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Design and Development of Modern Electric Bike

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***Abstract*:- The number of automobiles on the roads throughout the globe is increasing at a staggering rate year by year, but the dependence on oil-based fuel grows almost unchecked. Due to this, electric vehicles come into the picture as an alternative. Need for an affordable and efficient mode of transport created a growing demand for Electric Bikes in India too, and this project is taken as an opportunity, rather a challenge to design and develop the best in a class electric bike for the quotidian commute. An electric bike is a two-wheeler propelled exclusively by an electric motor, which is powered by an onboard dedicated battery pack providing it with the required traction energy. The electric bike has an electrical motor with an intelligent controller and a battery pack connected via efficient cabling systems and monitoring instruments in place of an engine and other supporting components of a fuel run bike. Also, the use of electric bikes will cause less environmental pollution and keep our surroundings lively. This project presents a study on the design and development process of a smarter, affordable, and safer electric bike achieved by comprehensive market research, studying the existing options to find what a customer desires, the challenges faced by them and benchmarking our design to meet industry standards.**

Keywords—Electric Bike ; Power ;Economical ; Hub Motor; Battery ; Analysis ; Chassis.

I. INTRODUCTION

The e-bike is an electric vehicle, an advanced version of the pedal bicycle, powered by a rechargeable battery. These bikes are an excellent alternative for people who want to switch from a car for their daily commute. The population of India is 1.35b billion, and nearly 253 million vehicles are there on the road [1]. In India, cities are experiencing excessive traffic and noise pollution, leading to inexorable air pollution from the last few years.

Year	**Stage**	**CO**	**HC**	**HC + NOx**	**PM**
1991	-	12-30	8-12	-	-
1996	-	4.5	-	3.6	-
2000	**BS I**	2	-	2	-
2005	**BS II**	1.5	-	1.5	-
2010	**BS III**	1	-	1	-
2016	**BS IV**	1.403	-	0.69	0.1
2020	**BS VI**	1	0.1	0.128	0.0045*

Table 1: Emission Standards for two-wheeler gasoline powered vehicles [2]

As the gasoline-driven two-wheeler sales figures increased during the late 20th and early 21st century, the number of exhaust emissions caused by them also increased. These exhaust emissions from the petrol-powered internal combustion engines gave out various harmful gases and particulate matter in the environment. With an increased fuel consumption trend, the toxic constituents are continuously being released in the surroundings every day [3]. The emissions led air around us to start degrading in quality, getting polluted, drawing extensive attention to the degree of the air pollution caused both locally and globally.

One of the primary sources of pollution in urban areas is the two-wheeler traffic. These exhaust emissions contain various toxic components, which are associated with severe adverse health effects, including premature death, respiratory symptoms, impaired lung function, and cardiovascular diseases. Assessing the impacts of air quality management strategies in urban areas is a significant concern worldwide. Besides, worldwide epidemiological studies show a consistent increase in cardiac and respiratory morbidity and mortality from vehicle exhaust pollution exposure [4].
Due to this, there is an immediate concern about air quality degradation globally, so the need for a cleaner and energy efficient fuel is created. Its where electric-powered two-wheelers come into the picture as a suitable alternative. Electrical energy driving the bike is a greener fuel and does not stress the end-user's pocket. Also, the electrical propulsion system is less susceptible to wear and tear than mechanical counterparts making it more economical. Among the various financial advantages, the average running cost of an electric bike per kilometer travelled is less than 0.08 rupees, which seems to be way less than a gasoline bike costing around 2 rupees per kilometer, taking the varying cost of the petrol into account [5]. A typical electric bicycle with a lead-acid battery pack needs to charge overnight, while the Li-ion battery pack needs 1-3 hours to recharge. The average range of an e-bike is 35 to 50 km at about 35-40 km/h making it enough to go to work, move around, and return home on an average day [6]. Also, an electric bicycle shows that for every 100 km, an average of 8.5 L of petrol is conserved, evading pollution [7]. Therefore, electric bikes have led to a new approach to personal mobility and concerns about environmental degradation. This paper aims to describe phases of design and development of a suburban e-bike since this domain is relatively new and has much room for improvement. Our Project proposes the solution to this challenging problem. The primary purpose of using this E-bike is to be user-friendly, economical, and relatively cheap. The efficiency of this system is undeniable compared to conventional modes of transport. The Electric Bike works on a battery-powered by the motor is the current mode of transportation to move.
keeping this in mind, these are the significant aspects of this research paper:

- To provide convenient and effortless commute
- Easy on the pocket and quick charge on the go vehicle
- Eco-friendly and energy-efficient bike

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II. METHODOLOGY

An electric bike is a battery-operated vehicle that runs on the stored chemical energy inside the rechargeable battery packs. An electric bike is a pure E-bike if it exclusively uses its electrical power and not any other secondary power source. Electric motors and motor controllers propel these vehicles via various drive mechanisms (as mid-drive, hub drive, etc.), delivering the wheel's power.

