DESIGN FOR SOLAR – POWERED E-BICYCLE: SUSTAINABLE RIDE FOR THE FUTURE

Dr. V. Pandyaraj[1], Mathan Raj S[2], Sakthi Babu N[3], Arun V[4]

[1]Assist. Prof, Dept of Mechanical & Automation Engineering, Sri Sai Ram Engineering College, Tamil Nadu, India
[234]Student, Dept of Mechanical Engineering, Sri Sai Ram Engineering College, Tamil Nadu, India

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Abstract - *Design a electric bicycle powered by solar technology to improve its efficiency and sustainability. The objective is to decrease dependence on fossil fuels by utilizing solar energy to meet the power demands of the electric bicycle, the design process includes integrating solar panels into the bike frame for effective solar energy collection, all while preserving the bicycle's aesthetic appeal and functionality. The fabrication phase emphasizes the selection of lightweight and durable material for the frame and components, ensuring performance and durability. Additionally, the electric system is designed with effective power control and solar solutions to maximize the solar energy, electric bicycle offers eco-friendly transportation option with extended range and reduced environment impact.*

***Key Words*: Eco-Friendly Ride, Green Transportation, Solar-Assisted Cycle, Energy-Efficient Mobility, Smart E-Bike**

1. INTRODUCTION

Electric bicycle (e-bike) and the selection of material showcase a dynamic relationship between technological advancement and user demands, beginning in the late 19th century e-bikes emerged as a practical and eco-friendly transportation option, gaining traction among companies largely due to advancements in battery and motor technology over recent decades. Concurrently, the material used in bicycle manufacturing have transitioned from wood and iron to contemporary composites that enhance the bike's performance and durability. Since the 1920s, lighter material such as aluminum and carbon fiber have become dominant, especially in high-performance and electric bike models.

1.1 LITERATURE REVIEW

E-bicycle are generally used two wheel transport system with the frame is crucial component. Composite have increases as not heavier but strong bicycle frame material. This suggest that mixture with flex reinforcement possible and lightweight choice for e-bicycle frame [1]. The three external road per button reluctance machine SRM planned for a e-bike application. The plan meets the e-bike 450-500W output power requirement with decreases gearbox approve a max speed 32 km hour the motor's torque who is optimized use torque ripple decrease [2]

The emergence of e-bikes is advance by driven battery and motor device and innovation industrial plan. This studies the developing vehicle type in sustainable transport, think mobility, safety and surrounding impact.[3] the paper give a study and design of hybrid bicycle framework in daily needs used to supported power source like Dynamo and solar based energy whether used to charge battery[4]

The pattern mixture three phase 20 pole/18slot outside rotor BLPM motor with 6 link 2 degree of freedom (2-dot) compound planetary gear train PGT to beat occurring pattern restriction. The incorporate device propose 6 forward speed, two drive system[5] The paper offers a common method for e-bicycle pattern based on all three dimensional system theory this method pointed on the time axis, comparing live product with the new national standard[6]

The e-tricycle pattern support on reverse engineering from common transport cabs and bicycle, that tricycle frame is thick that the bicycle frame due to its thick pattern. The oval tube provide better safety element and rendering opposed vertical weight.[7] This paper studies the possible of electric support e bikes to decreases badges to bicycle lightly rising the number of travels and variety of people cycling and online survey of 553 e-bikes user over North America[8]

The paper consider the interactive research between in bikes and the engineering university of find hoven on the general pattern and execution of an electrical supported bicycle structure protect all substructure [9] Custom patterned drivers for city, hill and distance and speedily bicycle can call high e bicycle cost and load supply[10] E motor influenced bicycle have been in the united states market for 2 years with modified model directing subjected like high cost and load, put analogue a direct drive DC drive e bicycle drive structure point on mechanical shows11]

The bicycle activity is stimulation using mathematical models, involves human power and emoted dynamic model based control study also convey to control the speed under slope level effect and experiment study12] The bicycle is make global notice due to its ecology and zero discharge benefits, a stimulation studies convey to grow a high performance of electric bicycle, regard factors mass wind, speed and slope[13]

structure gain insights before field mission, the stimulation pointed on supply parameter trip, rates, length and direction couple do with demand parameters like the number of e-bicycle.[14] The paper pattern on radial field pm brushless DC motor drive for electric bicycle particular structure performance analyze and design structure[15]

A survey of 806 defendant involves 363 e bicycle owning ones found that e bicycle are more essential for utility travel change and running errands groups with better health time millennia's reproduction x cycle for time saving and environment aspect[16] E-bikes are slowly improving in transport market with over 31 million deal in 2012 China leads in e-bicycle marketing come by the Netherlands and Germany[17]

The lay in light electric vehicle as raised specifically in e-power support cycle, this work introduce a project for full hybrid e-bicycle pointing on energy cyclist and motor to reform productivity the algorithm at 10 is based on biometric data[18]. This paper offer a new control advance for e-power support bicycle base on disturbance sense the advance calculate road slope and bicycle body weight adopts motor support power ratio in real time and upgrade riding experience and stimulation[19]

The study document the possible of the electrical supported bicycle as 24 converge physical activity criteria in terms of intensity 12 compulsive activity adult content cycle 4.3 km track at different intensity stage using three supported environment no support, eco assisted and power [20].

