

# Mechanical Design and Stability Analysis of a Self- Balancing Bicycle

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**Abstract—** The proposed project focuses on the development of a compact self-balancing electric cycle designed to improve stability, controlled mobility, and operational convenience. The system consists of a lightweight aluminum frame, two motorized wheels, a centrally mounted high-speed gyroscope wheel, lithium battery, controller, motor driver, voltage sensor, power supply unit, charging unit, and remote-control system. The high-speed gyroscope is positioned above the frame without contacting the ground and is driven by a dedicated DC motor to generate stabilizing torque during operation. The motorized wheels provide propulsion and controlled movement, while the controller manages motor-driver operation according to remote-control commands. A voltage sensor is incorporated to monitor the battery condition and support safe electrical operation. The proposed design aims to provide a compact and economical alternative to conventional two-wheeled mobility systems. The prototype will be developed through mechanical frame fabrication, wheel assembly, gyroscope modeling, electrical integration, and functional testing. Performance will be evaluated based on stability, movement, response, power consumption, and overall system reliability under different operating conditions.

**Keywords—** *Self-Balancing Electric Cycle, Gyroscopic Stabilization, High-Speed Flywheel, DC Motor Control Lithium Battery System.*

## I. INTRODUCTION

The development of intelligent and compact transportation systems has become increasingly important because of the growing demand for efficient, economical, and environmentally friendly mobility solutions. Conventional bicycles are simple, lightweight, and energy efficient, but maintaining balance requires continuous human interaction, particularly during starting, stopping, low-speed operation, and sudden disturbances. The integration of electrical drives and mechanical stabilization mechanisms provides an opportunity to develop advanced two-wheeled vehicles capable of improved stability and controlled movement. In this context, the proposed project

focuses on the development of a self-balancing electric cycle using a high-speed gyroscope wheel.

The proposed system is designed using a lightweight aluminum frame that supports the complete mechanical and electrical arrangement. Unlike conventional four-wheel or robotic self-balancing platforms, the proposed model follows a cycle-like configuration with two ground-contact wheels. The front and rear wheels are driven using DC motors to provide propulsion and controlled movement. A high-speed gyroscope or flywheel is mounted at the central portion of the frame without direct contact with the ground. The gyroscope is rotated using a dedicated high-speed DC motor and is intended to generate stabilizing torque through its angular momentum. This arrangement provides a mechanical approach to improving the stability of the two-wheeled structure.

The electrical system consists of a rechargeable lithium battery, controller unit, motor driver, voltage sensor, power supply unit, charging unit, and remote-control system. The lithium battery acts as the primary energy source for the motors and electronic components. The controller coordinates the operating commands received from the remote-control system and provides suitable signals to the motor driver. The motor driver regulates the operation of the wheel motors according to the required direction and speed. A separate high-speed motor is used for rotating the central gyroscopic wheel. The voltage sensor provides battery-voltage information, helping to monitor the electrical condition of the system during operation.

The working principle of the proposed cycle combines gyroscopic stabilization and motorized propulsion. When the gyroscope rotates at high speed, its angular momentum produces a resistance to changes in the orientation of its rotational axis. This mechanical effect can contribute to maintaining the stability of the cycle. At the same time, the wheel motors provide the required forward or reverse movement. The controller and motor-driver system coordinate these operations to achieve controlled vehicle movement. The remote-control arrangement allows the operator to provide commands for movement, stopping, and speed control.

The project involves several stages, including research on self-balancing vehicles, literature review, system architecture development, component identification, component procurement, aluminum-frame fabrication, wheel and motor assembly, gyroscope modeling, electrical wiring, and system testing. Particular attention is given to the design and placement of the central gyroscope because its mass, rotational speed, mounting arrangement, and position can significantly influence the mechanical behavior of the prototype.

The proposed self-balancing cycle has potential applications in personal mobility, educational demonstrations, engineering research, robotics, and intelligent transportation systems. Its compact structure and rechargeable battery operation can provide an economical platform for studying gyroscopic stabilization and electric vehicle technologies. The project therefore combines mechanical design, electrical power systems, motor control, and gyroscopic stabilization into a single experimental prototype. Through fabrication and performance evaluation, the study aims to demonstrate the feasibility of developing a compact cycle-style self-balancing vehicle with improved stability, controlled movement, and practical future development potential.

