

A Review of Design and Fabrication Methodologies for Dynamic Electric-Bike

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Abstract: This research paper details the design and fabrication process of an electric bicycle (e-bike) intended for urban commuting and recreational purposes. The project focuses on integrating a 24V, 250W DC geared motor and a 24V, 16Ah lead-acid battery system into a conventional bicycle frame. The paper outlines the key design considerations, component selection, fabrication steps, and relevant calculations pertaining to the e-bike's performance parameters, including range and speed. The aim is to provide a comprehensive understanding of the practical implementation of a cost-effective and sustainable electric mobility solution.

1. INTRODUCTION

The increasing awareness of environmental concerns, coupled with the desire for efficient and affordable personal transportation, has fuelled the growing popularity of electric bicycles. E-bikes offer a compelling alternative to traditional bicycles and internal combustion engine vehicles, providing a balance between human power and electric assistance. This research paper explores the design and fabrication of an e-bike utilizing readily available and cost-effective components: a 24V, 250W DC geared motor and a 24V, 16Ah lead-acid battery. This configuration aims to provide sufficient power and range for typical urban commutes and leisure rides while maintaining a manageable cost. The paper will delve into the selection of components, the mechanical integration process, the electrical system design, and the theoretical calculations underpinning the e-bike's performance characteristics.

2. LITERATURE REVIEW

The field of electric bicycle design and development has witnessed significant advancements in recent years. Existing literature highlights various motor types (hub motors, mid-drive motors), battery

technologies (lithium-ion, lead-acid), and control systems. Studies have focused on optimizing power efficiency, extending battery life, and enhancing the overall riding experience. Research on geared DC motors indicates their suitability for e-bike applications due to their high torque output at lower speeds, which is beneficial for acceleration and hill climbing. Lead-acid batteries, while heavier and having lower energy density compared to lithium-ion, remain a cost-effective option for many e-bike projects, particularly where budget constraints are a primary concern. This paper builds upon existing knowledge by providing a detailed account of the practical implementation of a specific component combination and the associated design considerations.

3. DESIGN CONSIDERATIONS

The design of the electric bicycle involved several key considerations:

- **Frame Compatibility:** The chosen components needed to be compatible with a standard bicycle frame. This involved considering the mounting points for the motor, battery, and controller.
- **Weight Distribution:** Proper weight distribution is crucial for stability and handling. The placement of the battery and motor needed to be carefully considered to maintain balance.
- **Ergonomics and User Experience:** The addition of electrical components should not compromise the comfort and ease of use of the bicycle.
- **Safety:** Safety was a paramount concern, requiring careful wiring, secure component mounting, and the inclusion of necessary safety features.
- **Cost-Effectiveness:** The selection of a DC geared motor and lead-acid battery was driven by the need for a cost-effective solution.

- Performance Requirements: The target top speed (around 25 km/h, within legal limits for many regions) and range (approximately 40 km) guided the selection of motor and battery specifications.

4. COMPONENT SELECTION AND SPECIFICATIONS

The core components of the electric bicycle are:

- Motor: 24V, 250W DC Geared Motor.
 - Voltage: 24V DC
 - Power Rating: 250W
 - Type: Geared DC Motor (offering higher torque at lower RPM compared to direct-drive motors)
 - Operating Speed: Typically around 250-350 RPM at the rated voltage.
 - Mounting: Designed for integration into the bicycle's drivetrain (e.g., as a hub motor or mid-drive unit). For this design, we will consider a rear hub motor for simplicity of integration.
- Battery: 24V, 16Ah Lead-Acid Battery.
 - Voltage: 24V (composed of two 12V batteries connected in series)
 - Capacity: 16 Ampere-hours (Ah)
 - Energy Storage: Voltage x Capacity = 24V x 16Ah = 384 Watt-hours (Wh)
 - Weight: Lead-acid batteries are relatively heavy compared to lithium-ion.
 - Cycle Life: Limited compared to lithium-ion, depending on the depth of discharge.
- Controller: 24V Motor Controller.
 - Designed to regulate the power flow from the battery to the motor, often including features like speed control, pedal assist system (PAS) interface, and battery protection. The controller's current rating should be compatible with the motor's requirements (250W / 24V \approx 10.4A, so a controller rated for at least 15A would be suitable).
- Throttle: A handlebar-mounted throttle to allow manual control of the motor's power output.
- Wiring and Connectors: Appropriate gauge wires and connectors to handle the current and voltage requirements of the system.
- Battery Charger: A charger specifically designed for 24V lead-acid batteries.

- Bicycle Frame: A standard bicycle frame (mountain bike or commuter bike) suitable for modification.
- Mechanical Drive Components: Chain, sprockets, pedals, etc., which may need adjustments depending on the motor mounting.