Design objective

The frame is inspired by the renowned two-wheeler manufacturers Harley Davidson and Super-73, which are leading market players in electric two-wheelers in Northern America [8]. It has an appealing design that will attract young customers who use traditional I.C. engine motorbike for their daily and short commute. It is a smart connected bike with a sturdy design, safe to use, and easy to move around. Other factors that contribute to the design are the Eco- friendly power unit and the cost of maintenance, which is very low compared to other gas propelled vehicles. The material used are of high quality and desired characteristics to balance and improve the bike's overall performance.

Desired Characteristics

The frame must be capable enough to carry the rider's weight, cargo, various assemblies, and electric bike accessories. The parts of a chassis come across different loading conditions, such as compressive and tensile shear, fatigue, which increases failure. This is mainly because a single material is not fit for every type of load [9]. They are designed in a way to be able to withstand accidental collisions and minor impacts. The selected material should be easy to manufacture and economically viable. The frame should be simple, aesthetic, and proportionally distributed weight. The design must also include details as mounts and casing for the electronic powertrain and other accessories.

III. ERGONOMICS AND ANTHROPOLOGY

The International Ergonomics Association defined ergonomics as a scientific discipline to design and optimize human well-being while interacting with industrial products. The fundamental aim of ergonomics is to eliminate the discomforting symptom, which causes low satisfaction, limits motion, and long-term disability. The research method of ergonomics dealing with measuring the human body's posture and physical characteristics is known as Anthropometry [10].
Ergonomics tells the producer the optimum output for sitting and the comfort while riding the bike. Enhancing the sitting posture and comfort while driving will automatically lead to a better ride for the rider, which will help the rider focus and provide the legerity to act when required [11].

Ergonomics when seated on the bike: Nearly 85% of the bike riders suffer from pain in their back, neck, shoulders, and arms region. The pain is not severe on less than average use, but its intensity increases during long runs.

- Bike ergonomics do not entirely depend on the frame size and saddle tube but, most importantly, on the frame's length.
- The sitting posture in a modern city bike is mostly upright, which increases reach to handlebars. This posture does not support the natural S-shape of the spine.
- The extended and higher frames require the head and neck bending in the tighter angles nearly 60^o, which causes more pain on the neck.
- The best sitting position while comfort riding is the old-Dutch position, which requires nearly half of the effort. [12]

IV. CHASIS FRAME

The bike's chassis is a skeletal frame that supports an e-bike's significant components, such as motor, battery pack, tires, Etc. It provides strength and stability to uphold the vehicle in any terrain. A frame is a support for the suspension system, springs, and shock absorbers, which as a result, helps in keeping the wheels in contact with the road and buffers the rider from bumps and jerks [13]. Hence the chassis is considered to be a vital part of an automobile. The backbone frame design offers the strength and durability to our e-bike for carrying weights up to 150 kg.

The frame must carry the rider's weight, cargo, various assemblies, and electric bike accessories. It should be designed with a high factor of safety to withstand accidental collisions and minor impacts. The E-bike's frame must be made up of a material that is easy to manufacture and economically feasible. There must be proper mounts and casing for the electronic powertrain. The structure should be simple, aesthetic, and with its weight distributed proportionally.

Considering the electric bike's desired characteristics and the availability of resources, the backbone type chassis frame is selected for its construction. The backbone type frame is a simple frame that acts as a spine for the whole bike with everything connected in place. This frame is relatively simpler to design and offers greater manufacturing flexibility. The frame has adequate strength and torsional rigidity. It is suitable for low-medium power propulsion and can be manufactured at a relatively lower cost due to lesser material consumption.