## II. PROBLEM IDENTIFICATION

- **Balance Difficulty:** Conventional two-wheeled cycles require continuous rider control to maintain equilibrium, particularly during starting, stopping, low-speed movement, and sudden disturbances.
- **Stability Challenges:** A cycle with only two ground-contact wheels can easily become unstable when its center of gravity shifts due to acceleration, braking, uneven surfaces, or external forces.
- **Gyroscopic Integration:** Existing self-balancing platforms often use complex robotic structures. Integrating a high-speed gyroscope into a compact cycle-style aluminum frame requires careful consideration of weight, mounting position, rotational speed, and available space.
- **Power Management:** The system requires coordinated operation of wheel motors, gyroscope motor, controller, and motor drivers while operating from a limited-capacity lithium battery.
- **System Integration:** Mechanical components and electrical units must be properly assembled to achieve reliable operation, efficient power distribution, and safe movement.
- **Prototype Performance:** Practical testing is required to evaluate stability, movement, response, power consumption, and reliability under different operating conditions.

### A. Existing System

Existing self-balancing vehicle systems mainly use two-wheeled robotic platforms, conventional bicycles with active steering, or reaction-wheel-based stabilization mechanisms. These systems generally combine electric motors with electronic controllers to achieve controlled movement and improved balance. Some research prototypes use flywheels or gyroscopic mechanisms to generate stabilizing torque, while others depend primarily on steering adjustments. Most existing designs are developed for experimental robotics and laboratory applications rather

than compact cycle-style transportation. Their structures, control systems, and stabilization mechanisms vary according to the intended application and required operating conditions.

### B. Drawbacks

Existing systems have several limitations related to mechanical complexity, cost, size, and practical implementation. Steering-based systems may require continuous and precise control to maintain stability, especially at low speeds. Reaction-wheel and gyroscopic systems can increase weight, power consumption, and structural requirements. Many prototypes use complex sensors and advanced control algorithms, increasing development cost and maintenance requirements. Furthermore, limited integration of battery, motor drive, gyroscope, controller, and remote operation within a lightweight bicycle-style frame remains a challenge for compact and economical prototype development.

## III. LITERATURE REVIEWS

### A) Literature Survey:

Siller-Alcalá et al. (2024), investigated the stabilization of an unmanned bicycle using a reaction wheel or flywheel. The researchers developed a nonlinear bicycle model using Lagrange formulation and linearized it for controller development. Two control approaches, PID and state-feedback control, were investigated. Digital simulations and real-time experiments were performed to evaluate stabilization performance. The study demonstrated that a rotating flywheel can provide an effective balancing mechanism for a two-wheeled bicycle, including situations where the vehicle must remain stable at low or zero speed. This research is highly relevant to the proposed project because it establishes the feasibility of using a centrally mounted high-speed gyroscopic/flywheel mechanism for bicycle stabilization.

Wang, Bruzelius, and Sjöberg (2024), studied balance control for an autonomous bicycle whose dynamics vary significantly with travelling speed. They developed a speed-dependent bicycle model using gray-box system identification and experimental data collected from a controlled bicycle robot. A gain-scheduled controller was subsequently designed to provide consistent closed-loop performance across different speeds. The controller was implemented on the physical bicycle and experimentally evaluated. Results showed improved balance-control performance compared with a controller that does not explicitly account for speed variation. The work demonstrates the importance of considering changing vehicle dynamics when designing self-balancing systems. It provides useful guidance for developing a reliable control strategy for the proposed cycle prototype.

Shihab et al. (2024), developed and experimentally tested a physical two-wheeled self-balancing robot to demonstrate computer-based control of an unstable mechanical system. Their prototype used a complementary filter to process rotational information and a PID controller to regulate motor power for maintaining the robot's upright position. Experimental results showed that the robot could

achieve self-balancing within a relatively small tilt-angle range. However, mechanical and sensor mounting limitations caused instability at larger tilt angles. The authors suggested investigating more advanced control algorithms and alternative mechanical configurations in future work. The study is relevant to the proposed cycle because it demonstrates the importance of proper mechanical construction, motor selection, control implementation, and prototype testing.

