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Design & Analysis of foldable E-Bicycle

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Abstract - *The aim of this paper is to present the detailed report of the project titled as Design and analysis of foldable electric bicycle chassis. The paper tries to cover all the prominent aspects of the project work i.e. 'market research', 'literature review', 'design', 'analysis', 'observations', and 'rectifications', etc. The electric bicycle, as a new mode of private transportation, has ushered in a new era of mobility, although electric bicycle research is very young, no one understands where the efforts are now focused or what the scientific community's primary topics of interest are. Because they are ecologically friendly, require less maintenance, produce less motor output noise, and are more efficient. The primary purpose of an E-Bike is to reduce and eliminate pollution. Rather than using a typical car. An E-bike combines the advantages of both a bicycle and a motorcycle. Meanwhile, a high-priority demand for urban bicycles is their availability in small sizes, which may be addressed by including a feature in their design that allows them to be folded into portable sizes. In other words, by reducing their capacity, bicycles may be transported on trains, buses, or any other method of public transit, as well as kept in small residential and office spaces. The installation of a pivot in the frame permits folding of a bicycle; the frame may then be folded around the pivot, decreasing the bicycle's size. As a result, we feel that our design must meet this need.*

***Key Words*: E-bike, foldable E-bike, Eco-friendly transportation, design and development, etc.**

1. INTRODUCTION

In the present era, humans aren't ready to dedicate specific time to their health. To deal with this deficit we will go cycling daily which can eventually help us mitigate the surplus amount of fats and calories which can lead us to a healthy lifestyle. Transportation on the opposite hand has significantly risen and therefore the amount of excess CO2 released into the air has resulted in heating. The world accounts for 1/3rd of the carbon emission within the atmosphere. The high rise in fuel prices is additionally a serious concern for the common man's life and this will be alternated by different modes of transport available within the market. Consistent with a report, short trips by car contribute disproportionately to transportation emissions. Europe contributes about 30% of trips with cars covering distances but three kilometres. Many countries within the world have given substantial emphasis to the promotion of active travel with a series of reports from the govt. and other private bodies making the case for people to steer or cycle for brief journeys. Cycling is that the preferred mode of transport for brief distances which is additionally an efficient mode of transportation that emits a really less amount of carbon footprint. Cycling is a cheap mode of transport with very low maintenance. Bicycles were introduced within the late 19th century in Europe, and by the first 21st century, quite 1 billion were alive at a given time. From the start and still today, bicycles are and are employed for several uses. The folding bicycle still is considered new technology. Generally, folding bicycle or folder may be a sort of bicycle that comes with hinges or joints within the frame and handlebar stem that let it to be weakened into a more compact. the primary folding bicycle known for the primary patent was originated some time past in 1939 from A.J. Marcelin by the name of "Le Petit Bi", a 16-inch wheeled folding bicycle. To date, enormous amount of manufacturer has begun with their own folder design that suit everybody needs also on compete in market domination. However, there are still more scopes for improvement mostly in term of fabric and functional design. This is often thanks to the frame that creates the folding bike susceptible to stresses and weakness within the overall structure. The big variety of folding bicycles reflects the various methods to permit a bicycle to fold. The only folding frames have one hinge which allows the bicycle to easily fold approximately in half. Bicycles built on this pattern usually even have quick-connect clamps to permit raising and lowering the steering and seat columns quickly. E-foldable Bicycle is essentially an environmentally friendly and economical mode of private transportation powered by human force also as electrical power, and therefore the use of bicycles as a mode of transportation is that the most promising step toward developing green transportation.

There are many situations where people could choose to ride a bicycle, whether it is to go to school, to a job, to meet with friends, or just for recreational purposes. However, once people reach their destination and have a break between their trips, they are left with a bicycle with little means of storing it while they go about their day. Some people buy a bike lock so that they can secure it in a safe location, while

others may just lean it against a wall or even roll it into the building with them. Traveling is also expensive already, and for those who travel so much may wish to take the bicycle with them and not want to rent an expensive vehicle when they reach their destination. The motivation for this project is to come up with a solution so that the bicycle is electrically powered but also compact and small so that people can bring the bicycle on a journey as carry-on, and not be an inconvenience with the bicycle weight and size.

