SELF-BALANCING TWO WHEELER USING GYROSCOPE

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Abstract - *Ensuring the stability of a two-wheeled vehicle is crucial in the modern transportation system. Gyroscopes are key in helping stabilize these vehicles. There is a belief that vehicles stabilized by gyroscopes would be safer than traditional two-wheelers. To achieve this dynamic stability, the torque on the vehicle must be counteracted by the torque generated by the gyroscope within the vehicle. In this case, the gyroscope acts as an actuator rather than a sensor, utilizing precession forces. When force is applied to a direction perpendicular to the rotation axis of a gyroscope, making it spin around, a force is created around a third axis, which is at right angles to both the force and rotation axes. As the vehicle leans away from the upright position, a force that induces precession is applied to the gyroscope unit and the counteracting gyroscopic reaction force will move to stabilize the vehicle. The main concept is that the movement of the gyroscope about the body is purposely managed to produce a stabilizing force. Our team created a self-balancing two-wheeler using an inverted pendulum principle. The project involved designing the model in software, fabricating it, assembling it, and conducting thorough testing.*

***Key Words*: Stability, Two-wheeled vehicle, Gyroscopes, Torque, Inverted pendulum**

1. INTRODUCTION

There are many different types of two-wheeled vehicles with parallel spin axis, commonly used for transportation or recreation. Lighter vehicles with smaller engines are generally more affordable compared to heavier models and are a popular choice for transportation in many Asian countries. Unfortunately, a large number of road accidents involve these types of vehicles. Despite significant investments in manufacturing and developing advanced technology for motorbikes, road safety ultimately relies on the skills and judgment of the rider. Accidents often occur when the rider loses control of the bike and falls. Additionally, children learning to ride bicycles may be hesitant due to a fear of falling.

The device operates using an inverted pendulum concept and utilizes electromechanical parts to function as a personal vehicle. It is a two-wheeled, self-balancing mode of transportation that is complex and inherently unstable. Managing this type of system is a challenging task, leading to ongoing research. [8]

This paper showcases a vehicle where all parts (mechanical, electrical) are custom-designed, manufactured, assembled, and tested. This vehicle is environmentally friendly, runs on batteries, and is user-friendly.

1.1 Scope

The problem with a traditional bike is that it requires the rider to maintain balance through constant adjustments of body position and steering. Hence, we need to develop a self-balancing bike that should be able to maintain balance when subjected to external disturbances, such as wind, and should also be able to respond quickly to rider input, such as steering and acceleration. The project will need to address several key challenges including adjusting the motor torque in real-time, and the design of a lightweight and durable mechanical structure.

1.2 Objective

Motorcycles are a widely used form of transportation across the world due to their energy efficiency, compact design, convenience, and stylish appearance. Many young people see them as a trendy way to get around, while in developing countries, they are often used as affordable, fuel-efficient vehicles. However, despite their popularity, motorcycles lack safety features and are considered high-risk vehicles. This leads to fatal accidents, with injuries being common and death a frequent outcome. One major safety issue with motorcycles is that the passenger's body is exposed during the ride, making them vulnerable to impacts with roadside objects.

2. METHODOLOGY

- Define the project requirements: Determine the purpose, target audience, and specific requirements of the self-balancing bike project.
- Research the state of the art: Explore the latest technologies, components, and materials used in self-balancing bikes, as well as their strengths and weaknesses.
- Design the self-balancing system: Develop a self-balancing control algorithm that can maintain the bike's balance using sensors and actuators.

- Select the appropriate components: Select the components required for the self-balancing system, such as motors, batteries, sensors, and microcontrollers, based on their compatibility, reliability, and cost.

- Assemble the bike frame: Design and assemble the bike frame with lightweight and durable materials, considering the bike's balance, ergonomics, and aesthetics.

- Integrate the self-balancing system: Integrate the self-balancing system with the bike frame, ensuring proper alignment, calibration, and synchronization.

- Test and validate the system: Test the self-balancing bike in various environments and conditions, validating the system's stability, agility, and safety.

- Optimize the system performance: Fine-tune the self-balancing algorithm, adjust the components, and optimize the bike's performance and efficiency.

- Showcase the project: Demonstrate the self-balancing bike project to the target audience, sharing its features, benefits, and innovation, and inviting feedback and suggestions for improvement.