Center of Gravity Calculation

The loads carried on each axle will consist of a static component, plus load transferred from front to rear (or vice versa) due to the other forces acting on the vehicle. The load on the front axle can be found by summing torque about the point under the rear tire. Presuming that the vehicle is not accelerating in pitch, the sum of the torques at rear point A must be zero. Formula used for the same is:

$$W_f \cdot wb + D_A \cdot h_a + \left(\frac{W \cdot a_x \cdot h_{cg}}{g}\right) + R_{hx} \cdot h_h + R_{hz} \cdot d_h + W \cdot h_{cg} \cdot \sin\theta - W \cdot P \cdot \cos\theta = 0 \quad (1)$$

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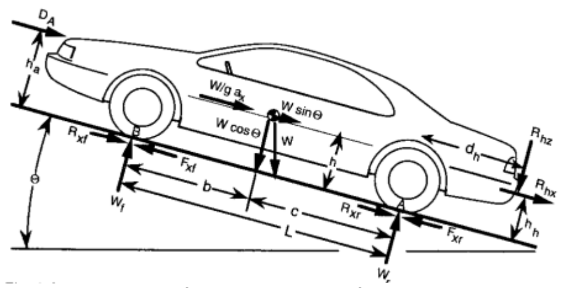

Figure 1: free body diagram of vehicle [14]

When the vehicle sits statically on level ground, the load equations simplify considerably. The sine is zero and the cosine is one, and the variables Rhx, Rhz , ax and DA are zero. Thus, Electric bike the following: (by the SAE convention, a clockwise torque about

To calculate the force distribution to the rear and front tyres, a maximum load of 150 kg is used i.e. gross weight of electric bike and rider. The assumed weight is distributed in a ratio of 2:3 from front to rear, that is 60 kg on the front wheel and remining 90 kg on the rear [14]

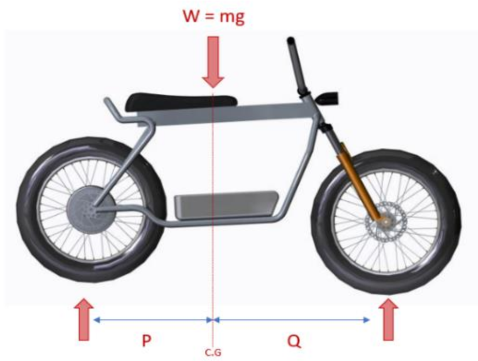

Figure 2: Free body diagram of Electric bike

Now computing the linear distance of CG from both wheels:
Now the height of the CG point from the ground is calculated by plugging the values in Equation (1) as:

$$\Rightarrow h_{cg} = \frac{(150)\cdot(609.6)\cdot\cos(5.71)-(60)(1016)}{(150)\cdot\sin(5.71)+\left(\frac{150}{9.81}\right)(0.78)}$$

$$\Rightarrow h_{cg} = 1110.77 \sim 1.11\,m$$

V. CAD MODEL OF FRAME

CAD or computer-aided design process is a technology for design and technical documentation of the product., which replaces manual drafting, that is time-consuming. Here, we have used Creo Parametric for our design process. It is a feature-based software with the capability of parametric design [15]. It allows us to build a model incrementally, from adding individual features to making a complete assembled model of the product while retaining the capability to change features independently.

Figure 3: CAD Model of e-bike frame

VI. ANALYSIS OF FRAME

The engineering analysis done to overcome the drawback of the product design with the aid of computer systems is known as Computer aided engineering (C.A.E). The FEA is the backbone of CAE and assists in performing the validation of design. The CAE software used is ANSYS workbench which is a computer aided finite element modelling and analysis tool [16]. The primary objective of frame is to have good structural rigidity and evenly spread load distributions.

The frame model is first imported in the software, then set by material assignment and applying load conditions. The test force can be evaluated using the impulse-momentum theorem as:

$$p = F_{impact} \cdot \Delta t$$

$$\Rightarrow F_{impact} = \frac{p}{\Delta t}$$

The momentum generated at vehicle's top speed is:

$$p = m \cdot v$$
$$= (15.29)\cdot(12.5)$$
$$= 191.125\ \mathrm{Kg\cdot m/s}$$

Time for impact is 0.1 seconds, thus the impact force can be computed as:

$$F_{impact} = \frac{191.125}{0.1} = 1911.25\ \mathrm{N}$$

Considering a 25% more impact force for analysis, the force becomes ~2400 N and the e-bike's frame is analyzed for the front suspension load condition. The model is imported into the static structural mechanical solver of ANSYS workbench. This is followed by material assignment and generating an automatic mesh dividing the model into 44353 nodes and 22695 elements. After this, the model frame is applied upon by the fixed constraints and the impact force in respective directions. Now, the model is analyzed for the defined constrained yielding the following results:

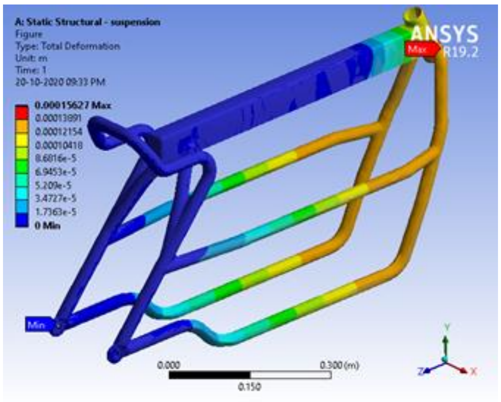

Figure 4: Total deformation of bike frame

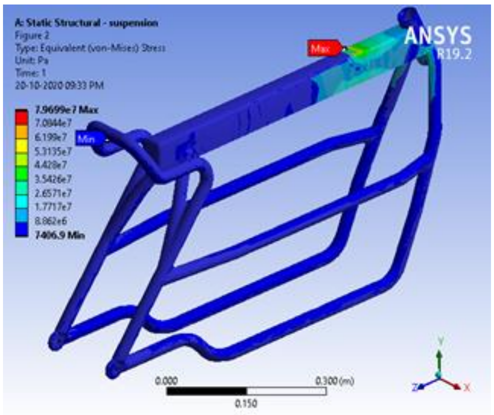

Figure 5: Von-Mises stresses generated in bike frame

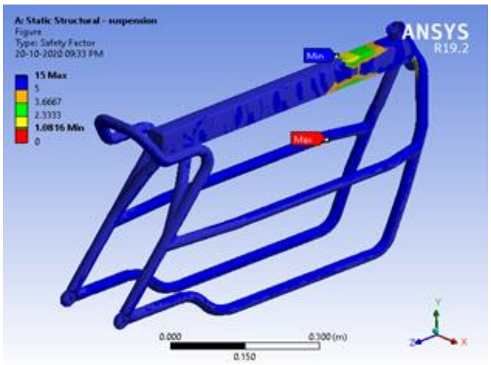

Figure 6: Factor of safety achieved over Max. Load condition

The results show high stresses being generated in the frame which are mainly absorbed by the front suspension and are generated due to sudden braking or hitting a rigid object or a pothole. All these forces are amplified at higher speeds; thus, the model is analysed at its top speed of 12.5 m/s.

Property:	Minimum	Maximum	Average
Total deformation (m)	0	1.56E-04	5.08E-05
Von-Misses Stresses (N/m2)	7406.9	7.97E+07	2.50E+06
Factor of safety	1.816	15	14.403

Table 2: Results of static structural analysis for front suspension loads

Next, the chassis frame is tested for its strength while carrying the weight of driver, pillion and its self-weight. For this analysis we will follow the same steps until the model setup as done before, but in this case the fixed geometries and magnitude of force is different from the previous analysis. The magnitude of fore is total of driver and passenger weight along with some cargo. The net weight can be taken as 300 kg at max, i.e. 3000 N force is used for static analysis. The analysis yielded the following results:

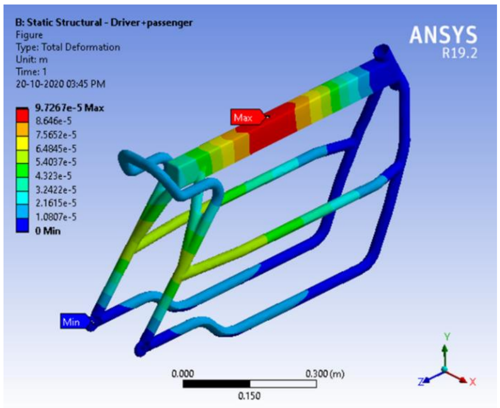

Figure 7: Total deformation

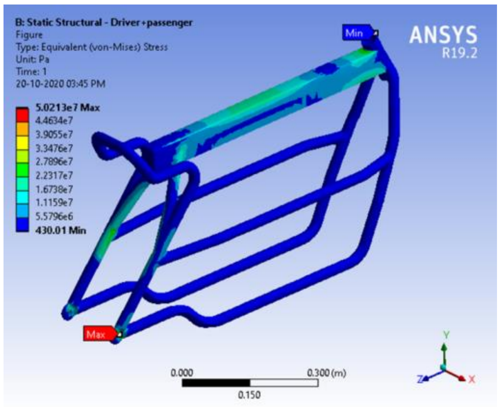

Figure 8: Von-Mises stresses

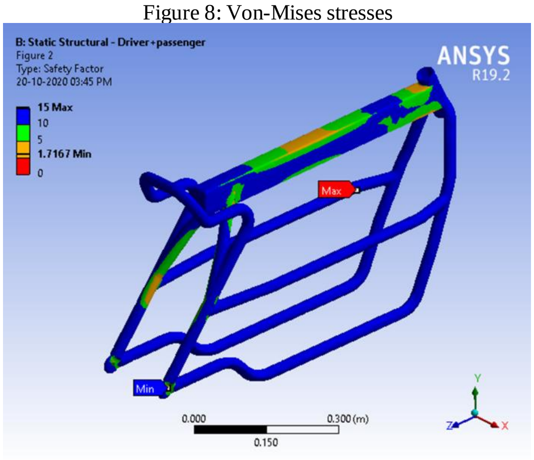

Figure 9: Factor of safety

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Property:	Minimum	Maximum	Average
Total deformation (m)	0	9.7267e-005	2.6502e-005
Von-misses stresses (n/m^2)	430.01	5.0213e+007	3.5253e+006
Factor of safety	1.7167	15	13.662

Table 3: Results of static structural analysis with driver, passenger loads and self-weight

The maximum deflection obtained during the analysis is less than a millimeter, thus the analysis results show that the chassis frame is strong enough to carry and drive along with the weight of driver and passenger without any mechanical failures. A factor of safety more than 1.5 assures better performance during the fatigue loading condition of the bike.

VII. ELECTRIC POWER-TRAIN

The powertrain provides the demanded power to the vehicle to drive. Electric Powertrain primarily consists of a battery pack, DC-DC converter, Electric motor and motor controller to run the vehicle. The electrical controlling and actuation can be understood via a functional decomposition. A functional decomposition simplifies large and complex functionalities which makes it easy to understand by breaking it into smaller, simpler steps that are obtained through thoughtful analysis of the system's process [17].

The architecture of the powertrain is similar to a pure electric bike. The 36V lithium-ion battery is mid-mounted and acts as the bike's power source connecting to all the electronics. The motor is fitted in the rear wheel hub and connected to the battery via the motor controller. The throttle and brakes are connected to the motor controller to manipulate the power flow. All the accessories that work at lower voltages are connected to a voltage converter for safe voltage input.

BLDC Geared Hub-Motor:

The Design of the hub motor is done so that the axle of the vehicle is replaced by the motor's shaft, passing through the middle of the wheel hub. Hub motor consists of a copper winding that is fixed to the axle of the shaft; this assembly is commonly known as the "stator". Some permanent magnets are placed around the outer shell of the hub motor. A sensor senses the position of the rotor and energizes the copper coils by passing current into the stator; this gives rise to the magnetic field, causing the rotor magnets to move. The simultaneous energizing and de-energizing of the copper coils in the stator makes the magnet move, making the motor shaft to rotate, following which the bikes come into motion and move forward.

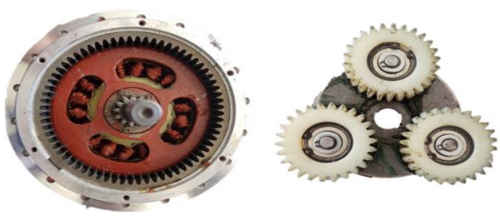

Figure 10: Inside of a BLDC geared hub motor

The specialty of the geared hub motors is a large amount of torque and power provided by them. The high-end performance bikes require torque and power simultaneously, making the geared hub motor an ideal choice for the performance electric bikes.

Motor controller:

The motors used in the electric bikes are driven by electronic controls, which offer better control of speed, position, and torque, as well as much higher efficiency, rather than via direct connection to their source of power. The switching works on the principle of pulse width modulation. The motor-control circuit does this by switching the current flow to the motor's coils ON and OFF quickly thus modulating the pulse, with minimal switching-time or conduction-period losses in the switch itself [18].

