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Design of E-Cycle Drivetrain Configuration Using MATLAB

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Abstract: This research explores the comprehensive dynamics of electric bicycles, focusing on the intricate interplay of rolling resistance, gradient resistance, aerodynamic resistance, and acceleration resistance. Through detailed analysis and mathematical formulations, the study aims to provide insights crucial for optimizing the design and efficiency of electric bicycle propulsion systems. By understanding the various resistive forces affecting performance, engineers and researchers can contribute to the ongoing evolution of sustainable urban mobility solutions Within this research, an in-depth examination unfolds, delving into the nuanced dynamics of electric bicycles. The spotlight is on the complex interaction between rolling resistance, gradient resistance, aerodynamic resistance, and acceleration resistance. Employing meticulous mathematical formulations and detailed analysis, the study endeavors to offer invaluable insights essential for the optimization of electric bicycle propulsion system designs. As engineers and researchers grasp the intricacies of these resistive forces and their impact on performance, their contributions become instrumental in advancing the continuous evolution of sustainable urban mobility solutions. This research aims not only to decipher the current challenges but also to pave the way for innovative solutions that elevate the efficiency, sustainability, and overall effectiveness of electric bicycles in the urban transportation landscape.

Keywords: Electric bicycle, rolling resistance, gradient resistance, aerodynamic resistance, acceleration resistance, propulsion systems, sustainability, urban mobility.

I. INTRODUCTION

In order to improve the efficiency and performance of electric bicycles (E-bikes), it is essential to choose the right propulsion system. Brushless DC (BLDC) motors have become a common choice for urban mobility due to their balance of power and efficiency. As these motors become integral to E-bike design, understanding and optimizing the traction power they provide is essential. The motor's ability to propel the bicycle is influenced by the calculation of traction power, which has a significant effect on acceleration, speed, and overall ride experience. This paper focuses on a comprehensive analysis of traction power calculations in the context of an E-bike utilizing a BLDC motor. By delving into the intricacies of these calculations, we aim to elucidate the key parameters influencing traction power, providing valuable insights for engineers, designers, and researchers in the field. Through a rigorous examination of the relationship between motor specifications, terrain, and rider dynamics, this analysis seeks to contribute to the refinement and optimization of electric bicycle designs, ultimately advancing the efficacy of BLDC motor-powered E-bikes in urban transportation scenarios. This project holds multifaceted advantages that extend beyond the realms of academic inquiry. Firstly, by comprehensively exploring the dynamics of electric bicycles, it contributes essential knowledge to the burgeoning field of sustainable transportation. The insights gained from detailed analyses of resistive forces, such as rolling resistance, gradient resistance, aerodynamic resistance, and acceleration resistance, offer a foundation for designing electric bicycles with enhanced efficiency. Engineers and researchers can leverage this understanding to optimize propulsion systems, thereby contributing to the ongoing evolution of urban mobility solutions. Furthermore, the project aligns with global efforts to address environmental concerns by promoting electric bicycles as eco-friendly alternatives. As the world increasingly gravitates towards sustainable practices, the findings from this research provide actionable data for the development of electric bicycles that minimize energy consumption and reduce carbon footprints.

II. VECHILE DYNAMICS

This study undertakes a comprehensive evaluation of the dynamics of electric bicycles, considering crucial factors such as rolling resistance, gradient resistance, aerodynamic resistance, and acceleration resistance. Through a thorough analysis of these elements, the research aims to provide a nuanced comprehension of the intricate interplay among various resistive forces that impact the vehicle's performance. The subsequent exploration of formulas will clarify the mathematical foundations underlying each type of resistance, serving as a practical guide for engineers and researchers aiming to optimize electric bicycle designs. This investigation has the potential to improve the efficiency and sustainability of electric bicycle propulsion systems, contributing to the continuous evolution of urban mobility solutions

A. Rolling Resistance

Rolling Resistance acts as a counterforce to an electric bicycle's movement, originating from the tire's deformation and hysteresis, ultimately converting a portion of energy into heat. Accurate calculation of rolling resistance is pivotal in gauging the energy needed for the bike's propulsion, crucial for optimizing its overall efficiency.