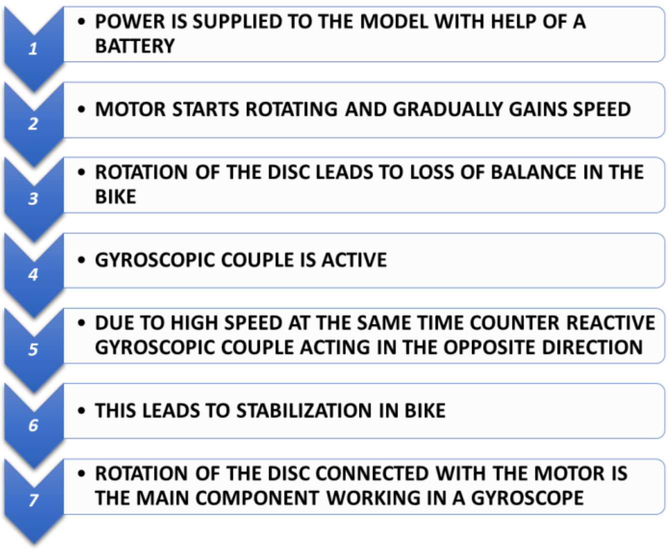

Fig -1: Flow Chart for Working of Self-Balancing Vehicle

2.1 Construction

This paper aims to demonstrate that a body can stay balanced on two parallel spinning wheels, whether idle or in motion, by utilizing a mechanical gyroscope. This gyroscopic principle can be applied effectively in designing a prototype of a two-wheeled vehicle to study the gyroscopic phenomenon.

The prototype was assembled with the following components:

1. Steel Frame
2. Wooden Base
3. 12 V DC Motor
4. Motor Driver
5. Regulator
6. Mild steel disc
7. Rubber Wheels
8. Nuts and bolts
9. Hub
10. Ball bearings

The gyroscope disc is created using a CNC lathe and drilling techniques. The steel framework is attached to the bottom steel base. Circular edge wheels are placed on the bottom steel base, and holes are drilled in the framework to accommodate the gyroscope assembly's gimbal. The DC motor is mounted on a U bracket on the gimbal. The key requirement for this setup is for the mass distribution to be top-heavy, with the majority of the mass located on the upper side of the gimbal. The center of gravity is therefore just above the gimbal axis, and stainless steel discs are mounted on the motor shaft to act as the gyroscope. The DC motor is securely attached to the U-bracket, allowing it to stay in place. The shaft of the DC motor is connected to a steel hub with holes drilled on the top surface. This hub is used to mount the gyroscope disc by bolting it on. The materials used for the gyroscope disc, hub, steel frame, and U-bracket are Mild Steel. To complete the assembly of the model, nuts and bolts of various sizes were used. One key design consideration we made in this model is that the gyroscope disc should be able to freely move within the U-bracket attached to the steel frame. To achieve this, we utilized ball bearings and studs to facilitate smooth and flexible angular movements and adjustments. The circlips were employed on the inner ends of the studs to prevent them from dislodging from the ball bearings, ensuring the model remained intact during operation. The design allows the front wheel to pivot and change direction to navigate turns effectively.

2.2 Working

- The machine runs on a 12V power source. When the motor begins to spin, a mild steel disc attached to the motor shaft starts turning and picks up speed slowly.

- When the disc rotates, it creates a gyroscopic effect that helps stabilize the prototype model by counteracting any imbalance in the wheels. This effect happens on both the left and right sides of the model.

- Therefore, the gyroscope's rotation creates a reactive gyroscopic force that stabilizes the prototype. The motor and gimble axle are intentionally made heavy to maintain stability.

- The center of gravity is positioned above the gimbal axle, causing the motor and gyroscope assembly to work towards a downward movement of the core's center of gravity. Simultaneously, the motor and gimbal assembly are set up within the frame with bearing reactions at both ends.
- So, the only possible way for the motor to attain stability is to either lean forward or backward. So, when the motor is started the body is about to fall on either side and the motor assembly is leaning this causes the precession of the spin axis.
- As the gyroscope precesses, the reactive gyroscopic couple follows the right-hand rule and stabilizes the vehicle by counteracting the disturbing couple. Through multiple rotations and oscillations, the motor and frame eventually reach a stationary position, allowing the gyroscope to smoothly roll about its spin axis.

Basic formulas used in calculations:

Centre of mass from ground (h) :
Centre of Mass (CM) from the ground, h= [(CMwheel * Mwheel) + (CMchassis * Mchassis) + (CMframe * Mframe) + (CMdisc * Mdisc) + (CMhub motor * Mhub motor) + (CMlinkage * Mlinkage)] / Total Mass.
Moment of Inertia, $I = mr^2/2$
Speed of Disc (N) = RPM
Precession speed of Disc (ω p): $\omega p = m.g.h.\sin\theta / I\omega$
Gyroscopic reaction Torque (τ): $\tau = I\omega\omega p$
m = Mass of the disc = 0.8012kg
r = Radius of the disc = 140 cm

Table -1: Speed in RPM and Angle of Tilt till Unbalance

Trail Number	Angle in Degree	Speed in RPM
1	5	400
2	10	426
3	15	478
4	20	546
5	25	638
6	30	994

Relationship between Tilt Angle and RPM: - As the angle of tilt increases, the speed in RPM also increases. This indicates that the gyroscope's response to maintain balance is more aggressive (faster) as the tilt angle becomes larger.