That's where MOSFET controllers come into the picture. These semiconductor devices serve the needs of motor drive and power control and are better suited in some application situations. These are field-effect transistor-based controller that, depending on size and design, can switch a few hundred milliamps to tens of amps and single-digit voltages to thousands of volts. The controller also controls the current flow path to two or more motor coils allowing full control of the motor speed and direction [19].

Li-ion Polymer Battery (LiPo):

Lithium–polymer batteries use lithium metal and a transition metal intercalation oxide (MyOz) for the negative and positive electrodes, respectively. This MyOz possesses a layered structure into which lithium ions can be inserted, or from where they can be removed on discharge and charge, respectively. A thin solid polymer electrolyte (SPE) is used, offering improved safety and flexibility in design [20].

Figure 11: 48V 18Ah LiPo battery pack with 5A fast charger

VIII. VEHICLE DYNAMICS

Motor power calculations:

The electric motor is the most critical part of the e-bike as it propels the vehicle forward. For that its design must have a good balance of lightness, reliability, efficiency, compactness, cost effectiveness. It should also possess high power to weight ratio with maximum specified speed in high

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acceleration and enough torque. The power delivery must be smooth and on demand of the user. The motor must be powerful enough to move the vehicle forward as well as overcome the physical, resistive forces opposing the motion. The motor power calculations are as below:

Total Tractive Effort (TTE) :
It is the sum of the forces required to push or pull a vehicle.

$$TTE = F_{rr} + F_{ad} + F_{hc} + F_a \quad (3)$$

[Total tractive effort = Rolling Resistance (RR) + Gradient Resistance (GR) + Acceleration force required (F_a) + Drag force (F_D)]

With the forces to overcome:

F_{rr}= Rolling resistance

F_{ad}=Aerodynamic drag

F_{hc}=Hill climb force (gradient)

F_a =Acceleration force

Rolling Resistance (F_{rr}) :
Rolling Resistance is the force necessary to propel a vehicle over a particular surface. This is the force required to propel the bike from the frictional force offered by the surface on which it is moving. This depends on the weight of the bike and the friction coefficient of that surface.

$$\begin{aligned} F_{rr} &= \mu \cdot mg \\ &= (0.015)\cdot(150) \\ &= 2.25 \text{ N} \end{aligned} \quad (4)$$

Aerodynamic drag (F_{ad}):-
This is the drag force offered by the air in our surrounding. This depends on the density of the air through which it is moving, area of the bike with rider and on the bike's velocity.

$$F_{ad} = \rho \cdot A \cdot c_d \cdot v^2 \quad (5)$$

Considering the approximate surface area to be 0.625 m^2 and expected top speed to 40 Km/hr the force required to overcome the aerodynamic drag is:

$$\begin{aligned} F_{ad} &= (1.25)\cdot(0.625)\cdot(0.9)\cdot(12.5)^2 \\ &= 54.93 \text{ N} \end{aligned} \quad (6)$$

Hill climb force (F_{hc}):-
This is the amount of force necessary to move the up a slope or a grade. This depends on the angle of accent the bike is climbing and the net weight it is carrying.

$$F_{hc} = mg \cdot \sin\theta \quad (7)$$

Considering a 10% gradient, which is roughly, the force required to overcome the hill climb will be:

$$\begin{aligned} F_{hc} &= (150)\cdot\sin(5.71) \\ &= 14.92 \text{ N} \end{aligned} \quad (8)$$

Acceleration force (F_a): -
It is the force necessary to accelerate from a stop to maximum speed in a desired time.
The net acceleration force required consists of linear and rotational components given below:

$$F_a = f_{linear} + f_{rotatioanl} \quad (9)$$

First calculating the linear element of the force required from:

$$F_{linear} = ma \quad (10)$$

Considering a stretch of 100 m, using third equation of motion:

$$v^2 = u^2 + 2 \cdot a \cdot 100 \quad (11)$$

The bike will achieve a top speed of 25 km/hr on a 10% gradient with an acceleration of a = 0.24 m/s^2 and a top speed of 45km/hr on flat surface with an acceleration of a = 0.78 m/s^2. So, the force required for linear acceleration on gradient will be:

$$\begin{aligned} f_{linear} &= (15.3)\cdot(0.24) \\ &= 3.68 \text{ N} \end{aligned}$$

And on flat road will be:

$$\begin{aligned} f_{linear} &= (15.3)\cdot(0.778) \\ &= 11.94 \text{ N} \end{aligned}$$