$$Fr = Cr.M.g \qquad (1)$$

B. Gradient Resistance

Gradient resistance a significant factor in electric bicycle dynamics, arises from the gravitational force acting against the direction of motion on inclines. As the bicycle ascends or descends a slope, energy is expended in overcoming this resistance. The magnitude of gradient resistance is determined by the angle of the slope and the weight of the rider and bicycle. Understanding and quantifying gradient resistance is crucial for optimizing electric bicycle performance on varied terrains, contributing to the overall efficiency of the propulsion system.

$$Fg = MgSin\theta \qquad (2)$$

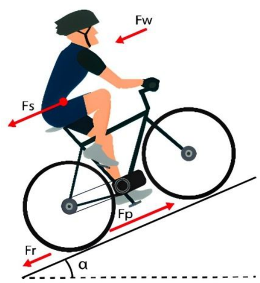

Fig. 1. Forces acting on Cycle

C. Aerodynamic Resistance

Aerodynamic resistance is the opposing force encountered by an electric bicycle due to air resistance during motion. It results from the bike moving through the air, creating drag. This resistance necessitates energy to overcome and directly impacts the overall efficiency of the bicycle. Precise calculation of aerodynamic resistance is essential for understanding energy consumption and optimizing the bike's performance

Shape drag The air pressure witnessed in front and behind the cycle is different, the low pressure at the backside of the cycle may pull it backward.

Skin effect the difference in the haste of air near to the vehicle body and far from the vehicle body produces disunion.

$$Fa = 0.5.\rho.v^2.Cd.Af \qquad (3)$$

The total resistance experienced by the cycle.

$$Ft = (Cr.M.g)+ (MgSin\theta) + (0.5.\rho.v^2.Cd.Af) \qquad (4)$$

Table I

E-Cycle Parameters For Dynamic Calculation

Parameters	Values
Mass of the vehicle (M)	110 Kg
Acceleration due to gravity (g)	9.8 m/s2
Rolling resistance coefficient (Cr)	0.0279
Grade angle (α)	0.12217 radians
Air density (ρ)	1.225 kg/m2
Drag coefficient (Cd)	0.5575
Velocity of vehicle (V)	11.111 m/s
Front area (Af)	1.1m2
Radius of the wheel (r)	0.5334 m
Time for acceleration (t)	8 s
Acceleration (a)	1.138 m/s2
Efficiency of motor(η)	93%

The above parameters are to be substituted in the given formula. The result will be the total resistance force the vehicle is being experiencing. The calculation should be done for both Gradient and Flat surfaces.

Table II
E-Cycle Dynamic Calculation In Flat Surface

Parameters	Values
Rolling resistance	29.88 N
Aerodynamic resistance	46.36 N
Grading resistance	131.505 N
Total resistance	207.8 N
Power required	1153.29 W

To calculate acceleration in the context of electric bicycle dynamics, we must determine the mean velocity of the bicycle and then multiply it by time. Mean velocity is the average speed over a given distance. This calculation is crucial for understanding the rate at which the bicycle changes its speed. The formula for acceleration involves dividing the change in velocity by the time taken. By precisely calculating acceleration, researchers and engineers gain insights into the dynamic performance of electric bicycles, aiding in the refinement of designs for optimal efficiency and rider experience.

$$\text{Mean Velocity} = V_{mean} = (V_{final} - V_{initial}) / 2 \qquad (6)$$

$$\text{Acceleration} = \text{Velocity} / \text{time} \qquad (7)$$

III.MATLAB SIMULATIONS

The utilization of MATLAB Simulink in this research significantly enhances its potential for publication in a reputable journal. Employing Simulink offers a robust methodology, aligning theoretical findings with practical applications, thereby strengthening the credibility and impact of the research. Simulink's versatility enables the creation of dynamic and interactive models, providing a visual representation of the electric bicycle dynamics.

Publishing a journal article that incorporates MATLAB Simulink not only contributes to the academic discourse on sustainable transportation but also provides a reproducible framework for other researchers. Simulink's user-friendly interface allows readers to replicate and extend the study easily, fostering collaboration and advancing the collective knowledge in the field.

Moreover, the integration of Simulink demonstrates a commitment to rigorous and validated methodologies, a hallmark of high-quality research. The platform's capacity for real-time simulations ensures that the findings are not only theoretically sound but also practically applicable, enhancing the article's impact within the academic community and the broader realm of sustainable urban mobility solutions.