1.2 MATERIALS

1.2.1 STEEL

The material is used on the bicycle is steel, Steel is a blend of press and carbon that has improved strength and resistance to breaking when compared to diverse sorts of press. Due to its solid capacity to stand up to pressure and its reasonableness, steel is broadly delivered and utilized around the world, steel is utilized in different application such as development, fortification for concrete, bridges, foundation, ship, trains, automobile bike etc. Steel continuously contains press as its essential component, in spite of the fact that it can to have different other components included or included. Stainless steel assortments, known for their resistance to rust and discolor, more often not have around 11% chromium, press serves as the foundational metal for steel.

TABLE 1– Mechanical Properties of Steel

Properties	Max-tensile Steel	Units
Tensile Strength	5500	MPa
Density	8050	Kg/m³
Yield Strength	3000	MPa
Hardness	67	HRC
Melting point	1540	ºC
Thermal Conductivity	80	W/(m.k)
Electrical Conductivity	10	S/m
Elongation	60	%
Modulus of Elasticity	210	GPa
Fatigue Strength	1100	MPa

1.2.2 ALUMINIUM

When it comes to solar panels, aluminum stands out because it builds tough yet light frames. These shields guard delicate parts while holding everything together. Over time, rust hardly touches it, so exposure to rain or sun does not weaken its role. Now engineers are slipping it into the actual energy-capturing layers instead of pricier silver. That swap slashes production costs without sacrificing strength. Panels last longer under extreme conditions - heat, ice, storms - all thanks to this metal's resilience. Since it weighs less than older materials, mounting them on roofs takes less effort. At end of life, nearly all of it can be pulled back and reused, closing the loop cleanly.

TABLE 2 – Mechanical Properties of Aluminium

Properties	Max-tensile Values	Units	Alloy
Density	2700	Kg/m³	6005
Tensile Strength	260	MPa	6005-T5
Yield Strength	245	MPa	6061-T6
Reflectivity	95	%	
Thermal Conductivity	235	W/(m.k)	6063
Elongation at Break	8	%	6005-T5

2. GRAPHICAL ANALYSIS OF E-BICYCLE STEADILY GREW IN PAST DECADE

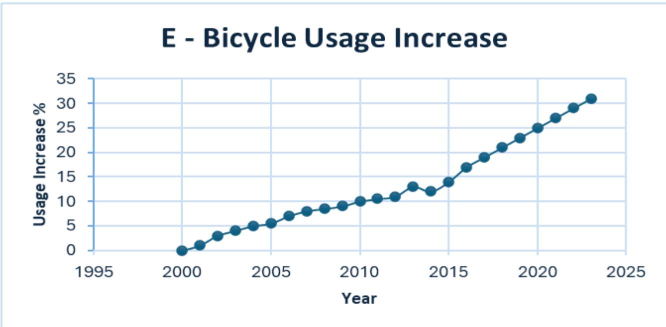

Chart – 1: E-Bicycle Usage Grew Over Years

From 2000 to 2023, the adoption of e-bicycle had a slow growth rate increasing from 0.1% to 6% by the end of 2013 due to advancement in technology. The product gained momentum “between” (2014 to 2019), with rapid urbanization and a growing concern for climate issues driving usage up to 22% by 2019. The COVID-19 pandemic in 2020 caused a further increases in demand, reaching 30% and beyond. E-bike adoption reached its peak at 50% by 2023, establishing itself as a transportation.

3. DESIGN OF THE E-BICYCLE

Fig - 1: 3D View of the Design

3.1. ANALYSIS ON E-BICYCLE FRAME

3.3.1. Type - Equivalent (Von – Mises) Stress

Lowest stress levels dropped near zero in areas without load. Moving into key sections, pressure shifted sharply - down from nearly 193 MPa to just over 21 MPa across changing zones.