Here we will consider the greater value fore for our calculations, so take 11.94 N as the force required for linear acceleration. The rotational element can be calculated as:

$$F_{rotational} = \omega a \quad (12)$$

Calculation this parameter is a bit complex as the moment of the motor is unknown so, this can be calculated using the value of linear element by increasing the mass by 5% and re-calculating:

$$\begin{aligned} f_{rotational} &= (5\% \ of \ m)\cdot ma \\ &= (0.05(150))\cdot(12.54) \\ &= 12.54 \text{ N} \end{aligned}$$

Thus, net acceleration force from equation (9) is given as:

$$\begin{aligned} F_a &= 11.94 + 12.54 \\ &= 24.49 \text{ N} \end{aligned}$$

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Now, the total tractive effort required to propel the electric bike is calculated using equation (3), by summing up all the forces together as below:

$$TTE = 2.25 + 54.93 + 14.92 + 24.49$$
$$= 81.67 \text{ N}$$

Wheel torque (τ_w):-

This is the amount of torque required at the wheels to move the bike from a stand-still. This depends on the tractive effort required and on the wheel's radius.

$$\tau_w = TTE \cdot R_{wheel}$$
$$= (81.67) \cdot (0.254) \quad (13)$$
$$= 20.74 \text{Nm}$$

{Radius of wheel= 10 inches = 0.254 m}

Power (P_w):

This is the power that the electric motor should capable to deliver for e-bike's propulsion. This is compute as following:

$$P = \frac{2\pi \cdot N \cdot T}{60} \quad (14)$$

Here, in equation (14), Rpm is the only unknown that can be calculated as:

Distance travelled per revolution of the wheel is equal to the circumference of the wheel

$$\rightarrow 1\, revolution = 2\pi \cdot R_{wheel} = 2\pi \cdot (0.254) = 1.6\, m$$

Thus, number of revolutions at required are:

$$n = \frac{750}{1.6} = 470$$

The motor will be geared having a single planetary gear assembly inside the hub casing. So, the gear ratio of the motor further decreases the Rpm. The gear reduction for a planetary gear set generally varies from 0.1 to 0.6, thus assuming a reduction of 0.25, and calculating final value as:

$$N = n \cdot gr$$
$$= (470) \cdot (0.25) \quad (15)$$
$$= 117.5 \sim 118$$

Now computing the power required from equation (14), by plugging in the obtained valued:

$$P_w = \frac{2 \cdot \pi \cdot (118) \cdot (20.74)}{60}$$

$= 256.15$ □ 256 Watts

On higher speed vehicles friction in drive components may warrant the addition of 10%-15% to the total tractive effort to ensure acceptable vehicle performance. Thus, on considering losses, the power that motor needs to deliver is:

$$P_w = 256 + (15\% \cdot 256)$$
$$= 294 \text{ Watts}$$

Looking to the power demand, market availability, product quality and price, the motor selected is a **350 Watts** geared hub motor with a peak power of 550 Watts operating at 48 Volts and giving a gear reduction of 0.195.

Range calculations:

The maximum distance travelled by an electric vehicle upon fully charging the battery is considered as the range of the vehicle. It depends on the power output of the battery and how hard the used throttles to accelerate the vehicle or in simple words, its consumption and usage.
The expected range of the bike is 45 kms per full charge. On an average, the amount of power required by the motor to drive about a kilometer is roughly 12.5 kWh but it varies significantly as per the usage.

Power requirement = desired range x average power consumption

$$P_{req} = R \cdot P_{avg}$$
$$= (50) \cdot (12.5) \quad (16)$$
$$= 625 \text{ Wh}$$

The net power required will be higher than this due to the internal losses of the motor and controller efficiency. Considering a motor efficiency of 90% and controller efficiency of 85%.

$$P_{net} = \frac{P_{req}}{(0.9) \cdot (0.85)} \quad (17)$$
$$= 816.99 \sim 820 \text{ Wh}$$

The current and voltage combination of the battery pack should be such that it can supply the net power required while operating at motor's voltage. The Geared hub motor chosen operates at 48 Volts, thus the only variable left is current rating of the battery in Ampere hour. The Battery current is computed as:

$$\Rightarrow P_{net} = V \cdot I$$
$$\Rightarrow 820 = (48) \cdot I$$
$$\Rightarrow I = \frac{820}{48}$$

$\Rightarrow I = 178.083$ □ 18 Ah

Thus, the battery pack of 48 V and 18 Ah will provide the desired power to the mor for vehicle propulsion while keeping the range in check. The battery pack uses li-po cells from Panasonic arranged in a 13 parallel and 8 series configurations with rating of 3.7 v 2.5 Ah each. The battery takes about an hour and a half to charge at a charge/discharge current of ~10 Amps via a DC fast charger, giving an average run-time of about 100 minutes.