Lau, Ahmad, and Goh (2023), developed a two-wheeled self-balancing robot and compared PID and Linear Quadratic Regulator (LQR) control approaches. The researchers first developed a mathematical model using Newtonian principles and implemented the control system using an NI myRIO-1900 embedded platform with LabVIEW. Experimental testing showed that PID control was effective for regulating tilt angle during external disturbances but required greater vehicle velocity for equilibrium. LQR demonstrated better performance for larger initial tilt angles. A hybrid PID-LQR controller was proposed to combine the advantages of both methods. The combined controller improved the maximum initial tilt angle and reduced settling time, demonstrating the importance of controller selection for self-balancing vehicle stability.

Guo et al. (2023), investigated balance control of a bicycle robot using synchronous reinforcement learning. The researchers developed a nonlinear bicycle dynamics model based on moment balance and transformed the nonaffine system into an affine representation using equivalent control. A feedback-linearization controller was combined with an actor-critic synchronous reinforcement-learning algorithm. The actor neural network was designed using the model-based control law, while tuning laws were developed for the actor and critic networks. Lyapunov analysis was used to establish closed-loop stability and convergence of network parameters. Simulations and real-world experiments verified the effectiveness of the proposed approach. The research demonstrates the potential of intelligent control techniques for improving future self-balancing bicycle performance.

Sanapala et al. (2023), investigated PID and Extended PID (EPID) control techniques for two-wheeled self-balancing robots. The research considered the self-balancing robot as an inverted-pendulum system requiring accurate control to prevent falling during small disturbances and tilt conditions. Conventional PID control was compared with EPID, which extends the traditional PID concept by incorporating relationships with tracking control and disturbance-observer principles. The authors highlighted the importance of properly tuned controllers for maintaining balance and improving robot movement. The study provides a useful foundation for selecting a suitable control strategy in self-balancing vehicle applications. Its findings are particularly relevant when designing a compact controller for the proposed electrically powered cycle.

Choudhry et al. (2023), addressed the difficulty of controlling self-balancing robots when system parameters and payload conditions are uncertain. The researchers developed a mathematical model incorporating payload variations and investigated a robust sliding-mode control strategy. An Extended Kalman Filter was used to estimate

unknown payload-related parameters, including changes affecting the robot's center of gravity. The proposed EKF-based sliding-mode controller was compared with conventional sliding-mode control under different conditions. The results showed zero steady-state error and no overshoot in the investigated scenarios, while parameter estimation improved controller performance. This research emphasizes the importance of considering changing mass and center-of-gravity conditions when developing reliable self-balancing vehicle systems.

Deulgaonkar et al. (2023), designed and analyzed a two-wheeled self-balancing vehicle incorporating a gyroscopic stabilization mechanism. The study included mechanical design calculations for the chassis, swing arm, braking system, suspension, gyroscope, and overturning couple. Computer-aided modeling and finite-element analysis were used to evaluate structural stresses and deflections. A scaled prototype was fabricated and tested for self-stabilization under static and dynamic conditions. The researchers used a self-processing gyroscope with a vertically oriented spin axis and positioned it near the engine region based on stability considerations. Experimental observations indicated improved overall stability after incorporating the gyroscope. This study directly supports the proposed centrally mounted gyroscope concept.

Chen, He, and He (2022), investigated control of a self-balancing mobile robot equipped with a reaction wheel. Their work proposed an adaptive double-fuzzy PID strategy incorporating anti-integral-saturation characteristics to improve the balancing response. The reaction-wheel configuration is particularly important because it provides an internal mechanical actuator capable of producing balancing torque without requiring an additional ground-contact wheel. The research examined the relationship between reaction-wheel actuation and stabilization performance and focused on improving controller adaptability under changing operating conditions. The study is closely related to the proposed project because the central high-speed gyroscope/flywheel similarly acts as an internal stabilization mechanism.

Peash et al. (2022), developed a two-wheeled self-balancing robot based on the inverted-pendulum principle and investigated a two-degree-of-freedom PID controller. The prototype used independently driven wheels with high-torque stepper motors and an Arduino-based control system. The researchers employed feedback from a gyroscope and accelerometer to determine the robot's inclination and maintain its upright position. The control architecture included inner and outer loops for motor-speed and body-angle regulation. Simulation results indicated that the 2-DOF PID controller provided better performance than conventional PID control. The study demonstrates the importance of coordinated motor control and feedback-based stabilization for two-wheeled vehicles and provides a useful reference for developing the proposed cycle's control architecture.