Specific Observations: - Between 5° and 10° tilt, the RPM increases by 26 RPM. - From 10° to 15°, the increase is 52 RPM. - From 15° to 20°, the RPM increases by 68 RPM. - From 20° to 25°, the increase is 92 RPM. - From 25° to 30°, the RPM increases dramatically by 356 RPM. This sharp increase may indicate that the system is designed to react more urgently as the risk of falling increases (i.e., at higher tilt angles).

Implications for Stability Control: - The data likely reflects a control strategy where the gyroscopic system applies more force (via higher RPM) to counteract greater angles of tilt. The strategy might be fine-tuned to prevent overcorrection at lower tilt angles but becomes significantly more aggressive when the bike reaches a critical tilt angle, as evidenced by the sharp RPM increase at 25° to 30°.

This analysis indicates that the gyroscope's functionality and its integration into the bike's control system are crucial for ensuring stability.

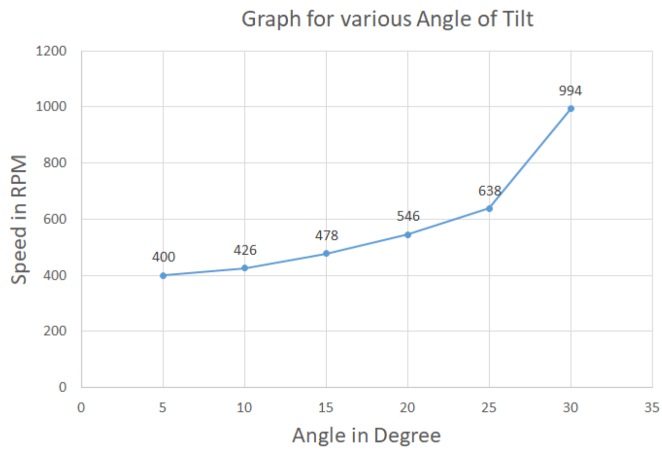

Chart -1: Relation between RPM and Angle of Tilt till the vehicle is unbalanced.

3. CONCLUSIONS

To sum up, a self-balancing bike project could change the way we view and use bikes for getting around, having fun, and getting help with mobility. The technology behind self-balancing bikes enhances their stability and ease of handling, making them safer and more accessible for riders of all ages and abilities. These bikes require less physical exertion to ride, are low-maintenance, and are eco-friendly, making them a great choice for transportation.

When designing and putting into action a self-balancing bike, it's crucial to take into account factors such as cost, weight, power source needs, environmental considerations, and the learning curve involved with the technology. The project of engineering a self-balancing bike presents a range of advantages and obstacles that need to be carefully considered to assess its potential success in different markets and applications.

Final Model Images:

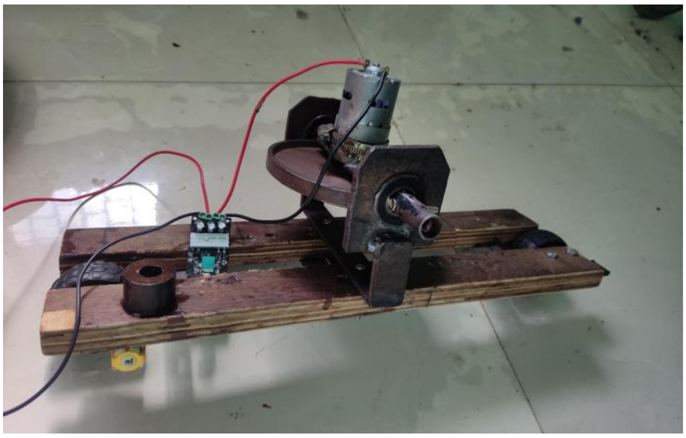

Fig -2: (Side View) Image of Self-Balancing Vehicle

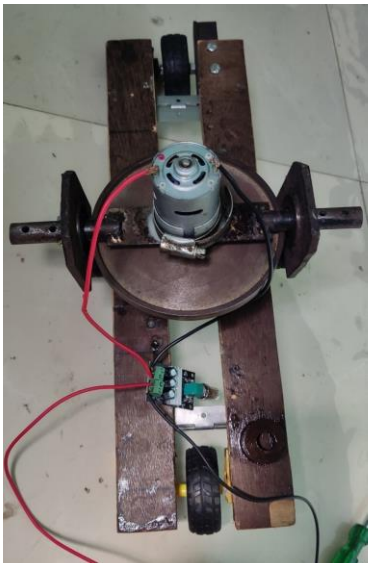

Fig -3: (Top View) Image of Self-Balancing Vehicle

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