2. DESIGN CONSTRAINTS

2.1 Design Optimisation

To design a product which is compact in size with enhanced ergonomic and aesthetic constraints and characteristics which are better than the typical product available in the market. To design an e-bicycle which is foldable, thereby easy to carry (can be fitted in a bag), light in weight with same strength, durability and load carrying capacity as of the mass produced bicycles available in the market along with an increased power harnessing efficiency from the motor.

2.2 Material Optimisation

To analyse the 3D model for different materials by conducting various tests like structural (stresses, bending, impact, etc.), thermal, etc.; to decide the best material to be used for manufacturing of the product.

Table -1: Advantages & disadvantages of E-Bicycle.

Conventional Bicycle		Foldable E-Bicycle	
Advantage	Disadvantage	Advantage	Disadvantage
Cheaper	Low performance & Heavier	Better performance	Expensive
Strong & Rigid single piece pattern	Bulky and basic structure	Compact & foldable	Less rigid structure due to 2 piece pattern
More Stable	Less Secured	Easy to carry & Secured	Less Stable

3. COMPONENTS

3.1 Bicycle Frame

It is a backbone of every automobile. The entire component is mounted in it. We are using frame with more rigidity and for better space management. We are considering two materials for the frame design. (a) Alloy (6061) Folding Type Frame. (b) Ultra-High Tensile Steel Frame Folding Type

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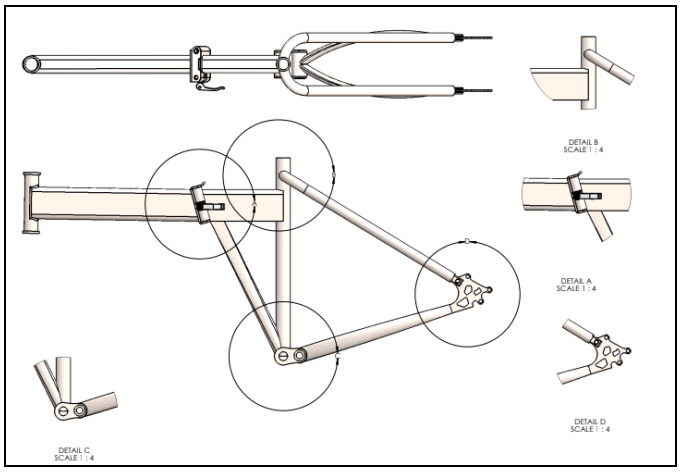

Fig -1: Foldable Bicycle Frame-Unfolded

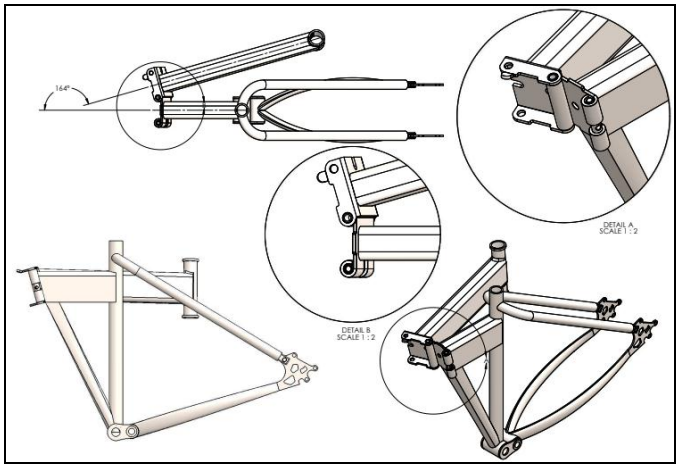

Fig -2: Foldable Bicycle Frame-Folded

Considering the overall DVP parameters associated with the product and considering the weight to strength ratio we can conclude that Aluminium has some significant pros over the steel frame. As it was mentioned above in design parameters, weight consideration was the main objective. It was necessary to opt the material which could bear the forces induced during the motion as well be light. Considering all the above factors, it has been decided to use ALUMINIUM 6061 ALLOY seems to be the most viable material for the component. The strength on weight ratio is sufficient to meet our standards.

Table -2: Material Comparison

Parameters	Aluminium 6061	Steel 4130
Total mass	7335.11 grams	11764.46 grams
Density	2.7 g/cm3	7.85 g/cm3
Volume	2342293.33 mm^3	2342293.33 mm^3

Material Cost	350 per kg	150 per kg
Machinability	Easy to machine	Little hard to machine
Weldability	Can weld to similar metal	Can weld any material
Yield Strength	276 MPa	460 MPa
Tensile strength	310 MPa	560 MPa
Extra comments /Observation	1. Easy to fabricate parts. 2. Material is sufficient to sustain the loads. 3. Cannot carrode. 4. SAE INDIA and major other industrial standard refers the material for cycle manufacturing. 5. Weight is much less compare to steel.	1. Easy to manufacture parts but weight and surface finish will differ. 2. Can corrode. 3. SAE INDIA and major other industrial standard refers the material for cycle manufacturing. 4. Weight is much higher so little affects the portability.

