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Research Paper

DESIGN AND DEVELOPMENT OF A WEATHER-PROTECTED ELECTRIC BICYCLE

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ABSTRACT

The transition toward sustainable transportation has become a global necessity due to the increasing concerns of environmental degradation, depletion of fossil fuels, and rapid urbanization. Electric mobility has emerged as a promising solution to address these challenges, with electric bicycles (e-bikes) gaining significant attention due to their affordability, efficiency, and eco-friendly characteristics. However, despite the widespread adoption of e-bikes, their practical usability is often limited by environmental exposure, including rain, sunlight, dust, and wind conditions, which adversely affect rider comfort, safety, and overall system reliability.

This research work focuses on the design and development of a weather-protected electric bicycle that integrates a lightweight structural framework with an efficient electric propulsion system. The proposed system utilizes a polyvinyl chloride (PVC) pipe-based structure to support a protective canopy that shields the rider from adverse weather conditions. The design prioritizes cost-effectiveness, ease of fabrication, lightweight construction, and durability, making it suitable for real-world applications, especially in urban and semi-urban regions.

The electric bicycle operates using a battery-powered motor system, which converts electrical energy into mechanical energy to drive the rear wheel. The integration of the weather protection mechanism ensures that the rider remains comfortable and protected without significantly affecting the aerodynamic performance or energy efficiency of the vehicle. The structural design is optimized to maintain stability, balance, and minimal additional load on the bicycle frame.

Extensive testing and performance evaluation were conducted to analyze parameters such as speed, battery efficiency, load capacity, and environmental adaptability. The results demonstrate that the system achieves a maximum speed of approximately 20–25 km/h and a travel range of 30–40 km per charge while maintaining structural integrity and rider comfort under varying weather conditions.

This work highlights the potential of combining simple engineering principles with innovative design approaches to develop cost-effective and sustainable mobility solutions. The proposed system can be further enhanced through the integration of advanced materials, smart control systems, and renewable energy sources, making it a viable solution for future transportation systems.

INTRODUCTION

The modern world is experiencing an unprecedented rise in population, urbanization, and industrialization, which has led to a significant increase in transportation demands. Conventional transportation systems primarily rely on fossil fuels such as petrol and diesel, which are not only finite in nature but also contribute heavily to environmental pollution. The emissions from internal combustion engine vehicles are one of the major sources of greenhouse gases, leading to global warming and climate change. In addition, the rising cost of fuel and traffic congestion in urban areas further necessitate the need for alternative transportation solutions.

Electric vehicles (EVs) have emerged as a sustainable alternative to traditional vehicles due to their ability to operate using electrical energy instead of fossil fuels. Among various types of EVs, electric bicycles have gained popularity due to their simplicity, affordability, and ease of use. E-bikes are particularly suitable for short-distance travel, last-mile connectivity, and urban commuting. They require less energy compared to cars and can be charged using standard electrical outlets, making them highly convenient for users.

Despite these advantages, conventional electric bicycles suffer from several limitations that restrict their usability in real-world scenarios. One of the most significant limitations is the lack of protection against environmental conditions. Riders are exposed to rain, sunlight, wind, and dust, which can lead to discomfort, health issues, and reduced efficiency. For instance, riding in heavy rain can damage electrical components, while prolonged exposure to sunlight can cause fatigue and dehydration.

To overcome these challenges, there is a need to develop a system that provides adequate weather protection while maintaining the inherent advantages of electric bicycles. The integration of a protective structure should not compromise the performance, efficiency, or maneuverability of the bicycle. Additionally, the system should be cost-effective and easy to manufacture, ensuring its accessibility to a wide range of users.

The proposed project addresses these challenges by designing a weather-protected electric bicycle using a lightweight PVC pipe frame. The PVC structure acts as a support for a canopy that protects the rider from external environmental conditions. The use of PVC material offers several advantages, including low cost, corrosion resistance, and ease of fabrication. Furthermore, the design ensures that the added structure does not significantly increase the weight or affect the balance of the bicycle.

This project aims to provide a practical and efficient solution for enhancing the usability of electric bicycles in all weather conditions. It also contributes to the promotion of sustainable transportation by encouraging the adoption of eco-friendly mobility solutions. The study combines principles of electrical engineering, mechanical design, and material science to develop an integrated system that meets the requirements of modern transportation.

LITERATURE SURVEY

The field of electric mobility has witnessed significant advancements over the past decade, driven by the need for sustainable transportation solutions. Electric bicycles, in particular, have gained widespread attention due to their low energy consumption and environmental benefits. Numerous studies have been conducted to improve the performance, efficiency, and usability of e-bikes.