5. FABRICATION PROCESS

The fabrication of the electric bicycle involved the following steps:

- Frame Modification (if necessary): Depending on the chosen motor mounting (hub or mid-drive), minor modifications to the frame might be required, such as installing mounting brackets or ensuring sufficient clearance. For a rear DC geared motor, the existing rear wheel is replaced.
- Motor Integration: The 24V, 250W DC geared motor was integrated into the rear wheel of the bicycle. This involves mounting of motor via external motor brackets. The motor's wiring was then routed towards the intended location of the controller.
- Battery Mounting: A suitable location on the bicycle frame was chosen for mounting the two 12V lead-acid batteries. This typically involves using a custom-built battery rack or securing them within a robust enclosure mounted on the frame's down tube. Secure mounting is crucial to prevent movement and damage during riding.
- Controller Installation: The 24V motor controller was mounted in a protected location, often near the battery. It needs to be shielded from water and physical damage.
- Wiring and Connections: The motor, battery, throttle, and controller were interconnected using appropriate gauge wires and connectors. Careful attention was paid to polarity and secure connections to ensure proper operation and prevent short circuits. Fuses were incorporated into the circuit for safety.
- Throttle Installation: The throttle was mounted on the handlebar within easy reach of the rider's hand and connected to the controller.
- Testing and Calibration: After assembly, the electrical system was thoroughly tested to ensure all components were functioning correctly. This included checking the motor's operation at

different throttle levels and verifying the battery voltage.

6. PERFORMANCE CALCULATIONS

To estimate the performance of the electric bicycle, we can perform the following calculations:

- Maximum Speed:
- Wheel diameter = 21 inches \approx 0.5334 meters
- Wheel circumference (C) = $\pi \times$ diameter = $\pi \times 0.5334$ m \approx 1.676 meters
- Motor speed (ω) \approx 300 RPM (approximate average under load).
- Linear speed (v) = $(\omega/60) \times C = (300/60) \times 1.676$ m/s = 5×1.676 m/s = 8.38 m/s.
- Converting to km/h: $v = 8.38$ m/s \times (3600 s/h)/(1000 m/km) \approx 30.17 km/h

(The theoretical no-load speed is now approximately 30.17 km/h. Real-world speed under load and with rider input will still likely fall within the 20-30 km/h range mentioned earlier due to various resistive forces and motor efficiency under load.)

- Range Estimation: The battery energy remains the same at 384 Wh. Assuming an average power consumption of 150W:
- Estimated Riding Time (t) = $E / P_{avg} = 384 \text{ Wh} / 150 \text{ W} \approx 2.56$ hours.
- Estimated Range (D) = $v_{avg} \times t$. Using the prototype's likely average speed of 20 km/h:
- Estimated Range (D) ≈ 20 km/h * 2.56 h ≈ 51.2 km.

(Again, the actual range will be lower due to real-world factors, aligning with the prototype's stated range of up to 40 km.)

- Motor Current: The motor current calculation remains the same as it depends on the motor's power and voltage, not the wheel diameter:
- Current (I) = Power (P) / Voltage (V) = $250\text{W} / 24\text{V} \approx 10.4$ Amperes (at maximum power).

7. DISCUSSION

The design and fabrication of the electric bicycle using a 24V, 250W DC geared motor and a 24V, 16Ah lead-acid battery demonstrate a practical approach to building a cost-effective electric mobility solution. The geared motor provides sufficient torque for urban commuting, and the lead-acid battery offers a

reasonable energy capacity for moderate range requirements.

However, it's important to acknowledge the limitations of using lead-acid batteries. Their higher weight and lower energy density compared to lithium-ion counterparts can impact the overall weight of the e-bike and the achievable range. Furthermore, lead-acid batteries typically have a shorter cycle life, especially if deeply discharged frequently.

The performance calculations provide a theoretical estimate of the e-bike's speed and range. In real-world scenarios, these values can be influenced by various factors, including rider weight, terrain, wind resistance, tire pressure, and the efficiency of the motor and controller. The prototype's reported top speed of 20-30 km/h and a range of up to 40 km suggest that these real-world factors do indeed play a significant role in the actual performance.

Future improvements could focus on exploring lighter and more energy-dense battery technologies like lithium-ion, optimizing the motor control system for better efficiency, and refining the mechanical design to reduce overall weight and improve aerodynamics. Integrating a pedal assist system (PAS) could also extend the range by supplementing the motor power with the rider's pedaling effort.

8. CONCLUSION

This research paper has detailed the design and fabrication process of an electric bicycle utilizing a 24V, 250W DC geared motor and a 24V, 16Ah lead-acid battery. The project demonstrates the feasibility of creating a functional and relatively affordable e-bike for urban commuting. While the chosen components offer a cost-effective solution, considerations regarding weight and energy density highlight potential areas for future improvement, particularly in the selection of battery technology. The performance calculations provide a theoretical framework for understanding the e-bike's capabilities, while real-world testing and further optimization would be necessary to refine its performance characteristics. This project contributes to the growing field of sustainable transportation by providing a practical example of electric bicycle development.

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