3.2 Rear Hub Motor

Hub motor is machine that converts electric power in mechanical power output. The motor output is rotational motion to the shaft and the input is to be direct current supply. In a hub motor the spinning rotor has an axle running through the middle that is used to drive the machine. Rear hub motors provide propulsion and assistance by spinning the back tire. The circuit switches the power on and off in the coils which creates forces in each one that make the motor spin. The brushes press against the axle of a normal motor which in turn introduce friction, slows it down and releases certain amount of noise and waste energy. They push the rider forward, thereby providing the extra power on demand. They are usually brushless motors which replace the commutator with half a dozen coils and an electric circuit. They are often more efficient at low speeds. The rear hub motor is the most common form of an e-bicycle motor placement in the market. We are using **BLDC 36V/250W, 40 Nm Rear Hub Motor.**

3.3 Integrated Batteries

Battery is an electrochemical device that stores energy in the form of chemical energy. When the battery us connected to a circuit due to the flow of electrons it generates electric energy. The electrolyte is used as an electron transportation medium between the anode and cathode. Integrated batteries on electric bicycles are placed inside the frame of the bicycle cannot be seen outside. Batteries are of two types that are primary and secondary. The Primary batteries are for one-time use and are non-rechargeable. The Secondary batteries are reusable and can be recharged and used frequently. Lead acid batteries and Lithium-ion batteries are the most common used in the industry as they are efficient and cheap. Placement of these integrated batteries are most commonly found inside the bottom tube of the frame. We are using **36V, 5.8Ah Li-Ion (IP65/67 protection) Battery. Mass = 2633.86 grams (approx.)**

3.3 Transmission

A Transmission system is the one which transmit the power developed by the motor to the driving wheel of the Bicycle. In chain Transmission the movement is transmitted by winding and engaging the chain wheel mounted on shafts. It is used to avoid slipping and transmit large forces making the gearshifts to drive the chain on sheets and pinion. In Bicycle the transmission does not transmit constant torque. In bicycle chain drive has maintained the advantage between the drive and driven sprockets to achieve maximum speed. The crank set is the component that converts the reciprocating motion into rotational motion which is used to drive the chain. It consists of one or more sprockets attached to the cranks to which the pedals are attached. We are using **Single - Speed Bicycle Chain - 12.7mmx3.175mm Crankset - 40T**

3.4 Brakes

Brake is the most important because by the help it, we can stop the vehicle. There are many types of brakes are present in the market but we are using the most suitable brake. Brakes used to slow down as kinetic energy (motion) is transformed into thermal energy (heat). There are different types of brakes however, the most common used are calliper brakes, cantilever brakes, V-Brakes and disc brakes. Disc brakes are more powerful and require less strength to operate. They require a compatible hub, wheel rim, and frame. There are two types of disc brakes they are Hydraulic or mechanical cable pull. They are great for fast application on Off-Road roads. Disc brakes can handle high heat and do not damage tyre by heating the rim like the rim-brakes do. Disc brakes are durable and high in strength hence; they are used on rough tracks. V-Brakes are also called as linear-pull or direct-pull brakes. They are extremely powerful and are commonly used in off-road bikes & mountain bikes. This breaks are little heavier than the cantilever brakes and can work on rough terrain. They have the power to stop on wet or muddy terrain and are more durable than the cantilever brakes. We are using **Mechanical Disc Brake at the front and a V-Brake at the rear.**

3.5 Wheel & Tires

A bicycle wheel is mostly wired frame which supports the tyre and frame of the bicycle. A bicycle wheel consists of several sub-parts like hub, Axle, Bearings, rims and spokes. Tubeless tires are used on mountain bikes due to its low air pressure which gives a better traction. We are using **a pair of 27.5" x 1.95" tires with Double Wall Alloy Rims.**