IX. RUNNING COST ESTIMATES OF E-BIKE:

The running cost estimate of the electric bike using a 350 W hub motor powered by a 36 V/ 20 Ah LiPo battery by computing the amount of electricity consumed per charging cycle. The calculations are tabulated below:

electricity price	₹ 4.80	Rs per Unit
battery voltage	36	V
battery capacity	20	Ah
battery power	720	Wh
Energy per charge	0.72	units
cost	₹ 3.46	per charge
range	45	km
running cost	₹ 0.08	per Km

Table 4: Running cost of E-bike

The estimated running cost of the electric bike comes out to be **8 paise/km**.

X. FINAL ASSEMBLY OF E-BIKE:

After the successful design and analysis of the chassis frame, all other various systems and sub-assemblies are now assembled on it to complete the overall electric bike. The final assembly consists of the electric power unit i.e. assembly of motor, battery case, controller, tires, steering handle, brake assembly, suspension assembly and other accessories of the bike.

Figure 12: Complete assembly of electric bike

XI. INNOVATION:

Wireless Charging for E-bikes

Wireless charging is the most exciting innovation in the present world for reducing human effort. This inductive power transfer (IPT) is broadly used in cellphones, smartwatches, and much more electronic equipment. The BMW group recently patents this innovation for its electric motorbikes.

Inductive Power Transfer (IPT), based on magnetic coupling, can be exploited to address the electric load's energy from the electric mains. The magnetic coupling occurs through two coil windings: the power transmitter winding, connected to the mains, is the primary inductor; the power receiver winding, connected to the load, is the secondary inductor [21].

We have infix IPT technology in our Electric bike by moving the receiver into the charging base. Whenever the side stand is placed on the base (composed of an AC coil), the charging will begin on its own.

Wireless charging is a convenient charging option for the Urban commuters, parking space consisting of wireless charging should be used to charge the e-bike, which will power up the bikes for the next run in a few mins.

Helmet Induced Unlock System

It gives immense pleasure and joy to ride any vehicle at high speed but securing oneself at high speed is a big task; this is where helmets come into play to secure a rider while driving into the traffic or surviving in the crash. In India, safety is the least priority for people while driving a vehicle, resulting in 1.5 million deaths in 2019. To make our roads safe, we have introduced an Ignition system which will work only when the rider is wearing a helmet.

The system runs on the technology of Radio frequency identification (RFID). In this technology, the transmitter sends the encoded message via radio signals to the receiver end, where it is decoded. The RFID system installed in the helmet, and the bike is an active type and needs the power to run. The helmet acts as the transmitter end, and the bike has the receiver. The transmitter circuit in the helmet is fitted with a pressure-sensitive physical switch and activates the transmitter circuit when pressed. When the rider wears the helmet, the button is pressed, completing the transmitter circuit and sending the Radiofrequency signals. The receiver end is active and always detecting signals. These signals are then decoded at the receiver's end for the coded instruction to unlock the correct code's E-bike. The rider can now ride the bike by switching on the ignition key.

XII. CONCLUSION:

This research paper projects the process of designing and developing an innovative electric bike. The idea of creating a non-conventional, modern and creative design vehicle played a key in realizing the design from a sketch to a 3D model. The final model emerged from vigorous analysis through static and dynamic bike models exposed to real-life conditions. The achieved robust design needs an appropriate power supply, provided by the 864-kWh battery pack to the powerful Geared hub motor with a peak power of 500 Watts. The bike has an expected top speed of 45 Kmph, that's way more than the standard electric bike and gives a range of about 50 km per charge. The Li-ion polymer battery plays a major role in the bike. It is way lighter than the conventional lead-acid battery and charges in approximately 1/6th of the time, and has a very low self-discharge rate. The bike can carry about 200 kgs of load and can easily climb a 10-15% gradient. The bike's overall design and construction increase its road performance and meet customers' desires by keeping it an efficient and economical package. All-in-all, electric mobility is a solution to a rather bigger problem than just being a day to day commuter, it's a step towards an eco-friendly and sustainable mode of transportation.

XIII. REFERENCES

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