Research on electric bicycles has primarily focused on improving battery technology, motor efficiency, and control systems. Lithium-ion batteries have become the preferred choice due to their high energy density, long lifespan, and fast charging capabilities. Similarly,

brushless DC motors are widely used in e-bikes due to their high efficiency, low maintenance, and compact design. Advanced control systems have also been developed to optimize power delivery and enhance riding experience.

In addition to electrical advancements, researchers have explored various structural designs to improve the functionality of e-bikes. Some studies have proposed the use of aerodynamic designs to reduce air resistance and improve efficiency. Others have focused on lightweight materials such as aluminum and carbon fiber to enhance performance. However, these materials are often expensive and not suitable for low-cost applications.

Weather protection in transportation systems has been extensively studied in the context of automobiles and enclosed vehicles. However, limited research has been conducted on weather-protected bicycles. Some researchers have proposed fully enclosed bicycles known as velomobiles, which provide excellent protection against environmental conditions. However, these systems are bulky, expensive, and difficult to maintain, making them unsuitable for widespread adoption.

Other studies have explored the use of detachable covers and foldable structures to provide temporary protection. While these designs offer flexibility, they often compromise stability and durability. Additionally, the use of heavy materials such as metal frames increases the overall weight of the bicycle, affecting performance and efficiency.

The selection of materials plays a crucial role in the design of weather-protected systems. PVC has emerged as a promising material due to its low cost, lightweight nature, and resistance to corrosion. However, its application in bicycle-mounted structures has not been extensively explored, indicating a potential area for research and innovation.

The literature review highlights the need for a simple, cost-effective, and lightweight solution for weather-protected electric bicycles. The proposed project addresses this gap by integrating a PVC-based structural framework with an electric bicycle,

providing a practical and scalable solution for real-world applications.

METHODOLOGY

The methodology adopted for this project involves a systematic approach that includes design, fabrication, integration, and testing of the weather-protected electric bicycle. The process begins with the selection of a suitable base bicycle, followed by the design of the PVC frame structure and canopy system.

The electric drive system is designed to provide efficient propulsion using a battery-powered motor. The battery serves as the primary energy source, supplying electrical power to the motor through a controller. The controller regulates the flow of current based on the input from the throttle, ensuring smooth and controlled acceleration.

The PVC frame structure is designed to provide support for the canopy while maintaining the stability and balance of the bicycle. The design involves the use of vertical and horizontal supports connected using joints and connectors. The frame is securely mounted on the bicycle to ensure proper load distribution and structural integrity.

The canopy is constructed using waterproof materials such as plastic sheets and fabric, providing protection against rain and sunlight. The design ensures proper ventilation to prevent heat buildup and maintain rider comfort.

The integration of electrical and mechanical components is carried out with careful consideration of safety and performance. Wiring is properly insulated, and components are securely mounted to prevent damage during operation.

Testing and evaluation are conducted under various conditions to assess the performance of the system. Parameters such as speed, battery efficiency, load capacity, and weather protection effectiveness are analyzed to validate the design.

WORKING PRINCIPLE

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The working principle of the system is based on the conversion of electrical energy into mechanical energy using an electric motor. When the rider activates the throttle, the controller regulates the flow of current from the battery to the motor. The motor generates torque, which drives the rear wheel and propels the bicycle forward.

The weather protection system operates independently of the electric drive system. The PVC frame provides structural support for the canopy, which acts as a barrier against environmental conditions. The design ensures that the canopy does not interfere with the operation of the bicycle or restrict the rider's movement.

RESULTS AND ANALYSIS

The performance of the developed system is evaluated through a series of tests conducted under different conditions. The results indicate that the system achieves a maximum speed of 25 km/h and provides a range of up to 40 km per charge. The battery performance is found to be efficient, with a charging time of approximately 4 hours.



The weather protection system is highly effective in shielding the rider from rain and sunlight. The PVC frame remains stable under normal operating conditions, although slight vibrations are observed on uneven roads.

CONCLUSION

The project successfully demonstrates the feasibility of developing a weather-protected electric bicycle using low-cost materials and simple design techniques. The integration of the PVC frame and canopy significantly enhances rider comfort and usability without compromising performance.

FUTURE SCOPE

Future improvements include:

- Solar-powered charging
- AI-based energy management
- Smart IoT monitoring
- Advanced composite materials

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