3.6 Suspension

Bicycle suspensions are used to insulate the bike from rough terrain. The suspension geometry is design such that it comforts the driver's ride over any terrain maintaining the good ride height. Being an off road bicycle it is suitable to have a long travel suspension that could easily bounce and rebound with minimum shock transfer to the rider & also help to negotiate sharp corners comfortably. They are primarily used in mountain bikes and off road bikes. In front telescopic suspension is used because of durability, strength and handling characteristics. In a bike it has 1 or 2 shock absorbers which are designed to mitigate the impact of rough terrain by compressing and rebounding. Most mountain bike forks will feature during aspects like a degree of adjustability, firm to plush as well as adjustability in the travel amount. It is based around a spring and a damper and on the lower end or on the occasional gravity focused fork, a metal coil spring. We are using **Steel Rigid Aerodynamic Fork Rigid suspension**

Fig -3: Suspension and Wheel System.

3.9 Electrical Subsystem Assembly

As it was mentioned above in design parameters, for the electrical assistance to support with motor assist and the maximum terrain conditions we have decided to use
Battery: 36V, 5.8Ah Li-Ion (IP65/67 protection) (Mass = 2633.86 grams), Motor: BLDC 36V/250W, 40 Nm, PCB Controller (Mass = 153.39 grams).

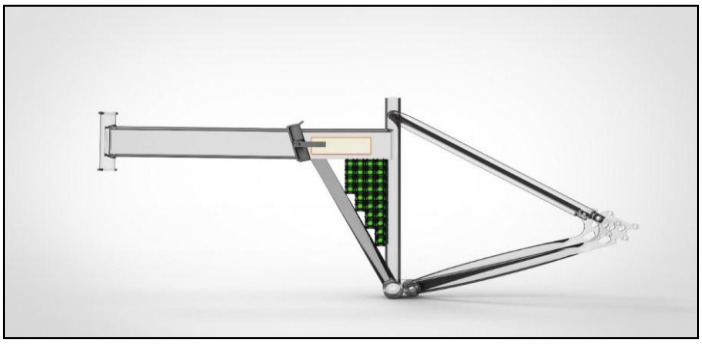

Fig -4: Electrical Subsystem Assembly.

4. DESIGN TESTING AND ANALYSIS

4.1 Frame Analysis

Material: Aluminium 6061
Density: 2.7 g/cm3
Maximum Tensile Strength: 310 MPa=3.1e+8 N/sq. m.
Maximum Yield Strength: 276 MPa=2.76e+8 N/sq. m.
Maximum Stress: 1.389e+7 N/sq. m. (which is much less compare to allowable material strength)
Maximum Total Deformation: 1.329e-10 mm (which is much less for practical considerations)
Maximum strain: 1.516e-4
Maximum force applied: Due to weight consideration of rider as 70 kg.

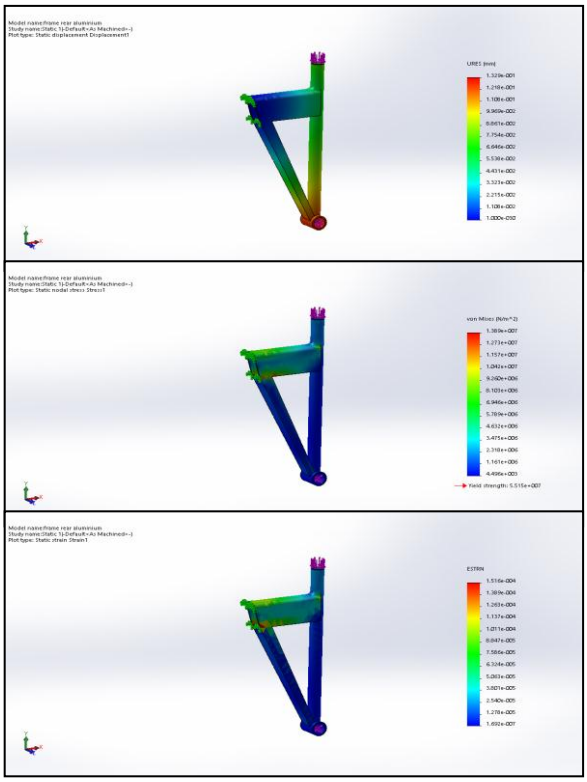

Fig -5: Stress, strain and deformation analysis under static load conditions for main frame.