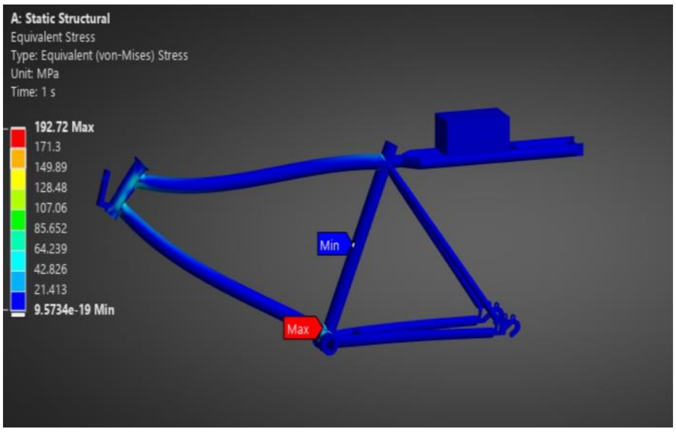

Fig – 2: Equivalent Stress

Under the limit of structural steel’s yield strength - between 250 and 355 mega pascals - the stresses stay within elastic behavior. Sharp changes in shape likely cause those concentrated spots. Fatigue often begins where the form turns abruptly.

3.3.2. Type – Total Deformation

Up to 0.329 mm of movement happens near open edges. That shift shows where flexibility matters most under load

From one side to the other, movement shifts between 0.041 mm and 0.329 mm. This stretch isn’t even across both ends. One direction pulls harder than the opposite. The change in shape follows a tilted path. Unequal force bends it off center Just 0.047 percent shift across the part’s full span showed it holds firm when pushed. That tiny bend proved the structure meets rigidity specs under load.

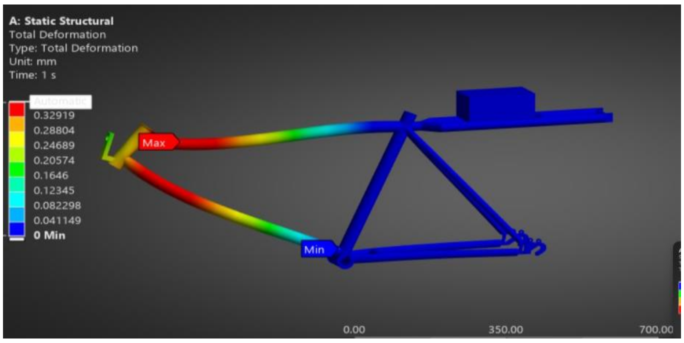

Fig – 3: Total Deformation

What stands out is that the shift in position stayed under half a millimeter - tight enough for exacting steel fits. Movement like that doesn’t mess up fine construction work. Even slight changes matter here. The frame held firm where it needed to.

3.3.3. Type – Safety Factor

Critical safety factor 1.297 found at stress hotspots
Optimum safety factor over 15 for bulk materials

Finding a global safety factor above 1.0 doesn’t automatically rule out trouble spots. Where local values near 1.3 pop up, fatigue effects might need extra scrutiny. Because stress repeats can weaken materials over time, checking cyclical forces becomes necessary even if overall margins look fine. Safety isn't uniform - high points elsewhere don’t guarantee weak zones stay intact.

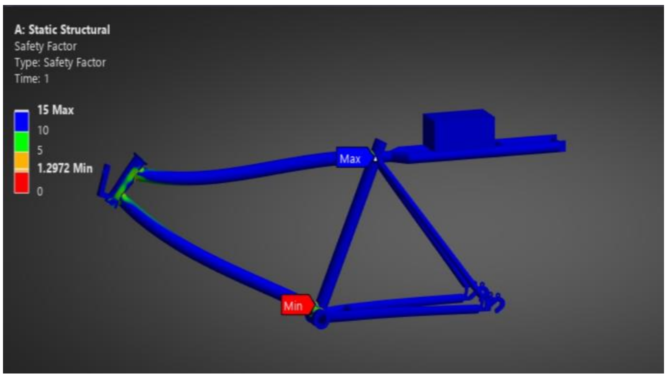

Fig – 4: Safety Factor

Stress hits 192.72 MPa under load. The material handles up to 250 MPa before risk rises. That leaves a safety buffer of nearly 30%. Strength stays within limits because of this gap

A shift up to 0.329 mm shows one peak. Another reaches half a millimeter. Nearly a third of the total stretches under strain. A little above one point two nine seven is the smallest safety margin when set to one. That change means nearly thirty percent more room before reaching limit.

4. CONCLUSIONS

To sum up, the available literature on the solar e-bicycles promotes the enthusiasm in the realization of clean energy sources in personal mobility. Such bicycles are able to minimize the consumption of energy from the national power grid and are more efficient in promoting travel. From the light weight structures to the creative ways of storing energy, we have seen cases of many approaches to improvement of performance and function. The clinical studies conducted on the solar e-bikes further strengthens the argument that such systems are suitable for those who are trying to be green in the modern society. As the requirements of the cities to provide urban mobility in a more environmentally friendly manner rise, solar e-bicycles emerge as a high standard means of transport integrating comfort, safe usage and energy efficiency. There is a lot more that can be done in this area and we hope that it will encourage many others to adopt green transport solutions thus contributing to a better and clearer world.

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