Badgujar and Mohite (2023), developed a Control Moment Gyroscope (CMG) mechanism for stabilizing an electric moped in stationary and moving conditions. The system used two continuously rotating flywheels driven by

DC motors and a gimbal mechanism to generate restoring torque. The researchers designed the flywheel using moment-of-inertia calculations and developed the complete mechanism in CREO, followed by ANSYS analysis and physical testing. Their prototype successfully demonstrated self-balancing capability. However, the gyroscopic system increased power consumption, weight, and cost. The study provides strong technical support for using a centrally mounted high-speed gyroscopic mechanism in the proposed self-balancing cycle.

Tao Zhao et al. (2022), This study investigated the application of gyroscopic principles for stabilizing a two-wheeled self-balancing bicycle. The researchers discussed the instability problems associated with conventional two-wheelers and proposed a gyroscope-based stabilization mechanism. The work examined the basic principles of angular momentum and gyroscopic effect for generating stabilizing forces. The study emphasized that gyroscopic stabilization can potentially improve vehicle safety by reducing the tendency of a two-wheeler to overturn. The research is relevant to the proposed project because it supports the use of a rotating flywheel as a mechanical stabilization element. It also provides a foundation for designing the central gyroscope and selecting suitable rotational characteristics.

Zhang et al. (2021) investigated the control of two-wheeled self-balancing robots operating on inclined road surfaces. Since the robot is nonlinear and inherently unstable, maintaining equilibrium on an inclined surface is more difficult than on level ground. The authors proposed a fuzzy fractional-order PID controller and compared its performance with conventional PID, fuzzy PID, and fractional-order PID controllers. Simulation results demonstrated that the proposed controller provided better control performance and improved anti-interference capability. The research highlights the importance of advanced control techniques when operating self-balancing vehicles under disturbances and non-ideal road conditions.

Chheda, Mandava, and Vundavilli (2021), developed a two-wheeled self-balancing robot based on the inverted-pendulum principle. A PID controller was implemented to maintain the robot in an upright position during static and dynamic operation. Controller gains were tuned experimentally using a trial-and-error approach. The robot was also equipped with a wireless control arrangement to support manoeuvrability. Experimental evaluation considered stability, strength, and load-carrying capacity. The study demonstrated that a relatively simple PID-based architecture can achieve self-balancing when the mechanical structure and controller parameters are appropriately selected. This work is useful for developing the motor-control architecture of the proposed cycle.

Tengenkai and Prajwal (2021), presented a two-wheeled self-balancing robot using an inverted-pendulum approach. The system used sensor feedback and a microcontroller to determine the tilt condition and generate corrective motor commands through a conventional PID controller. The research incorporated gyroscope and accelerometer information for estimating the inclination angle. The controller calculated the difference between the desired and actual angle and adjusted the motor response

accordingly. The work demonstrated the practical implementation of sensor-based balancing using embedded electronics. Although the proposed cycle does not use these sensors, the study provides useful background regarding controller implementation, motor actuation, and real-time operation of two-wheeled balancing systems.

Khatoon et al. (2021), investigated the stabilization of a two-wheeled mobile robot using modern estimation and control techniques. The research considered the self-balancing robot as an inverted-pendulum system characterized by nonlinear and unstable dynamics. A Kalman-filter-based estimation approach was combined with a Linear Quadratic Gaussian regulator to improve balancing performance. The approach aimed to estimate system states accurately while controlling the robot around its unstable equilibrium position. The study demonstrates how mathematical modeling, state estimation, and optimal control can be integrated to improve self-balancing performance. Its findings provide useful theoretical background for future improvements to the controller of the proposed self-balancing cycle.

Aldhalemi, Chlahawi, and Al-Ghanimi (2021), developed a low-cost remotely controlled two-wheel self-balancing robot. The prototype combined hardware and software components and used Bluetooth wireless communication for remote navigation. A gyroscope-based feedback arrangement was incorporated to determine the vehicle's orientation, while a PID controller was employed for stabilization. The researchers focused on developing a practical and economical prototype that could be operated remotely. Experimental implementation demonstrated the feasibility of combining wireless control with self-balancing functionality. This work is particularly relevant to the proposed project because it supports the integration of remote control, motor actuation, embedded control, and a compact two-wheel mechanical structure.