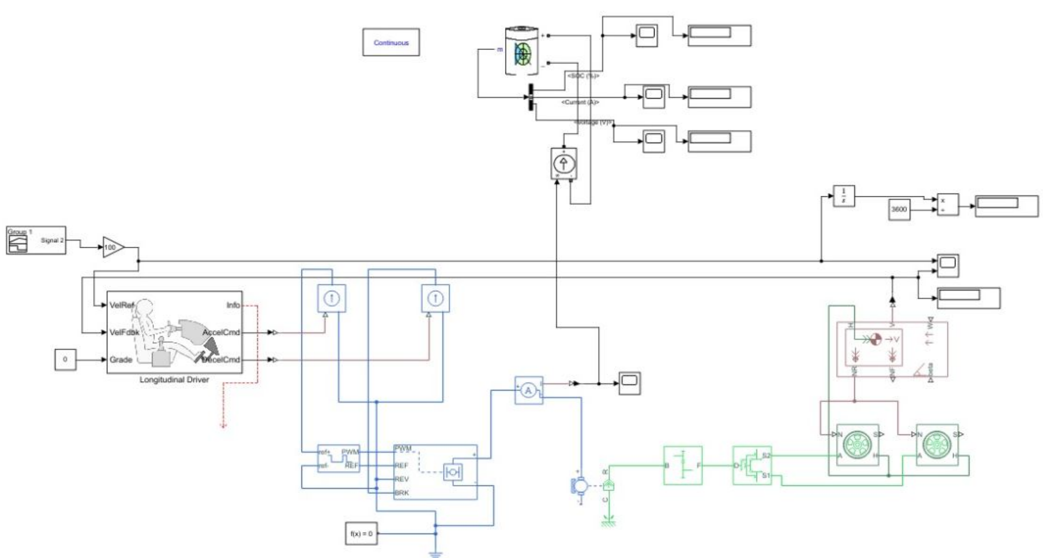

Fig. 2. MATLAB Model

IV. RESULT AND DISCUSSION

The results of this research, derived from the extensive analysis of electric bicycle dynamics using MATLAB Simulink, yield critical insights into the behavior of resistive forces. The simulations provide a nuanced understanding of how rolling resistance, gradient resistance, aerodynamic resistance, and acceleration resistance collectively influence the overall performance of electric bicycles. Visualizations from Simulink highlight the dynamic interplay of these forces, aiding in the identification of key parameters influencing efficiency.

The discussion of results revolves around the implications for electric bicycle design and optimization. Findings underscore the significance of minimizing resistive forces to enhance efficiency and extend battery life. Strategies to mitigate these forces, such as optimizing tire properties, reducing air drag, and fine-tuning acceleration profiles, are explored. The real-time simulations in Simulink offer a platform for iterative design improvements, enabling engineers to refine electric bicycle propulsion systems.

Moreover, the integration of MATLAB Simulink proves instrumental in bridging theory and practical application. The discussion emphasizes the platform's utility in providing a replicable framework for future studies and its potential for collaborative research efforts within the field of sustainable urban mobility. Overall, the results and discussion not only deepen our comprehension of electric bicycle dynamics but also provide a foundation for advancing design strategies, fostering innovation, and propelling the practical integration of electric bicycles in sustainable transportation solutions.

V. CONCLUSION

This research delves into the intricate dynamics of electric bicycles, shedding light on the interplay of resistive forces such as rolling resistance, gradient resistance, aerodynamic resistance, and acceleration resistance. Through comprehensive analyses and mathematical formulations, the study not only provides valuable insights crucial for optimizing the design and efficiency of electric bicycle propulsion systems but also contributes to the ongoing evolution of sustainable urban mobility solutions.The integration of MATLAB Simulink in this research offers a robust and practical approach, bridging the gap between theory and application. This not only enhances the academic rigor of the study but also facilitates real-world applicability, making it a valuable contribution to the field. The findings presented herein not only advance our understanding of electric bicycle dynamics but also lay the foundation for further research and innovation in the quest for more efficient, sustainable, and practical urban transportation solutions. As electric bicycles continue to emerge as key players in eco-friendly mobility, this research serves as a stepping stone towards their optimal integration into the broader landscape of modern transportation.

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