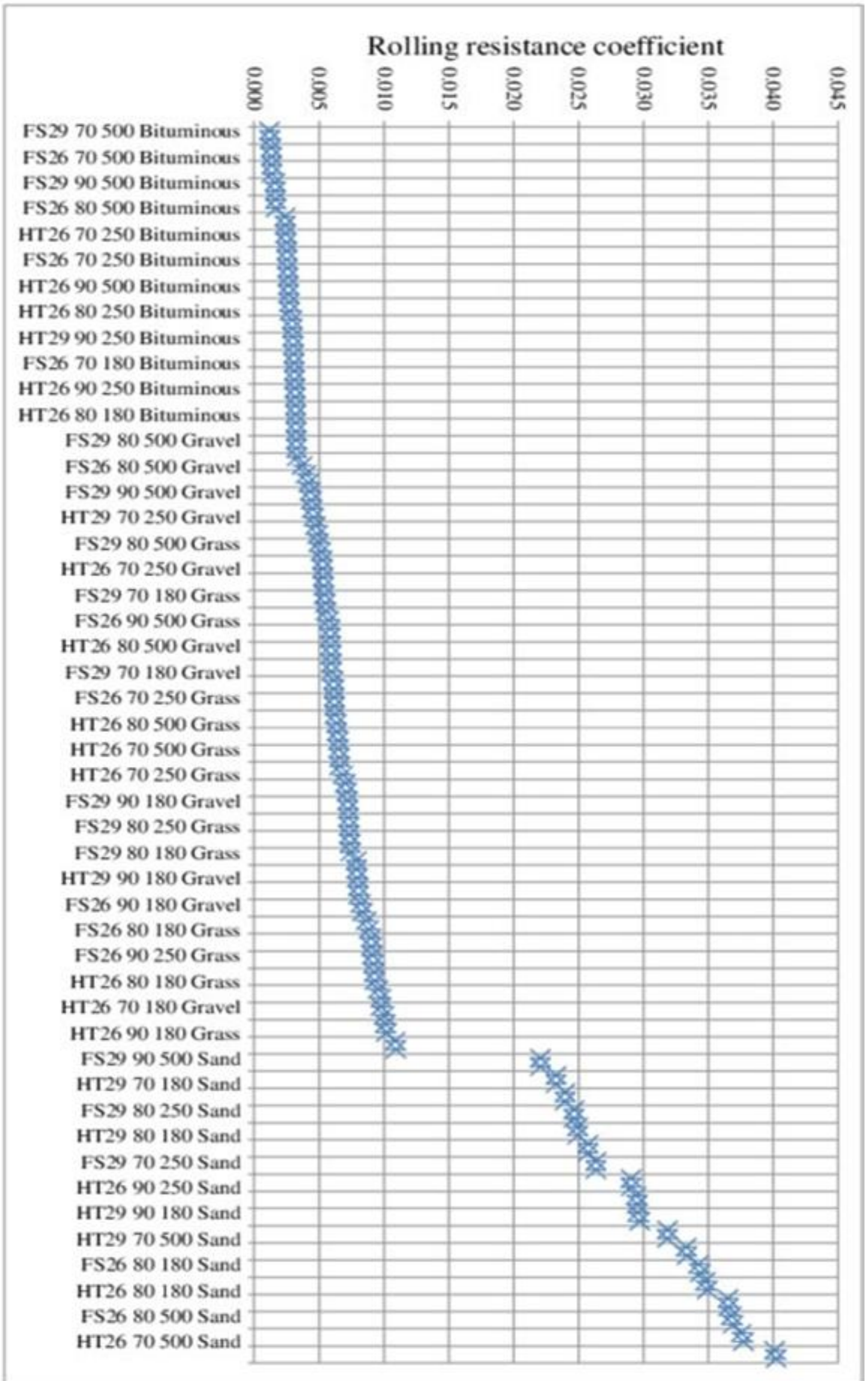

Figure XVII - Rolling Resistance Coefficient

APPENDIX II – ARDUINO CODE

The Arduino code for pedal assist is given below;

```
int throttlePin = 0;
int pulseoff = 600;
int pulseon = 0;
int val = 0;
bool pulse = false;
bool throttle = false;
int pedalin = 7;
unsigned long startMillis;
unsigned long currentMillis;
void setup() {
  pinMode(LED_BUILTIN, OUTPUT);
  pinMode(pedalin, INPUT);
  digitalWrite(LED_BUILTIN, LOW);
  attachInterrupt(digitalPinToInterrupt(pedalin), pedalon, CHANGE);
  startMillis = millis();
  Serial.begin(9600);
}
void loop() {
  currentMillis = millis();
  val = analogRead(throttlePin);
  pulseoff = (600 - (val / 1.7)) + 120;
  pulseon = int(pulseoff / 3);
  if (pulse == false) {
    if (pulseoff < 550) {
      if (throttle == false) { //removes the halfsecond possible delay on first start up.
        digitalWrite(LED_BUILTIN, HIGH);
        throttle = true;
        pulse = true;