Alex Mathew et al. (2021), This research presented the design and control of a two-wheeled self-balancing mobile robot with emphasis on obtaining adequate stability without relying on an excessively complicated control architecture. The researchers developed a suitable mechanical configuration and derived a mathematical model for the system. The resulting model was simulated using MATLAB/Simulink under different input conditions, including step, ramp, and uneven-terrain disturbances. The study demonstrated the importance of mechanical structure in determining the balancing performance of a two-wheeled vehicle. Its findings are relevant to the proposed project because careful frame design, weight distribution, and stabilization-mechanism placement are essential for achieving reliable operation.

Guo et al. (2021), investigated reinforcement-learning-based optimal control for a two-wheeled self-balancing robot. The research addressed the nonlinear and unstable dynamics of the robot and investigated Q-learning as an alternative to conventional control approaches. The objective was to obtain control policies capable of maintaining balance while improving robustness under different operating conditions. The study demonstrated the potential of reinforcement learning for handling complex balancing problems without relying entirely on manually

tuned conventional controllers. This research is valuable for the proposed project as a possible future development direction, particularly for improving adaptive stabilization, disturbance rejection, and intelligent motor-control performance.

Huaqiang Zhang et al. (2025), This comprehensive review examined different control strategies used for two-wheeled self-balancing robotic systems. The study discussed conventional PID and LQR approaches along with nonlinear, robust, adaptive, optimal, intelligent, and reinforcement-learning-based control methods. It emphasized that self-balancing vehicles are nonlinear and unstable systems requiring rapid and accurate corrective action. The review also compared the advantages and limitations of different control approaches according to computational requirements, robustness, tuning complexity, and disturbance rejection. The findings provide a broad theoretical foundation for selecting suitable control strategies. For the proposed cycle, the review supports beginning with a practical control architecture while leaving scope for advanced intelligent control in future development

#### B) Literature Summary

- **Gyroscopic Stabilization:** Recent studies demonstrate that flywheels, reaction wheels, and control-moment gyroscopes can generate stabilizing torque for two-wheeled vehicles, particularly during low-speed or stationary operation.
- **Controller Development:** PID, LQR, fuzzy PID, sliding-mode, and reinforcement-learning controllers have been investigated for improving balance, response time, disturbance rejection, and robustness.
- **Prototype Development:** Researchers have developed experimental two-wheeled robots and bicycle prototypes integrating motors, controllers, wireless communication, and stabilization mechanisms. These studies confirm the feasibility of compact self-balancing platforms.
- **Mechanical Design:** Research emphasizes appropriate weight distribution, center-of-gravity location, flywheel position, rotational speed, and structural stiffness for achieving effective stabilization.
- **Performance Evaluation:** Existing studies commonly evaluate tilt response, settling time, stability, speed, and disturbance rejection through simulation and experimental testing.
- **Overall Observation:** Literature establishes a strong technical foundation, but practical integration of gyroscopic stabilization with a lightweight cycle-style frame remains comparatively limited.

#### C) Research Gap

- **Limited Cycle-Style Designs:** Most existing research focuses on laboratory robots, autonomous bicycles, or moped platforms rather than compact cycle-style prototypes with a simple aluminum frame.
- **Gyroscope Integration:** Although reaction wheels and gyroscopes have been investigated, limited work focuses on a centrally suspended high-speed gyroscope combined with two motorized ground-contact wheels.
- **System Integration:** Few prototypes integrate the gyroscope motor, wheel motors, lithium battery, controller, motor driver, voltage monitoring, charging system, and remote control within one compact platform.

- **Practical Development:** Many studies emphasize mathematical modeling and simulation, while comparatively fewer demonstrate economical hardware prototypes suitable for academic fabrication and testing.
- **Energy Consideration:** Gyroscopic stabilization can require significant motor power; therefore, battery capacity, operating duration, and energy consumption require further investigation.
- **Future Improvement:** Further research is required to optimize gyroscope speed, mounting position, frame dimensions, stability, power consumption, and overall prototype performance.