Material: Steel 4130 alloy
Density: 7.85 g/cm3
Maximum Tensile Strength: 560 MPa=5.6e+8 N/sq. m.
Maximum Yield Strength: 460 MPa=4.6e+8 N/sq. m.
Maximum Stress: 5.78e+5 N/sq. m. (which is much less compare to allowable material strength)
Maximum Total Deformation: 1.326e-5 mm (which is much less for practical considerations)
Maximum strain: 1.81e-6
Maximum force applied: Due to weight consideration of rider as 70 kg.
Factor of safety: FOS > 1

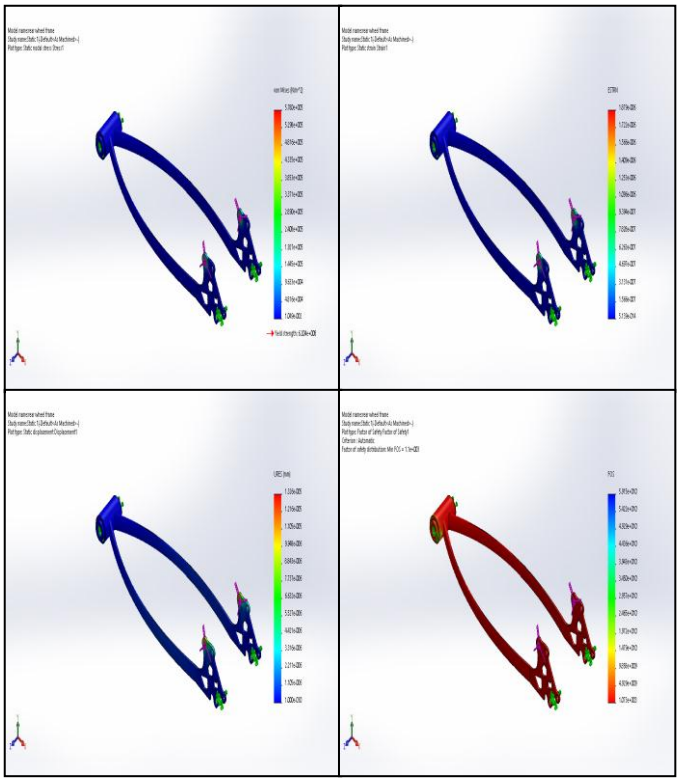

Fig -6: Stress, strain and deformation analysis under static load conditions for rear frame.

4.2 Hinge Analysis

Material: Mild steel
Density: 8 g/cm3
Maximum Tensile Strength: 440 MPa=4.4e+8 N/sq. m.
Maximum Yield Strength: 370 MPa=3.7e+8 N/sq. m.
Maximum Stress: 2.8e+5 N/sq. m. (which is much less compare to allowable material strength)
Maximum Total Deformation: 7.798e-5 mm (which is much less for practical considerations)
Fig -7 left: direction of actual load consideration to justify the strength of axle used in hinge. (OEM part capable of handling standard cycle load and variation).
Fig -7 right: Deformation concentration zone.

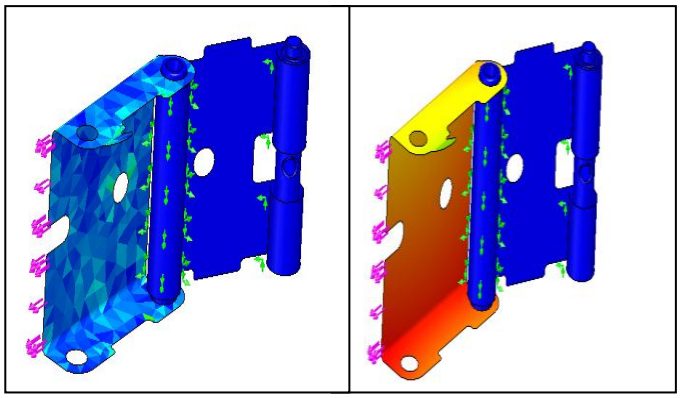

Fig -7: Deformation concentration zone for hinge.

5. CONCLUSIONS

This study aimed to understand the convenience of using foldable E-bicycles as a mode of transportation in modern cities. In this study, we proposed that the design of the folding mechanism of bicycles should be considered from three aspects. First, the advantage of foldable bicycles is that the greater the number of pivots, the smaller is the bicycle size after folding. On the other hand, if the number of pivots is small, the hand movement is shortened and the performance time is reduced. Therefore, folding usability is improved. Due to its high strength and compact size it is very easy to park it inside the office, home, public places etc. Due to its efficient and green electric drive we can ride this bicycle to a great distance and it also help us to move one step toward the use of green energy.

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