      } else {
        if (currentMillis > (startMillis + pulseoff)) { //send pulse
          digitalWrite(LED_BUILTIN, HIGH);
          Serial.println(pulseoff);
          pulse = true;
```

```
      startMillis = millis();
      throttle = true;
     }
    }
   } else {
    throttle = false;
   }
  } else {
   if (currentMillis > (startMillis + pulseon)) {
    pulse = false;
    digitalWrite(LED_BUILTIN, LOW);
   }
  }
}
void pedalon()    //Called when pedal is moved
{
  if (throttle == false) { //Only passes signal if throttle is not being used, otherwise ignored.
   if (digitalRead(2) == HIGH) {
    digitalWrite(LED_BUILTIN, HIGH);
   } else {
    digitalWrite(LED_BUILTIN, LOW);
   }
   Serial.println("pedal round..");
  }
}
```

APPENDIX III – ELECTRICAL CIRCUIT

Below here is the circuit for the connections of the E-bike electrical components.

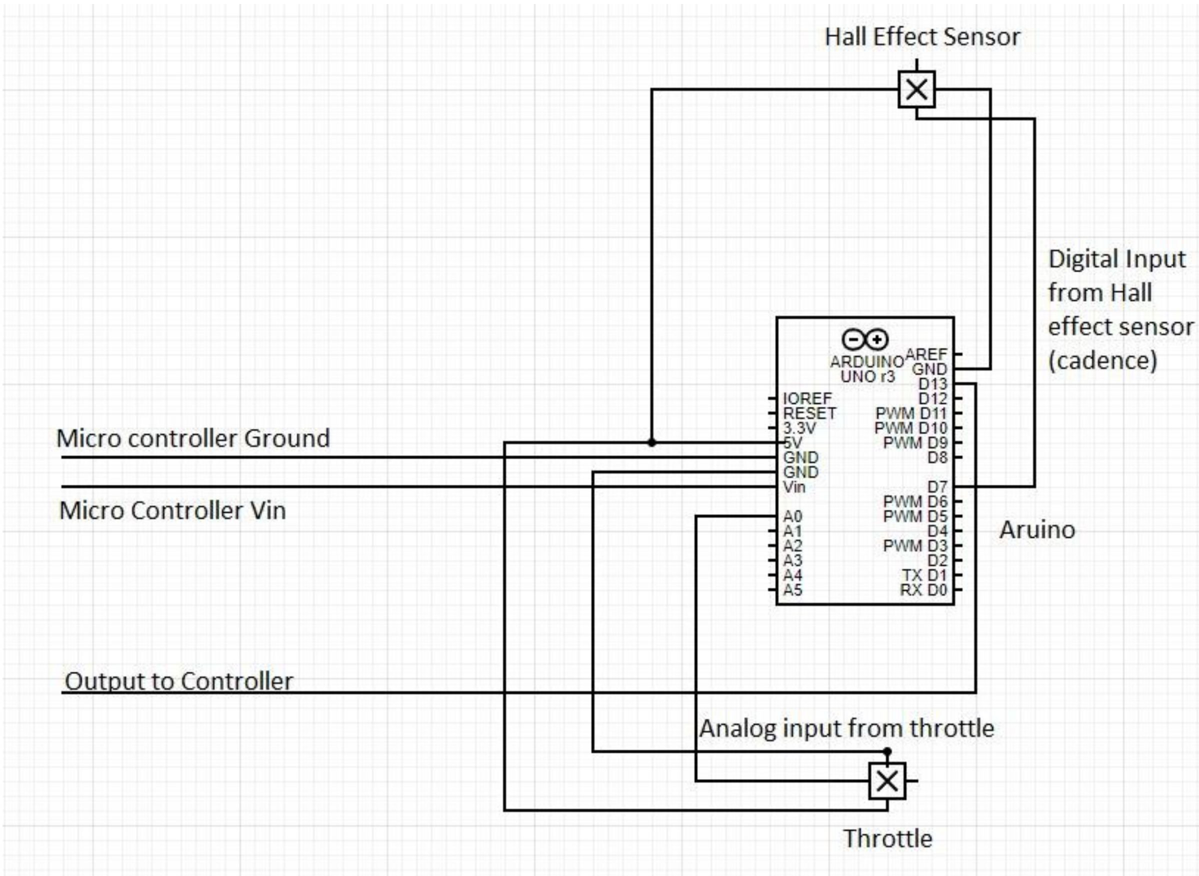

Figure XVIII - Electrical Circuitry of E-Bike