### IV. RESEARCH METHODOLOGY

#### A) Proposed System

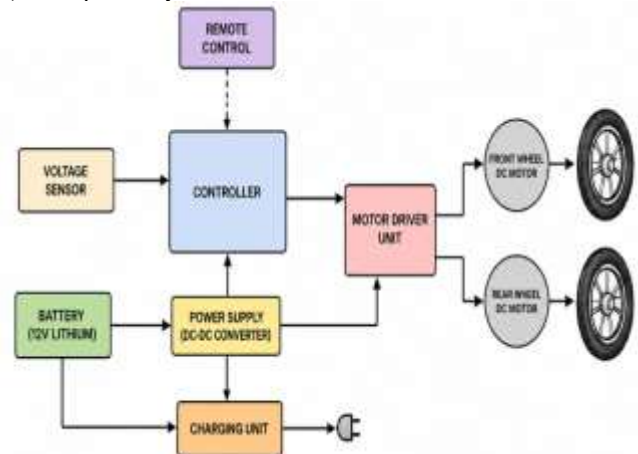


Figure 2. Block Diagram

- **Battery Supply:** The 12V lithium battery acts as the main energy source. It supplies electrical power to the controller, power supply unit, motor driver, and other connected components.
- **Power Regulation:** The power supply unit, consisting of a DC-DC converter, regulates the battery voltage and provides suitable voltage levels to the controller and motor-driver circuit.
- **Remote Control:** The operator sends wireless commands through the remote control for forward, reverse, stopping, and speed-control operations. These commands are received by the controller.
- **Voltage Monitoring:** The voltage sensor continuously monitors the battery voltage and sends the measured information to the controller. This helps observe the battery condition during operation.
- **Controller Processing:** The controller receives the remote-control commands and voltage information. It processes these inputs and generates appropriate control signals for operating the motor driver.
- **Motor Driver Operation:** The motor driver receives signals from the controller and controls the voltage and current supplied to the front and rear DC motors according to the required operating condition.
- **Wheel Movement:** The front and rear DC motors rotate their respective wheels to provide propulsion. Coordinated motor operation allows the cycle to move forward, reverse, and change speed.
- **Charging:** When the battery requires charging, the charging unit is connected to the appropriate charger. The battery is recharged and made ready for the next operating cycle.

## B) Hardware Used

- **Aluminum Frame:** A lightweight aluminum frame forms the main mechanical structure of the self-balancing cycle. It supports the wheels, motors, battery, controller, motor driver, power supply, and gyroscope assembly.
- **Front DC Motor:** The front DC motor provides rotational power to the front wheel and supports controlled forward and reverse movement.
- **Rear DC Motor:** The rear DC motor drives the rear wheel and assists in propulsion and controlled vehicle movement.
- **High-Speed DC Motor:** A dedicated high-speed DC motor is used to rotate the central gyroscope/flywheel at high rotational speed.
- **Gyroscope/Flywheel:** The centrally mounted rotating flywheel produces gyroscopic angular momentum intended to improve the stability of the two-wheeled cycle.
- **12V Lithium Battery:** The rechargeable lithium battery supplies the primary electrical energy required by the motors and electronic control system.
- **Controller Unit:** The controller receives operating commands and generates suitable control signals for the motor-driver system.
- **Motor Driver Unit:** The motor driver regulates motor speed and direction according to signals received from the controller.
- **Voltage Sensor:** The voltage sensor measures battery voltage and provides monitoring information for safe system operation.
- **Power Supply Unit:** The DC-DC converter regulates and distributes suitable voltage levels to the controller and electrical components.
- **Remote Control and Receiver:** The wireless remote system provides commands for movement, stopping, and speed control.
- **Charging Unit and Charger:** These components provide a suitable charging arrangement for safely recharging the 12V lithium battery.
- **Wheels, Shafts, Bearings and Wiring:** Mechanical and electrical accessories provide wheel support, smooth rotation, secure connections, and reliable power transmission throughout the prototype.

## V. CALCULATION

### 1. Battery Capacity

Given: 12 V, 20 Ah

$$E = V \times Ah = 12 \times 20 \\ = 240 \text{ Wh}$$

### 2. Total Motor Power

Two DC motors, each 150 W:

$$P = 2 \times 150 = 300 \text{ W}$$

### 3. Motor Current

$$\text{For one motor: } I = \frac{P}{V} = \frac{150}{12} = 12.5 \text{ A}$$

For two motors:

$$I = 2 \times 12.5 = 25 \text{ A}$$

### 4. Wheel Speed

Wheel diameter = 0.30 m, motor speed = 300 rpm.

$$v = \frac{\pi DN}{60}$$

$$v = \frac{3.14 \times 0.30 \times 300}{60} = 4.71 \text{ m/s}$$

$$v = 4.71 \times 3.6 = 16.96 \text{ km/h}$$

### 5. Flywheel Moment of Inertia

Flywheel mass = 1 kg, radius = 0.15 m.

$$I = \frac{1}{2}mr^2$$

$$I = \frac{3.14 \times 0.30 \times 300}{60} = 4.71 \text{ m/s}$$

$$v = 4.71 \times 3.6 = 16.96 \text{ km/h}$$

### 5. Flywheel Moment of Inertia

Flywheel mass = 1 kg, radius = 0.15 m.

$$I = \frac{1}{2}mr^2$$

$$I = \frac{1}{2}(1)(0.15)^2 = 0.01125 \text{ kg/m}^2$$

### 6. Flywheel Angular Speed

$$\omega = \frac{2\pi N}{60}$$

At 12,000 rpm:

$$\omega = \frac{2(3.14)(12000)}{60} = 156 \text{ rad/s}$$

### 7. Battery Operating Time

Assuming total power consumption = 400 W:

$$t = \frac{240}{400} = 0.6 \text{ h}$$

$$t = 36 \text{ minutes}$$

Therefore, the prototype has approximately 240 Wh battery energy, 300 W wheel-motor power, 25 A motor current, and a theoretical speed of about 17 km/h.

## VI. ADVANTAGES AND APPLICATIONS

### A) Advantages

- **Improved Stability:** The high-speed gyroscope provides stabilizing angular momentum, helping the two-wheeled cycle maintain better balance during movement and low-speed operation.
- **Compact Structure:** The aluminum frame provides a lightweight and compact construction, making the prototype easy to handle, transport, assemble, and modify.

- Efficient Operation: DC motors provide controlled wheel movement, while the rechargeable lithium battery supplies electrical energy for repeated operation.
- Remote Control: Wireless remote operation allows convenient control of forward, reverse, stopping, and speed functions.
- Low Emission: Battery-powered operation produces no direct exhaust emissions, making the system cleaner than conventional fuel-powered vehicles.

#### B) Applications

- Personal Mobility: The self-balancing cycle can be developed for short-distance transportation in campuses, residential areas, parks, and other controlled environments.
- Educational Demonstration: It can demonstrate practical concepts involving gyroscopic stabilization, electric motors, battery systems, controllers, and mechanical design.
- Engineering Research: The prototype provides a platform for studying self-balancing mechanisms, flywheel behavior, motor control, stability, and energy consumption.
- Robotics Development: The system can support research into autonomous and remotely controlled two-wheeled robotic transportation platforms.
- Future Smart Mobility: With additional automation, the design can be further developed for intelligent, compact, and energy-efficient personal transportation systems.

#### VII. CONCLUSION

The proposed self-balancing electric cycle provides a compact and innovative approach to improving the stability and controllability of a two-wheeled vehicle. The design integrates a lightweight aluminum frame, two motorized wheels, a centrally mounted high-speed gyroscope, lithium battery, controller, motor driver, voltage sensor, power supply, charging unit, and remote-control system. The high-speed gyroscope is expected to generate stabilizing angular momentum, while the DC motors provide controlled propulsion and movement. The integrated electrical system enables efficient power distribution and convenient remote operation. Preliminary calculations indicate that the proposed prototype can achieve suitable motor power, wheel speed, and gyroscopic performance for experimental development. The project also provides an economical platform for studying mechanical stabilization, electric mobility, motor control, and energy management. During prototype development, particular attention should be given to gyroscope speed, flywheel mass, frame strength, weight distribution, motor torque, battery capacity, and safety. Experimental testing will be required to validate the theoretical calculations and determine actual stability, operating time, speed, and power consumption. Overall, the proposed cycle has significant potential for educational demonstrations, engineering research, personal mobility, and future development of intelligent self-balancing transportation systems.

#### VIII. FUTURE SCOPE

- Advanced Stabilization: Develop improved gyroscopic mechanisms with optimized flywheel speed, mass, and control for better stability.

- AI-Based Control: Integrate artificial intelligence and adaptive control algorithms for automatic balance adjustment under varying operating conditions.
- Smart Mobility: Add GPS, IoT connectivity, obstacle detection, automatic navigation, and mobile-app control for intelligent transportation applications.

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